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Bhoomi R Viradiya
Department of Genetics and Plant Breeding, C. P. College of Agriculture, Sardarkrushinagar Dantiwada Agricultural University, Sardarkrushinagar, Dantiwada, Gujarat, India

Rehana Niyaria
Department of Basic Sciences, Aspee College of Horticulture, Navsari Agricultural University, Navsari, Gujarat, India

Shivangi Vanapariya
Department of Genetics and Plant Breeding, N. M. College of Agriculture, Navsari Agricultural University, Navsari, Gujarat, India

Kruti Gorasiya
Department of Genetics and Plant Breeding, N. M. College of Agriculture, Navsari Agricultural University, Navsari, Gujarat, India

Rinkal Goswami
Department of Genetics and Plant Breeding, N. M. College of Agriculture, Navsari Agricultural University, Navsari, Gujarat, India

Corresponding Author:
Bhoomi R Viradiya
Department of Genetics and Plant Breeding, C. P. College of Agriculture, Sardarkrushinagar Dantiwada Agricultural University, Sardarkrushinagar, Dantiwada, Gujarat, India

Estimation of gene action and combining ability in ridge gourd [*Luffa acutangula* (L.) Roxb.]

Bhoomi R Viradiya, Rehana Niyaria, Shivangi Vanapariya, Kruti Gorasiya and Rinkal Goswami

Abstract
This research was carried out to study the combining ability and gene action for yield and yield attributing traits in the ridge gourd by using seven diverse parents which were crossed in half diallel matting design. This research was carried out at a college farm, Navsari Agricultural University, Navsari, during *late Kharif*- 2021-22. GCA and SCA mean squares revealed that additive and non-additive gene actions were involved in the inheritance of these traits. While σ^2sca was higher than σ^2 gca for all traits denoting preponderance non-additive gene action. Results of general combining ability effects revealed that GLC^{-1} and GLC-3 had higher GCA effects for fruit yield per plant.

Keywords: Ridge gourd, GCA, SCA, combining ability, Non-additive

Introduction
Ridge gourd is a vegetable crop belonging to the genus *Luffa* of the *Cucurbitaceae* family, which originated from the Asian sub-tropical area probably India and has chromosome number 2n = 26. It is popularly known as kalitori, angeled loofah, angeled gourd or Chinese okra. It is cultivated for its tender edible fruits both on a commercial scale and for household consumption.

Ridge gourd is a monoecious and cross-pollinated annual crop though cultivated species of ridge gourd is monoecious in nature, six different sex forms *viz.,* andromonoecious, gynomonoecious, gynoecious, androecious and hermaphrodite plats are also reported (Chaudhary and Thakur, 1965) [1].

The fruit of ridge gourd is club-shaped, angled with prominent ridges and multiple seeded. Tender fruits are green in colour, and are used in soup and curries as cooked vegetables. The 100g of edible fruit contains 95.2 g moisture, 0.5g protein, 0.1 g fat, 0.3 g minerals, 0.5g fibre, 5.0g carbohydrate, 20 Cal energy, 40 mg calcium, 11mg magnesium, 40 mg phosphorus, 1.6 mg iron, 2.9 sodium, 50 mg potassium, 0.16 mg copper, 13 mg sulphur, 7.0 mg chlorine, 56 (I.U.) Vit-A, 0.07 mg Thiamine, 0.01 mg Riboflavin, 0.2 mg Nicotinic acid, 5mg Vit-C, 27 mg Oxalic acid (Rahman *et al.*, 2008) [10].

Combing ability analysis is a powerful tool, which provides an estimate of the combing ability effect and it aids in selecting desirable parents and crosses for further exploitation. General combing ability provides information on additive variance and Additive × Additive interaction which help the breeder for choice of good combiner parent while, specific combing ability expresses non-additive genetic variance arising from dominance and epistasis, which is estimation used to identify superior crosses for further exploitation. The diallel analysis given by Gaffing (1956 a & b) is used here for the estimation of combing ability.

