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Estimation of heterosis and combining ability for yield and yield- attributing traits in spine gourd (*Momordica dioica*)

Vivek Sandilya[1], Sanjay Bhagat[1], Jyoti Bajeli[1], Arunima Tripathi[1], S. K. Sinha[1] and Jitendra Kumar Tiwari[2]*

[1]*RMD Collage of Agriculture and Research Station, IGKV, Ambikapur, Chhattisgarh, India*

Abstract

Heterosis for quantitative characters in 31 spine gourd genotypes, including 10 parents and 21 F_1s, was investigated in spine gourd (*Momordica dioica* Roxb.) during 2016-2018. Analysis of variance revealed highly significant differences among parents and hybrids for 10 characters. Considerable coefficient of variation for various characters was observed to distinguish among various genotypes. The cross, NDM-5 x AJSG-2, showed heterosis over mid-parent and NDM-5 x AJSG-2 over better parent for single fruit weight. Crosses Ambika 13-5 X Chhattisgarh Kankoda-2 (69.24 q/ha), Ambika 13-6 X AJSG-2 (68.30 q/ha), RMDSG-4 x Chhattisgarh Kankoda-2 (66.60 q/ha), NDM-5 X AJSG-2 (66.19 q/ha), RMDSG-3 X Chhattisgarh Kankoda-2 (62.89 q/ha), AJSG-1 x IK-1 (61.47 q/ha), NDM-5 X IK-1 (59.26 q/ha), Ambika 13-5 X AJSG-2 (58.15 q/ha) and RMDSG-3 X IK-1 (55.56 q/ha) can be used to get good heterotic combination and it will be multiply through stem cuttings after fixation of heterosis in the form of asexual propagating material, *i.e.* tubers. Therefore, these cross combinations could be utilized in isolation of superior parents for incorporating yield-attributing and qualitative traits in spine gourd.

Key words: Heterosis, Combining ability, Parents, Stem cuttings, Yield-attributing traits

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Spine gourd (*Momordica dioica* Roxb.) belonging to the family Cucurbitaceae with chromosome number of 2*n*=28, is a highly valued wild yet edible vegetable with rich nutraceutical properties consisting of proteins, lectins, triterpenes and ascorbic acid (Kushwaha *et al.*, 2005; Ameen *et al.*, 2022a). Since, spine gourd is one of the least exploited vegetables among cucurbits, it offers immense scope for exploitation of hybrid vigour to increase the production and productivity on commercial scale. (Rasul, 2003; Saroj *et al.*, 2020). Spine gourd is highly cross-pollinated and has high levels of heterozygosity due to dioecious nature, male plant has heterozygous (XY) and female has homozygous (XX) sex type. So, after fertilization in a single fruit both male and female seeds are present in 1:1 ratio (Tiwari *et al.*, 2022; Ameen *et al.*, 2022b). It is easy to raise healthy planting materials of true-to-type plants (Tiwari *et al.*, 2022). The diallel, partial diallel and line x tester are commonly used. So many reports on combining ability and heterosis breeding are available in different gourds (Kundu *et al.*, 2022), except spine gourd. Line × tester analysis is a useful tool for preliminary evaluation of genetic stock for use in hybridization programmes with a view to identify good combiners (Mondal *et. al.*, 2009). Therefore, study was undertaken to select elite parental lines to explore heterosis for fruit yield and other attributes through line × tester analysis.

***Corresponding author :** tiwarijk5@gmail.com
[2]Department of Genetics and Plant Breeding, Rani Lakshami Bai Central Agricultural University, Jhansi, Uttar Pradesh, India

MATERIALS AND METHODS

The study was carried out at RMD College of Agriculture and Research Station, Ambikapur, India, during rainy season of 2016-18. Seven diverse lines and 3 testers (Table 1) were crossed during rainy season 2016-17 in a line x tester mating fashion to produce 21 F_1s. The test material was grown in a complete randomized block design with three replications, in each replication 9 (8 female and 1 male) plants were maintained for each cross. After final land preparation, pits of (30 cm × 30 cm × 30 cm) were prepared in each plot with a spacing of 2 × 2 m. The pits were filled with 200 kg FYM, NPK 100:60:40 kg/ha and 3g chloropyriphos to prevent termite and three times topdressing of urea @ 50:25:25kg/ha. Since spine gourd is a dioecious crop, the male/ female ratio needs to be essentially maintained in the field. The female and male plant tubers were planted in the field at 8:1 ratio (female: male). This can be easily achieved by design advised by Tiwari *et al.*, 2022.

