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Analysis of Combining Ability and Gene Action in Ridge Gourd [*Luffa acutangula* (L.) Roxb.]

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ABSTRACT: An experiment was conducted in randomized block design with three replications (*kharif*, 2023) to assess the combining ability and nature of gene action of the parents and crosses in the expression of fruit yield and its components for twelve characters in ridge gourd [*Luffa acutangula* (L.) Roxb.]. The material for the present study involved seven diverse parents and their twenty-one resultant hybrids derived from half diallel mating and one standard check (GJRGH 1), which were grown and evaluated at Horticultural Instructional Farm, S.D.A.U, Sardarkrushinagar. The objectives of this study were to investigate combining ability and gene action for different characters under study. The observations were recorded for days to first male flower, days to first female flower, primary branches per plant, node number of first male flower, node number of first female flower, days to first picking, main vine length (m), fruit weight (g), fruit length (cm), fruit girth (cm), fruits per plant and fruit yield per plant (kg). Analysis of variance (ANOVA) for combining ability revealed that GCA and SCA mean sum of square were significant for all of the traits indicating that both additive and non-additive gene actions were involved in the inheritance of these traits. However, for primary branches per plant and node number of first male flower non-significant GCA mean square values and for fruit yield per plant non-significant SCA mean square values were noted. The σ^2gca/σ^2sca ratio was less than unity, indicating that the σ^2sca was greater than the σ^2gca for all characters except fruit yield per plant, suggesting a preponderance of non-additive gene action for these characters. GRG-2 and JDNRG-19 were the two parents with a substantial gca effect for fruit output per plant, according to the results of general combining ability effects. There was no discernible pattern in the sca consequences for the parent's gca. Any combination of the parent's Good × Good, Average × Good, Poor × Good, Average × Average, Average × Poor, and Poor × Poor was included in the crosses with the desired sca result. An examination of every cross that showed notable sca effects revealed that these crosses also included average and low combiner parents, demonstrating the presence of favorable interallelic interactions for the characters. For the majority of the qualities, a positive correlation was found between per se performance, gca impacts of parents, and sca effects of hybrids. Therefore, in addition to the effects of general combining ability, the parent's performance alone could be taken into consideration when choosing which parents to include in the breeding program.

Keywords: Ridge gourd, analysis of variance (ANOVA), combining ability, gene action, gca, sca.

INTRODUCTION

Ridge gourd [*Luffa acutangula* (L.) Roxb.] belongs to the family Cucurbitaceae and genus Luffa. It is widely grown in tropical and subtropical parts of the country. Its chromosome number is 2n=2x=26. It is also called as angled gourd, angled loofah, chinese okra, silky gourd and ribbed gourd (Muthaiah *et al*., 2017a). The genus Luffa derives its name from the product 'loofah' which is used in bathing sponges, door mats, pillows and also for cleaning utensils (Srikanth *et al*., 2021). The centre of origin and the primary gene centre of Luffa is India. *Luffa acutangula* (Ridge gourd) and *Luffa cylindrica* (Sponge gourd) are grown throughout India in tropical and subtropical climate. Ridge gourd is cultivating in 24,500 acres approximately in India with production of 3,16,925 tonnes (Bellamkonda *et al*., 2020). Ridge gourd is delicious vegetable and its tender fruits can be cooked to prepare various curries and it is also used in making chutneys in South India. Ridge gourd is grown both as spring-summer and rainy season crop.

Luffa has nine species out of which six species [*Luffa acutangula* (L.) Roxb, *L. cylindrica M. Roem, L. echinata* Roxb., *L. graveolens, L. tuberose* Roxb., *L. umbellata*] are found in India (Doijode, 2002). Ridge gourd is monoecious and cross-pollinated crop. The staminate flowers with five stamens (synandry) are borne in 10-20 flowered racemes, while pistillate flowers are solitary, short or long pedunculate and fragrant (Muthaiah *et al*., 2017a). Ridge gourd is generally monoecious in nature but hermaphrodite, andromonoecious, trimonoecious and gynoecious flowering behaviour has also been reported (Swarup, 2006). On the leaf axil, pistillate and staminate flowers are produced. The pistil has three placentas with numerous ovules, and the anthers are free. Stigmas are three and bilobate. Between 5 and 7 p.m. anthesis starts and the flowers stay open all night.