Materials and Methods
The investigation was carried out at Navsari Agricultural University, Navsari in late Kharif 2022. The experimental material was composed of seven parents *viz*., GLC-5, GLC-1, GLC-3, GLC-6, Jaipuri, JL-7 and JVRS-12 which crossed in diallel mating design to develop 21 hybrids. The resulting hybrids along with their parents were grown under randomized block design (RBD) with three replications. The spacing of 2.0 m between rows and 0.6 m between plants was maintained. Observations were recorded from five randomly selected plants in each replication on fifteen characters *viz*., days to the first female flower, days to first male flower, node number of first female flower, node number of first male flower, vine length (m), fruit length (cm), fruit girth (cm), fruit weight (g), fruits per plant, fruit yield per plant (kg), days to marketable maturity, 100 seed weight (g), crude fibre (g/100g), moisture (%) and total soluble sugar (g/100g). these characters were subjected to statistical analysis to derive information on

combing ability by using Model-I and Method-II proposed by Griffing (1956). This includes partitioning of variation among sources attributed to general combing ability (GCA) and specific combing ability (SCA) components.

Results and Discussion

Analysis of variance for combining ability showed that the GCA and SCA mean sum of square was significant for all the traits indicating the involvement of both additive as well as non-additive gene action for these traits (Table 1). Similar kind of results were reported by Kumar *et al.* (2014) [7], Kaniti (2016) [6], Muthaiah *et al.* (2017a) [8] and Sarkar and Singh (2017) [11].

A perusal of genetic variance revealed that the SCA variance (σ^2sca) was higher than the GCA variance (σ^2gca) for all the characters denoting the preponderance of non-additive gene action for all the characters this was further confirmed by σ^2gca/ σ^2sca was less than unity (Table 1). This finding was in accordance with Kaniti (2016) [6], Muthaiah *et al.* (2017a) [8] and Hadiya *et al.* (2020) [5].

General Combing ability

GCA effects of parents for days to first female flower varietal from -2.37 to 2.93, while parent GLC-3 (-2.37) and GLC-5 (-1.85) are good combiners for this trait. Node number of first female flower appearance GCA range 0.75 to -0.55 while only one parent GLC-5 (-0.55) was found good general combiner for this trait. A range of 0.18 to 0.25 appeared for the node number of first male flower. Good negative combiner parents were GLC-3 (-3.5) and GLC-5 (-2.09) for days to marketable maturity and the range for these traits was -3.50 to 3.50 (Table 2).

For the vine length (m) Range of GCA, effects varied between -0.52 to 0.69, while two parents GLC-3 (0.69) and GLC-1 (0.51) were good general combiners. A range of -1.28 to 1.47 was obtained for fruit length (cm), GLC-1 (1.27) and GLC-6 (1.43) was a good combiners for this trait. GCA effect for fruit girth (cm) varied between -0.78 to 0.57 while, GLC-3 (0.57), GLC-6 (0.33) and JVRS-12 (0.19) were good general combiners. GCA effect of fruits per plant varied between -0.31 to 0.96 while GLC-5(0.59) and GLC-1 (0.96) were good combiners for this trait. The magnitude of the GCA effect for fruit yield per plant (kg) was laid down between 0.11 to 0.10, while only two GLC-1 (0.11) and GLC-3 (0.10) were found good combiners for fruit yield per plant.

GCA effect for crude fibre (g/100g) content varied between -0.17 to 0.20, while four parents GLC-3 (-0.17), Jaipuri (-0.14), JL-7 (-0.09) and JVRS-12 (-0.08). JL-7 (-0.61) was a good combiner for moisture (%). For total soluble sugar (g/100g) GCA effects ranged from -0.13 to 0.26, while two parents GLC-5 (0.26) and GLC-6 (0.09) were good combiners for this trait.

Results of GCA effects revealed that none of the parents showed good GCA effects for all the characters. But, from all two parents GLC-1 and GLC-3 also had good significance for fruit yield per plant. Elsewhere, these parents also had a good significant performance for yield attributing traits and earliness traits *viz*., days to the first female flower, days to first male flower, the node number of the first female flower, node number of first male flower and days to marketable maturity.

Specific combining ability

For days to first female flower range of SCA effect varied between -5.36 to 7.71 while JL-7 × JVRS-12 was best cross. The range of SCA effects was found between -2.17 to 2.42 for the node number of the first male flower and the best cross for this trait was GLC-1 × JL-7. SCA effects for days to first male flower ranged from -6.18 to 11.05, while GLC-5 × JVRS-12 was the best cross. The magnitude of SCA effects for node number of the first male flower, while GLC-5 × GLC-3 was the best cross for this trait. For days to marketable maturity, SCA effects magnitude ranged between -4.48 to 7.96 while the best cross was GLC-3×Jaipuri.