Observations were recorded on five random plants selected from each plot on ten quantitative traits, *viz.* days to first flowering, days to first flowering node, number of branches per plant, ovary length (cm), ovary diameter (cm), fruit length (cm), single fruit weight (g), number of fruits per plant and fruit yield (q/ha). To measure fruit traits, fruits were harvested at matured green stage suitable for marketability. The mean value of data was subjected to analysis of variance (ANOVA) using the standard procedures of Panse and Sukhatme (1985). Combining ability analysis was done by using Kempthorne (1957).

Table 1. Analysis of variance (mean squares) for economic traits of spine gourd parents and hybrids.

Source	df	Days to first flowering	No. of first flowering node	No. of branches per plant	Fruit length (cm)	Ovary length (cm)	Ovary diameter (cm)	Fruit diameter (cm)	Single fruit weight (g)	No. of fruit per plant	Fruit yield (q/ha)
Parents	9	1.92*	5.81**	2.07*	0.26	0.25	0.00	0.28	1.64	19.20**	26.60**
Females	6	69.92**	4.93**	15.49**	0.75	0.35	0.02	0.15	3.43**	653.88 **	563.39 **
Males	2	4.55**	1.57	6.19**	2.99**	0.21	0.01	0.18	1.56	118.02 **	73.33**
Female vs. male	12	4.43**	8.04**	3.76**	0.74	0.19	0.00	0.33	5.02**	50.52**	98.53**
Hybrids	20	24.09**	6.46**	7.52**	0.97	0.24	0.01	0.26	4.20**	238.28 **	235.47 **
Parent vs. hybrids	1	22.45**	8.69**	52.30**	0.60	0.14	0.00	0.00	0.00	1523.8**	1063.45**
Error	30	9.12**	2.14*	0.64	0.13	0.03	0.00	0.06	0.36	3.27**	4.35**
$2\sigma^2g/(2\sigma^2g + \sigma^2s)$		0.73	0.24	0.47	0.41	0.17	0.72	0.19	0.17	0.73	0.48

Mid parent/average, better parent/ heterobeltiosis and standard heterosis were calculated according to method suggested by Shull (1909), Fonseca and Patterson (1968) and Meredith and Bridge (1972), respectively. Variety "Indira Kankoda-1 and Chhattisgarh Kankoda-2 was used as the standard check.

RESUTS AND DISCUSSION

The analysis of variance indicated that the mean squares for days to first flowering, number of first flowering node, number of branches/plant, number of fruits/plant and fruit yield of parents and hybrids were significantly different. In addition to above traits, mean squares for single fruit weight of hybrids was also significant (Table 1). The total genetic variability found among genotypes was partitioned to general combining ability (GCA) and specific combining ability (SCA). The GCA variances due to females was significant for days to first flowering, number of first flowering node, number of branches/plant, number of fruits/plant, single fruit weight and fruit yield while days to first flowering, number of branches/plant, fruit length, single fruit weight, number of fruits/plant, fruit yield GCA variances due to males was significant. This revealed the important role of additive type gene effects.

Mean squares of SCA for crosses were significant for days to first flowering, number of first flowering node, number of branches/plant, number of fruits/plant, single fruit weight and fruit yield. The variance due to GCA was lower than SCA for fruit diameter, single fruit weight and first flowering node, indicated non-additive gene action (dominant or epistatic). The GCA variance was higher than SCA for number of fruits/plant, days to first flowering, number of branches/plant, fruit length and fruit yield, indicating role of additive type of gene action. The variation due to parent vs hybrids was significant for all traits, indicating a substantial difference between parental and hybrid means (Table 2).