The crop has enormous potential for improvement and is significant both commercially and medicinally. Ridge gourd is a cross-pollinated crop that is primarily monoecious, which means there is plenty of room to take advantage of the hybrid vigour. Compared to other vegetables, the cost of producing F_1 seeds is low, and a single fruit yields a large number of seeds. Therefore, evaluating and utilizing the genetic variability can result in rapid improvement. The genetic makeup of traits that contribute to yield determines crop improvement. One of the possible methods for taking advantage of yield and features that contribute to it is heterosis breeding. Earlier, Abusaleha and Dutta (1994); Kadam *et al*. (1995); Niyaria and Bhalala (2001) reported that heterosis was found effective for early bearing and gave higher yields in ridge gourd. For development of promising hybrids, the identification of genetically superior plants is prerequisite.

Combining ability analysis is one of the powerful tools available which gives the estimates of combining ability effect and aids in selecting desirable parents and crosses for further exploitation (Sprague and Tatum 1942). In actual plant breeding, combining abilities have found their principle use in predicting the performance of parents and hybrid populations of outbreeders, often in the form of test-crosses or polycrosses (Munshi and Verma 1999). Despite being widely grown, there aren't many studies being done to improve ridge gourd. The goal of the current study was to choose appropriate combiner lines for the hybridization program and take advantage of hybrid vigour due to its extensive variety and importance as a vegetable crop.

For plant breeders, combining ability analysis is crucial because it helps them determine the future breeding strategy by elucidating the nature of gene activity that controls the development of the character. The development of the idea of combining elements that can show the most hybrid vigour in F_1. While specific combining ability refers to a particular crosses departure from expectations based on the average performance of the lines involved, general combining ability is the average performance of the lines in hybrid combinations. Whereas specialized combining ability contains non-additive genetic variations resulting from dominance and epistatis, general combining ability includes additive variance and variance resulting from additive x additive interaction. So, there is information accessible regarding the ridge gourd's combining ability.

However, to substantiate this information and to derive additional information on all the characters and also for locating all the possible combinations. More use of the available variability is required for exploitation of heterosis. Yield is highly complex character and many factors are responsible for the expression. It is necessary to understand the mode of inheritance in governing such characters (Malve *et al.*, 2020).

MATERIAL AND METHODS

The experiment was undertaken during summer and kharif season in the year 2022. The field experiment for evaluation was conducted at Horticultural Instructional Farm, S.D.A.U, Sardarkrushinagar which is situated at an altitude of 152.52 meters above mean sea level on 240 – 19′N latitude and 720 – 19′E longitude. The soil of the experimental site is sandy loam, porous and poor in organic matter content with a 7.5 pH. The experimental material consisted of seven parents and their resulted twenty-one crosses by half diallel mating and one standard check (GJRGH 1). The seeds of hybrids were produced during summer 2022 at Centre for Crop Improvement, S.D.A.U, Sardarkrushinagar – 385 506 by manual emasculation and crossing. The seeds of parental lines were maintained through selfing. The list of genotypes selected for crossing programme and check used is mentioned in Table 1.

Seeds of parents were sown in February, 2022 at the Centre for Crop Improvement, S.D. A.U, Sardarkrushinagar, for attempting crosses in half diallel fashion. Sowing was done at a spacing of 2.0 m × 1.0 m. A total of twenty-one hybrids were developed by crossing seven genotypes. Bagging of selected male and female flowers was done in the morning with butter paper bags to avoid outcrossing and contamination. These flowers were utilized for crossing in the evening. Between 5:00 and 7:00 p.m., pollination was conducted using the desired male parent's pollen. The female flower buds were tagged and once more covered with butter paper bags to prevent contamination after pollination. To obtain pure seeds of each type, the parents were also selfed at the same time. When the fruits reached full maturity, they were harvested separately from the crossed and selfed fruits. Fruits were kept for curing before the seeds were extracted. The seeds were extracted from fully dried fruits for evaluation.

A set of twenty-nine genotypes comprising of seven parents, their twenty-one F_1 hybrids and one standard check (GJRGH 1) were sown in randomized block design (RBD) with three replications, during *kharif* 2022 at Horticultural Instructional Farm, S.D.A.U. Each genotype was grown in single row using 2.0 m × 1.0 m spacing. In each single line, 10 plants were grown to evaluate the material for elucidate combining ability and nature of gene action. To cultivate the healthy crop, the suggested agronomic package of techniques was followed. Five randomly chosen plants from each replication's twelve characters were observed *viz*., days to first male flower, days to first female flower, primary branches per plant, node number of first male flower, node number of first female flower, days to first picking, main vine length (m), fruit weight (g), fruit length (cm), fruit girth (cm), fruits per plant and fruit yield per plant (kg). The pooled data of all above characters were subjected to statistical analysis carried out under this experiment were done using the R statistical software. The analysis of variance was carried out for randomized block design as per procedure described by Panse and Sukhatme (1985). Analysis of variance for combining ability (Half-diallel) was carried out with the data obtained for parents and crosses according to the procedure given by Griffing (1956) as per Method II (in which parents and a set of F_1's without reciprocals are included) and Model I [which assumes that the genotypes and block effects are constant (fixed) but environmental effect is variable].