Estimates of SCA effects for vine length (m) varied between -1.78 to 1.27, while the best cross for this trait was GLC-5 × JVRS-12. For fruit length (cm) range of SCA effects was -5.24 to 3.56, while the best cross was GLC-6 × Jaipuri. SCA range for fruit girth (cm) between -1.12 to 1.29, while the best cross was GLC-3 × JVRS-12. For fruit weight (g) range of SCA effect lay between -41.05 to 31.77 and the best cross for this trait was GLC-5 × GLC-6. For fruits per plant SCA effect valued between -3.03 to 2.87, five crosses had significant SCA effect among them best was GLC-1 × GLC-3.

SCA values for 100 seed weight (g) varied from -2.81 to 3.75, while the best cross was GLC-1 × GLC-3. A range of 0.91 to 1.36 was found for the crude fibre (g/100g) and the best cross was GLC-3 × GLC-6. For total soluble sugar SCA effects ranged from -1.09 to 1.02, while the best cross was GLC-5 × GLC-6.

Meanwhile, SCA effects of fruit yield per plant and moisture content was not counted as SCA mean sum of squares of these traits were non-significant (Table 3).

The SCA effect did not show any specific trend for the SCA of parents. Parents involved in all types of combinations *viz.*, Good × Good, Average × Good, Poor × Good, Average × Average, Average × Poor, Poor × Poor. In this study, it found that 60.86 per cent of crosses had both or at least one parent was a good general combiner while 28.26 per cent had one or both parents were Average general combiner and 10.86% were derived for a poor combiner

Table 1: Analysis of variance for combining ability and variance component for various traits in ridge gourd

Source of variation	d.f.	Days to first female flower	Days to first male flower	Node number of first female flower	Node number of first male flower	Vine length (m)	Fruit length (cm)	Fruit girth (cm)	Fruit weight (g)
GCA	6	33.07**	20.23**	2.10**	0.24**	1.83**	9.61**	1.69**	170.24**
SCA	21	14.58*	16.39**	2.09**	0.20**	0.83**	9.12**	0.53**	415.91**
Error	54	6.68	3.62	0.31	0.09	0.11	2.87	0.08	0.68
Variance components									
σ^2gca		2.93	1.84	0.21	0.02	0.19	0.75	0.18	17.10
σ^2sca		7.90	12.76	1.78	0.12	0.72	6.25	0.44	399.57
σ^2gca/ σ^2sca		0.37	0.14	0.11	0.15	0.27	0.12	0.40	0.04

Source of variation	d.f.	Fruits per plant	Fruit yield per plant (kg)	Days to marketable maturity	100 seed weight (g)	Crude fibre (g/100g)	Moisture (%)	Total soluble sugar (g/100g)
GCA	6	2.42**	0.05**	49.64**	8.68**	0.22**	1.50**	0.17**
SCA	21	2.78**	0.02	12.63**	4.36**	0.40**	0.68	0.49**
Error	54	0.68	0.01	3.56	0.21	0.09	0.39	0.003
Variance components								
σ^2gca		0.17	0.004	5.12	0.94	0.02	0.12	0.02
σ^2sca		2.10	0.009	9.08	4.15	0.39	0.29	0.49
σ^2gca/ σ^2sca		0.08	--	0.56	0.23	0.06	--	0.04

*, ** Significant at 5% and 1% levels, respectively.

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

Sr. No.	Parents	Days to first female flower	Days to first male flower	Node number of first female flower	Node number of first male flower	Vine length (m)	Fruit length (cm)	Fruit girth (cm)	Fruit weight (g)
1.	GLC-5	-1.85*	0.49	-0.55*	-0.05	-0.52*	-0.18	-0.12	-1.69
2.	GLC-1	-1.11	-0.32	0.57*	-0.18	0.51*	1.27*	-0.78*	-3.85*
3.	GLC-3	-2.37*	-1.98*	-0.31	0.04	0.69*	0.16	0.57*	9.45*
4.	GLC-6	1.63*	0.02	-0.11	-0.14	-0.29*	1.43*	0.33*	-1.22
5.	Jaipuri	2.93*	2.87*	-0.03	-0.09	-0.08	-1.28*	-0.20*	-2.16
6.	JL-7	0.04	-0.98	-0.31	0.18	-0.35*	-0.54	0.02	0.01
7.	JVRS-12	0.74	-0.09	0.75*	0.25*	0.04	-0.86	0.19*	-0.54
SE (g_i)		0.79	0.59	0.17	0.09	0.10	0.52	0.09	1.25
CD 5%		1.60	1.18	0.34	0.18	0.21	1.05	0.18	2.50