The relative importance of GCA and SCA was also assessed by estimating the components of variance and expressing them in the ratio, $2\sigma^2g/(2\sigma^2g + \sigma^2s)$. This ratio is known as Predictability Ratio. The closer this ratio is to unity, the greater the predictability based on GCA. The proportion of additive genetic variance in the total genetic variance ranged from 0.17 to 0.73 for different characters, expressed the predominance of additive gene action in determining the progeny performance. These economically important traits can be improved through direct selection for their higher mean values in subsequent segregating generation.

GCA and *per se* performance

The parents differ in their GCA. Indira Kankoda-1 and Ambika13-6, both high-yielding genotypes, differed in their GCA even though they were originated from the same cross. Parents differ in their breeding value. However, it was possible to select parents showing favorable GCA for days to first flowering to fruit yield, and genotypes that proved to be good general combiners for fruit yield on the basis of their desirable GCA effects and *per se* performance were Indira Kankoda-1 among the females and Ambika13-5 and Ambika13-6 among the testers. When parents were assessed for their overall combining ability for fruit diameter, fruit length and single fruit weight, Chhattisgarh Kankoda-2, NDM-2 and NDM-5 were identified as good combiners that could be utilized in breeding programmes specifically to improve the yield-contributing traits under rainfed conditions.

Heterosis and SCA

All crosses showed positive MPH, BPH and CCH 100% heterosis for days to first flowering and number of branches/plant, showing a positive heterosis for number of first flowering node as 33.33%, 52.38% and 95.23%, respectively. Moreover, crosses also exhibited positive MPH, BPH and CCH with 47.61, 71.42 and 4.76, respectively, for fruit length. In fruit diameter, there was positive 66.66% MPH, 28.57% BPH and 33.33% CCH.

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Table 2. Mean performance of parent for various traits of economic importance in spine gourd

Genotype	Days to first flowering		No. of first flowering node		No. of branches/ plant		Fruit length (cm)		Ovary length (cm)		Ovary diameter (cm)		Fruit diameter (cm)		Single fruit weight(g)		No. of fruits/ plant		Fruit yield (q/ ha)	
	Mean	GCA	Mean	GCA	Mean	GCA	Mean	GCA	Mean	GCA	Mean	GCA	Mean	GCA	Mean	GCA	Mean	GCA	Mean	GCA
Line																				
AJSG-1	48.6	-2.00*	11.2	0.26	6.9	-5.99**	3.64	-0.19	1.7	5.80**	0.66	5.80**	3.37	-2.86**	17.1	-18.15**	50.5	3.17**	43.06	-11.16**
RMDSG-3	46.3	-3.16**	14.2	1.04	6.6	-0.34	4.54	-3.37**	2.4	3.39**	0.63	3.39**	4.01	-1.24	18.3	-9.13**	50.5	-2.72*	46.07	-9.03**
RMDSG-4	47.4	-2.28*	14.9	0.65	6.7	-6.24**	5.08	1.43	2.7	-0.56	0.59	-0.56	3.6	0.51	17.8	-15.45**	50.5	-1.76	44.82	-12.51**
AMBIKA13-5	45	-0.08	15.2	1.65	8.2	-1.16	3.66	3.94**	2.4	-2.16*	0.64	-2.16*	4.09	-0.38	16.2	3.06**	61	-2.38*	49.40	0.28
AMBIKA13-6	46.2	1.76	15	-1.31	9.05	3.07**	3.84	1.04	2.2	-1.70	0.71	-1.70	4.29	1.23	16.5	10.29 **	60	-2.92**	49.47	4.27**
NDM-2	46.8	0.95	11.5	0.48	8.5	4.39**	4.34	-1.49	1.7	-2.66*	0.61	-2.66*	3.07	1.68	16.1	15.48 **	50.5	2.48**	40.52	13.79**
NDM-5	46.2	4.79**	15.4	-2.76*	7.9	6.27**	4.84	-1.36	2.1	-2.11*	0.69	-2.11*	3.37	1.06	15.4	13.90 **	51.5	4.13**	39.52	14.37**
CD (5%)	2.90	2.98	1.40	1.44	0.77	0.79	0.34	0.35	0.17	0.17	0.05	0.05	0.22	0.23	0.57	0.59	1.73	1.79	1.21	2.06
Tester																				
INDIRA KANKODA-1	49.35	-0.67	9.9	0.63	6.4	-3.01**	5.5	-5.05**	1.4	1.31	0.63	1.61	4.08	-1.64	19.5	-4.38**	55.5	-1.96*	54.10	-4.49**
CHHATTISGARH KANKODA-2	45.8	0.74	15.7	0.34	5.65	-0.18	3.64	4.38**	1.9	-2.92**	0.67	-1.58	4.51	1.87*	14.6	6.85**	50.5	-0.25	36.87	3.58**
AJSG-2	47.1	-0.07	13.6	-0.97	6.9	3.19**	4.07	0.67	1.9	1.61	0.62	-0.03	3.52	-0.23	15.3	-2.46*	52.5	2.21*	40.02	0.91
CD (5%)	2.90	2.68	1.40	1.30	0.77	0.71	0.34	0.32	0.17	0.15	0.05	0.05	0.22	0.21	0.57	0.53	1.73	1.60	1.21	**1.85**