RESULTS AND DISCUSSION

Every crop improvement project must have genetic variability in order to succeed. Table 2 shows the mean squares for a total of twelve characters. There may have been variability in the parental material used in this study, as indicated by the highly significant mean squares due to genotypes, parents, and hybrids (F_1) for the majority of the characters. The analysis of variance revealed significant differences among the genotypes, parents and hybrids for all the characters excluding primary branches per plant, node number of first male flower, fruits per plant and fruit yield per plant. This indicated that a considerable amount of genetic variability was present in the material studied and the material was suitable for the study of the manifestation of combining ability and genetic parameters involved in the inheritance of different traits. For the main vine length, the mean squares resulting from parents *vs* hybrids were highly significant at 1%, indicating that there may be heterosis due to variations between parents and hybrids. In contrast, mean squares for fruit weight and node number of the first female flower resulting from check *vs.* hybrids are only 5% significant.

The analysis of variance for combining ability of various characters is presented in Table 3. Analysis of variance for combining ability revealed that GCA and SCA mean sum of square was significant for all the traits indicating that both additive and non-additive gene actions were involved in the inheritance of these traits. However, for fruit yield per plant SCA mean square value was non-significant suggesting involvement of additive gene action for these traits. Similar results were reported by Kumar *et al.* (2014); Kaniti (2016); Malviya *et al.* (2017); Muthaiah *et al.* (2017a); Muthaiah *et al.* (2017b); Sarkar and Singh (2017); Patel and Mehta (2021). Pursual of genetic variance revealed that the SCA variance ($\sigma^2 sca$) was higher than GCA variance ($\sigma^2 gca$) for all characters except fruit yield per plant denoting preponderance of non-additive gene action for all of these characters. This was further confirmed by $\sigma^2 gca/\sigma^2 sca$ ratio which is less then unity. Non-additive gene action for various characters reported by Kaniti (2016); Bhatt *et al.*(2017); Malviya *et al.* (2017); Muthaiah *et al.* (2017a); Chandan *et al.* (2018); Naik *et al.* (2018); Hadiya *et al.* (2020); Srikanth *et al.* (2021).

General combining ability effects of parents are presented in Table 4. Considering the importance of fruit yield per plant in the present investigation, out of 21 F_1 hybrids and their parents, the gca effects for fruit yield per plant, ranged from -0.12 (JDNRG-39) to 0.10 (GRG-2). Out of seven parents, two parents GRG-2 (0.10) and JDNRG-19 (0.09) showed significant gca effect in a positive direction whereas, only one parent JDNRG-39 (-0.12) exhibited significant gca in negative direction (Fig. 1). Nature and magnitude of the combining ability effects provide guidelines in identifying parents and their fruitful utilization. The genotypes studied are classified as good, average and poor combiners based on gca effects for various traits and presented in Table 5. For all the characters, the results showed that none of the parents had good gca effects. But for one character or another, all of the parents were deemed to be good combiners. GRG-2 and JDNRG-19 were the two parents with the greatest gca effect on fruit yield per plant.

Along with fruit yield per plant GRG-2 was good general combiner for node number of first female flower, fruits per plant, main vine length, fruit length. Parent JDNRG-19 was good general combiner for days to first male flower, days to first female flower, primary branches per plant, days to first picking, main vine length, fruit weight, fruit girth and fruit yield per plant. It was observed that good combiner for fruit yield per plant was also good combiner for one or more yield contributing characters. In general, the top general combiners were also the best *per se* performance parents, demonstrating a positive relationship between the two criteria. These findings showed that, in addition to the effects of general combining ability, parent's *per se* performance may be taken into account when choosing which parents to include in a breeding program. A similar association between these two parameters was also observed by Muthaiah *et al.* (2017b); Varalakshmi *et al.* (2019); Srikanth *et al.* (2021) in ridge gourd.