Sr. No.	Parents	Fruits per plant	Fruit yield per plant (kg)	Days to marketable maturity	100 seed weight (g)	Crude fibre (g/100g)	Moisture (%)	Total soluble sugar (g/100g)
1.	GLC-5	0.59*	-0.07	-2.09*	1.84*	0.12*	-0.26	0.26*
2.	GLC-1	0.96*	0.11*	-0.68	-0.50*	0.16*	0.32	-0.13*
3.	GLC-3	0.01	0.10*	-3.50*	-0.09	-0.17*	-0.61*	-0.03
4.	GLC-6	0.26	-0.01	1.69*	-0.18	0.20*	-0.21	0.09*
5.	Jaipuri	-0.31	-0.06	3.50*	-1.01*	-0.14*	0.26	-0.05*
6.	JL-7	-0.24	-0.01	0.13	0.70*	-0.09*	0.58*	-0.02
7.	JVRS-12	-0.09	-0.04	0.95	-0.76*	-0.08*	-0.07	-0.12*
SE (g_i)		0.25	0.04	0.58	0.14	0.03	0.19	0.02
CD 5%		0.51	0.07	1.17	0.28	0.06	0.39	0.03

*, ** Significant at 5% and 1% levels, respectively.

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

Sr. No.	Crosses	Days to first female flower	Days to first male flower	Node number of first female flower	Node number of first male flower	Vine length (m)	Fruit length (cm)	Fruit girth (cm)	Fruit weight (g)
1.	GLC-5 × GLC-1	7.71**	11.05**	-0.18	-0.28	-1.78**	-4.07**	-1.12**	-30.04**
2.	GLC-5 × GLC-3	3.97	-0.29	0.02	-0.63*	0.07	3.17*	0.13	30.07**
3.	GLC-5 × GLC-6	-0.03	-2.95	-0.28	-0.38	-0.03	1.64	1.04**	31.77**
4.	GLC-5 × Jaipuri	5.34*	3.19	-0.53	-0.03	0.59*	-1.76	0.37	-41.05**
5.	GLC-5 × JL-7	-0.77	-1.95	-0.08	0.03	1.09**	-5.24**	0.35	-15.47**
6.	GLC-5 × JVRS-12	2.47	-6.18**	-0.08	0.89**	1.27**	-2.37	-0.89**	-14.42**
7.	GLC-1 × GLC-3	-0.10	-1.47	-1.36**	0.76**	0.13	-1.00	-0.61*	-17.17**
8.	GLC-1 × GLC-6	-1.44	-0.81	0.17	0.15	-1.03**	-1.29	-0.64*	-3.02
9.	GLC-1 × Jaipuri	1.60	1.34	2.36**	-0.44	-0.39	3.20*	-0.24	22.44**
10.	GLC-1 × JL-7	-0.84	-2.47	-2.17**	-0.44	0.01	2.85	-0.19	-2.48
11.	GLC-1 × JVRS-12	-0.21	0.64	-0.19	0.02	-1.15**	1.02	0.64*	-8.58*
12.	GLC-3 × GLC-6	-3.18	-1.47	-1.45**	0.32	-0.97**	1.11	-0.65*	-12.95**
13.	GLC-3 × Jaipuri	-4.14	-0.99	-1.83**	0.01	0.64*	0.86	0.08	26.02**
14.	GLC-3 × JL-7	-0.25	0.53	-0.26	0.21	0.02	-2.12	-0.21	-9.06*
15.	GLC-3 × JVRS-12	-1.29	-0.03	0.26	0.00	0.43	3.01*	1.29**	21.69**
16.	GLC-6 × Jaipuri	-2.14	-0.99	1.30**	0.39	-0.06	3.56**	0.05	4.06
17.	GLC-6 × JL-7	5.75*	6.53**	1.14*	0.19	-0.24	0.66	0.17	-1.59
18.	GLC-6 × JVRS-12	2.05	0.64	2.42**	0.18	0.45	1.30	-0.21	1.02
19	Jaipuri × JL-7	0.79	2.34	0.16	0.14	-0.30	2.75	0.30	6.66
20.	Jaipuri × JVRS-12	-1.92	-3.21	-0.23	-0.20	-0.91**	0.71	-1.07**	-1.73
21.	JL-7 × JVRS-12	-5.36*	-4.69**	1.41**	0.60*	-0.34	-1.88	1.04**	9.36**
S.E. (s_{ij})		2.32	1.71	0.50	0.26	0.30	1.52	0.27	3.63
CD 5%		4.65	3.43	1.00	0.53	0.61	3.05	0.53	3.63

*, ** Significant at 5% and 1% levels, respectively

Table 3: Cont.