Various crosses exhibited a positive MPH, BPH and CCH with 50.00, 45.54 and 43.24, respectively, for number of fruits/plant. For fruit yield, crosses revealed positive MPH, BPH and CCH with 66.80, 65.38 and 30.81, respectively. All the crosses showed positive MPH, BPH and CCH with 100% positive showed in fruit yield.

The average MPH was 12.19 for days to first flowering, ranging from 7.28 to 25.23. The average BPH was 12.40 (7.48-23.44). Similarly, average CCH was 5.27 with a range of 1.32-15.30. The average MPH, BPH and CCH recorded for number to first flowering node was -3.88, 7.54 and 28.48, respectively. The average MPH for number of branches/plant was 47.76 with a range of 6.67-18.91. The average BPH was 34.62, while, average CCH was 61.01. The average MPH, BPH and CCH were 2.55, 13.00 and -19.79, respectively, for fruit length; fruit diameter was 4.53, -2.23 and -1.73, respectively. Single fruit weight 3.50, -2.47 and -12.59. For the number of fruits/plant, the mean MPH, BPH, and CCH were 39.35, 34.82, and 33.34, respectively, while for fruit yield, these values were 44.07, 33.54, and 16.49, respectively. The range for fruit length varied from 0.60 to 53.30 (MPH), 0.21 to 53.30 (BPH), and 0.91 to 1.45 (CCH). The range for fruit diameter was recorded as 0.13 to 34.40 (MPH), 0.25 to 31.53 (BPH), and 0.25 to 13.48 (CCH). Single fruit weight varied between 2.17 to 20.92 (MPH), 0.82 to 20.52 (BPH), and 0.51 to 24.62 (CCH). The number of fruits/plant ranged from 24.23 to 50.00 (MPH), 15.57 to 45.54 (BPH), and 25.23 to 43.24 (CCH). Fruit yield showed a range of 10.92 to 66.80 (MPH), 2.70 to 65.38 (BPH), and 1.47 to 30.81 (CCH).

Low levels of heterosis for fruit yield might be due to high *per se* performance of parents. The rationale for this is that heterosis depends on mean performance of parents involved and, therefore, there can be a cross with high *per se* performance but low heterosis if parental performance is also high. The single fruit weight, ovary length, fruit length and higher magnitude of MPH and BPH for number of fruits/plant indicate that scope for increasing fruit yield. The crosses showed significant positive heterosis for days to first flowering, number of fruits/plant and ovary length, fruit length.

The direction and magnitude of heterosis showed the possibility of developing hybrids to increase fruit yield and enhance productivity.

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Table 3. Per se performance, relative mid parent heterosis, relative better parent heterosis, relative useful heterosis and estimation of SCA effect for different economic traits in spine gourd hybrids.

Hybrid	Number of branches/ plant					Fruit length (cm.)					Single fruit weight (g.)					Fruit yield (q/ha)				
	$\bar{X}$	MP	BP	CC	SCA	$\bar{X}$	MP	BP	CC	SCA	$\bar{X}$	MP	BP	CC	SCA	$\bar{X}$	MP	BP	CC	SCA
AJSG-1 X IK-1	9.3	39.85**	34.78**	45.31**	1.43	5.45	19.26**	49.73**	-0.91	-1.12	16.5	-9.71**	-15.38**	-15.38**	1.66	61.47	26.54**	13.63**	13.63**	1.92*
RMDSG-3 X IK-1	8.8	35.38**	33.33**	37.50**	0.46	4.99	-0.60	9.91**	-9.27	0.79	14.7	-22.12**	-24.62**	-24.62**	4.65**	55.56	10.92**	2.70	2.70	11.45**
RMDSG-3 X CK-2	11.55	88.57**	75.00**	80.47**	0.89	4.82	17.85**	32.42**	-12.36**	-2.07*	18.1	10.20**	-0.82	-7.18	-0.37	62.89	51.65**	36.49**	16.26**	2.14*
RMDSG-4 X CK-2	12.9	108.91**	92.54**	101.56**	-0.37	4.58	5.05	25.82**	-16.73**	1.61	18.5	14.37**	4.23	-5.13	-0.24	66.60	63.04**	48.56**	23.11**	18.14**
AMBIKA13-5 X CK-2	11.6	67.51**	41.46**	81.25**	1.80	3.55	-2.74	-2.47	-35.45**	-0.04	18.6	20.78**	14.81**	-4.62	3.93**	69.24	60.52**	40.16**	27.99**	10.74**
AMBIKA13-5 X AJSG-2	11	45.70**	34.15**	71.88**	-0.44	4.76	23.16**	30.05**	-13.45**	1.87*	16.5	4.93	1.85	-15.38**	5.10**	58.15	30.05**	17.71**	7.49**	14.26**
AMBIKA13-6 X AJSG-2	11.6	45.45**	28.18**	81.25**	2.06*	4.17	5.44	8.59**	-24.18**	0.59	18	13.39**	9.09**	-7.69	-0.63	68.30	52.62**	38.04**	26.25**	9.70**
NDM-5 X IK-1	9.45	32.17**	19.62**	47.66**	0.70	4.85	-6.19**	0.21	-11.82**	0.29	15.6	-10.47**	-20.00**	-20.00**	0.74	59.26	26.60**	9.54**	9.54**	14.51**
NDM-5 X AJSG-2	10.1	36.49**	27.85**	57.81**	0.29	4.08	-8.42**	0.25	-25.82**	-2.96**	18.5	20.92**	20.52**	-5.13	1.19	66.19	66.43**	65.38**	22.36**	4.95**
$\bar{X}$	**10.30**	47.76	34.62	61.01		**4.41**	2.55	13.00	-19.79		**17.05**	3.50	-2.47	-12.59		**63.02**	44.07	33.54	16.49	
Range	7.2-12.9	6.67-18.91	4.35-92.54	12.50-101.56	0.17-3.67	3.55-5.48	0.60-53.30	0.21-53.30	0.91-1.45	0.04-2.67	14.7-19.4	2.17-20.92	0.82-20.52	0.51-24.62	0.09-5.10	**55.5-70.7**	10.92-66.80	2.70-65.38	1.47-30.81	0.82-18.14
+Heterosis (%)		100	100	100			47.61	71.42	4.76			61.90	52.38	0			100	100	100	
IK-1 (C)	6.4					5.5					19.5					**54.10**				
CD (5%)	0.77	1.27	1.48		0.56	0.34	0.55	0.66		0.25	**0.57**	0.94	1.09		0.42	**1.21**	3.33	3.84		1.47