Sr. No.	Crosses	Fruits per plant	Fruit yield per plant (kg)	Days to marketable maturity	100 seed weight (g)	Crude fibre (g/100g)	Moisture (%)	Total soluble sugar (g/100g)
1.	GLC-5 × GLC-1	-0.01	--	7.96**	-0.44	-0.03	--	-0.82**
2.	GLC-5 × GLC-3	-2.25**	--	1.78	-0.26	-0.21*	--	0.57**
3.	GLC-5 × GLC-6	-3.03**	--	0.26	3.34**	0.53**	--	1.02**
4.	GLC-5 × Jaipuri	1.95**	--	5.11**	-2.39**	0.14	--	-0.69**
5.	GLC-5 × JL-7	0.51	--	-3.52*	0.78	-0.68**	--	-0.04
6.	GLC-5 × JVRS-12	2.60**	--	-3.67*	-1.09**	-0.06	--	0.61**
7.	GLC-1 × GLC-3	2.87**	--	-0.96	3.75**	-0.04	--	-0.25**
8.	GLC-1 × GLC-6	0.01	--	-2.48	0.11	-0.03	--	-0.21**
9.	GLC-1 × Jaipuri	-1.73**	--	2.04	-0.32	-0.67**	--	0.38**
10.	GLC-1 × JL-7	0.40	--	-2.26	-1.58**	-0.06	--	0.67**
11.	GLC-1 × JVRS-12	1.83**	--	-0.74	-1.46**	0.54**	--	-0.33**
12.	GLC-3 × GLC-6	1.29**	--	-3.00	2.80**	-0.91**	--	-0.32**
13.	GLC-3 × Jaipuri	-1.46*	--	-4.48**	-1.69**	-0.64**	--	-0.40**
14.	GLC-3 × JL-7	1.05	--	1.22	-0.61	-0.53**	--	-0.07
15.	GLC-3 × JVRS-12	-2.25**	--	-0.92	-0.19	-0.30**	--	-0.33**
16.	GLC-6 × Jaipuri	-0.01	--	-1.67	-2.81**	0.03	--	-0.89**
17.	GLC-6 × JL-7	0.56	--	3.70*	1.45**	0.06	--	-1.09**
18.	GLC-6 × JVRS-12	-1.19	--	3.56*	1.73**	-0.86**	--	-0.57**
19	Jaipuri × JL-7	-0.81	--	1.89	0.45	-0.08	--	0.37**
20.	Jaipuri × JVRS-12	-0.11	--	-2.59	2.82**	0.32**	--	0.87**
21.	JL-7 × JVRS-12	-0.23	--	-3.56*	0.92*	1.36**	--	1.01**
S.E. (s_{ij})		0.74	--	1.69	0.41	0.08	--	0.05
CD 5%		1.48	--	3.39	0.82	0.17	--	0.10

*, ** Significant at 5% and 1% levels, respectively.

Note: [--] SCA effect of hybrids were not calculated for fruit yield per plant (kg) and moisture (%) because mean sum of squares for particular traits were non-significant

Results of this study revealed that there was some degree of correspondence between SCA effects of hybrids as well as GCA effects of parents. Relationships between this parameter were also observed by Sarkar *et al.* (2015) [11], Chauhan *et al.* (2019) [2] and Patel and Mehta (2021) [9].

Conclusion

All traits studied in this study were governed by additive as well as non-additive gene action, non-additive gene action is prevalent for most traits as σ^2gca/σ^2sca ratio is less than unity. Genotypes GLC-5, GLC-3 and GLC-1 were good general combiners for fruit yield per plant and yield attributing traits like fruits per plant, vine length (m), fruit length (cm) and also for earliness. While, none of the parents and crosses showed continuous good GCA and SCA for all of the traits, respectively.

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