*, **Significant at 1% and 5% Level of Significance, respectively

However, high-performing heterotic cross combinations involving parents with at least one good general combiner that produced superior F_1 progenies in spine gourd and thus could be advantageously utilized in breeding programmes. As *per se* performance is realized value and the heterotic response is an estimate, former should also be given preference when making a selection in cross combinations (Table 3). In our study, all crosses showed significant MPH, BPH and CCH in desirable direction for days to first flowering,

Crosses AJSG-1 × IK-1, RMDSG-3 × IK-1, RMDSG-3 × Chhattisgarh Kankoda-2, RMDSG-4 × Chhattisgarh Kankoda-2, Ambika 13-5 × Chhattisgarh Kankoda-2, Ambika 13-5 × AJSG-2, Ambika 13-6 X AJSG-2, NDM-5 × IK-1 and NDM-5 X AJSG-2 were showed a significant positive SCA for single fruit weight.

The specific combining ability (SCA) effects for fruit length and single fruit weight were non-significant in most crosses. However, crosses exhibiting significant positive mid-parent heterosis (MPH), better-parent heterosis (BPH), and commercial heterosis (CCH) for traits such as days to first flowering, first flowering node, number of branches plant, fruit length, ovary length, ovary diameter, fruit diameter, single fruit weight, number of fruits plant, and fruit yield also showed significant positive SCA effects. Heterotic crosses involving good × good general combining ability (GCA) parents with insignificant SCA effects suggest the predominance of additive × additive interactions in heterosis. Therefore, direct selection for superior single fruit weight (Ambika 13-5, Ambika 13-6, NDM-2, NDM-5, and Chhattisgarh Kankoda-2) and a higher number of fruits per plant (Ambika 13-6, NDM-2, NDM-5, and Chhattisgarh Kankoda-2) is recommended in advanced generations, as additive gene effects contribute significantly to trait variation.

All crosses, except one involving poor × poor GCA parents, exhibited negative or low positive MPH, BPH, and CCH for single fruit weight, indicating that high-performing parents with poor GCA may not yield

highly heterotic crosses. Similar findings were reported by Mahla *et al.* (2023) in *Allium* and Thangamani *et al.* (2011) in bitter gourd, where hybrids derived from good × good and medium × poor or medium × medium combiners exhibited significant SCA effects.

The selection of parents should be based on per se performance as well as combining ability and heterosis. RMDSG-4 × CK-2 (66.60 q/ha), Ambika 13-5 × CK-2 (69.24 q/ha), Ambika 13-5 × AJSG-2 (58.15 q/ha), Ambika 13-6 × AJSG-2 (68.30 q/ha), NDM-5 × IK-1 (59.26 q/ha) and NDM-5 × AJSG-2 (66.19 q/ha) were the crosses with desirable yield attributing traits and good combining ability. Ambika 13-5, Ambika 13-6, NDM-2, NDM-5 and Chhattisgarh Kankoda-2 were identified as good parent for single fruit weight and fruit yield.

The Propagation of spine gourd through stem cutting was standardized by Tiwari *et al.* (2022). Once the best combiner identified there is no need to go for hybrid seed production in proper parental combination. Though seed germination is also a problem along with early-stage male and female identification (Amin *et al.*, 2022). Crosses Ambika 13-5 × Chhattisgarh Kankoda-2 (69.24 q/ha), Ambika 13-6 × AJSG-2 (68.30 q/ha), RMDSG-4 × Chhattisgarh Kankoda-2 (66.60 q/ha), NDM-5 × AJSG-2 (66.19 q/ha), RMDSG-3 × Chhattisgarh Kankoda-2 (62.89 q/ha), AJSG-1 × IK-1 (61.47 q/ha), NDM-5 × IK-1 (59.26 q/ha), Ambika 13-5 × AJSG-2 (58.15 q/ha) and RMDSG-3 × IK-1 (55.56 q/ha) can be used to get good heterotic combination and it will be multiply through stem cuttings after fixation of heterosis in the form of asexual propagating material, *i.e.* tuber. Therefore, these cross combinations could be utilized in isolation of superior parents for incorporating yield attributing and qualitative traits.

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