The estimates of sca effects for all the characters are presented in Table 6. Estimates of sca effects for fruit yield per plant varied from -0.21 (JDNRG-39 × GRG-2) to 0.34 (GRG-2 × JDNRG-19). Positive significant sca effects were observed only in GRG-2 × JDNRG-19 (0.34) cross while, JDNRG-39 × GRG-2 (-0.21) cross showed negative significant sca effect (Fig. 2). Specific combining ability is the manifestation of the non-additive component of genetic variance and is associated with interaction effects, which may be due to dominance and epistatic component of genetic variation that are non-fixable. Such non-additive components are potential parameters for heterosis breeding which is useful for commercial exploitation of heterosis. The sca effects did not show any specific trend for the gca of the parents. They involved all types of combinations *viz.,* Good × Good, Average × Good, Poor × Good, Average × Average, Average × Poor, Poor × Poor of the parents. Parental combination of either poor × good or good × average also resulted in high sca effects. This suggests presence of positive interallelic interactions for the characters. Relationship between these parameters was also observed by Sarkar *et al.* (2015); Bhatt *et al.* (2017); Mishra *et al.* (2019); Patel and Mehta (2021).

The best performing hybrids have at least one parent which showed higher *per se* performance and high gca. Thus, gca, sca effects and *per se* performance all have a role in manifesting heterosis for various characters. This positive relationship between heterosis and other parameters was also observed by Sarkar *et al.* (2015); Janaranjani *et al.* (2016); Mallikarjunarao *et al.* (2018); Mishra *et al.* (2019); Masud *et al.* (2021).

It was proposed that (i) traits with a preponderance of additive genetic variance may be improved by simple selection using the pedigree technique of selection in order to improve the material under consideration. (ii) The use of hybrids vigour for commercial purposes could enhance traits with a preponderance of non-additive genetic variance. (1) No cross combination showed consistently high specific combining ability effects for all the characters studied. (2) The crosses with high sca effects did not always involve parents with high gca effects, indicating that interallelic interactions were important for the characters and (3) A cross with high sca effects for fruit yield may or may not have high sca effects for yield contributing characters. These are the conclusions that can be made from the present investigation regarding specific combining ability effects.

The possibility of improving these characters through hybridization was indicated by the cross that showed high specific combining ability effects for different characters. Either average × good, average × poor, poor × good, or poor × poor parents were involved in the cross that showed substantial positive or negative specific combining ability effects. As a result, data on combining ability might not be enough to forecast the degree of heterosis. Therefore, data on *per se* performance must be added to those on combining ability effects. High sca denotes undoubtedly a high heterotic response, but this may be due to the very poor performance of the parents in comparison with their hybrids. With the same amount of heterotic effects, the sca may be less, where the mean performance of the parents was higher but this estimate may also be biased (Ziauddin *et al.*,1979). This suggested that the selection of cross combination based on a heterotic response would be more realistic rather than based on sca effects. While there may be a lack of co-adaptation between the parent's favourable alleles in crosses between good × good and good × average combiners, there may be a better complementation between the parents' favourable alleles in crosses between poor × poor, poor × average, or average × average that results in markedly desirable specific combining ability effects. The present investigation suggested that non-additive genetic variances were important for most of the characters. Suggested trying heterosis breeding to increase the ridge gourd's potential for fruit production.

Table 1: List of genotypes selected for crossing programme and check used.

Sr. No.	Genotype	Source
1.	JDNRG-19	Seed Spices Research Station, SDAU, Jagudan
2.	JDNRG-32	Seed Spices Research Station, SDAU, Jagudan
3.	JDNRG-10	Seed Spices Research Station, SDAU, Jagudan
4.	JDNRG-39	Seed Spices Research Station, SDAU, Jagudan
5.	JDNRG-15-27	Seed Spices Research Station, SDAU, Jagudan
6.	IC-523892	Seed Spices Research Station, SDAU, Jagudan
7.	GRG 2	Vegetable Research Station, JAU, Junagadh
8.	GJRGH 1 (check)	Vegetable Research Station, JAU, Junagadh

Table 2: Analysis of variance (mean sum of square) for twelve characters under study in ridge gourd.

Source of variation	d.f.	Days to first male flower	Days to first female flower	Primary branches per plant	Node number of first male flower	Node number of first female flower	Days to first picking
Replications	2	8.68	171.34**	0.52	4.18**	6.77**	4.17
Genotypes	28	50.62**	55.41**	0.36*	0.61**	6.22**	61.00**
Parents	6	45.66**	107.41**	0.50*	0.58	4.77**	91.87**
Hybrids	20	57.12**	44.23**	0.33	0.63**	6.96**	56.76**
Parents *vs.* Hybrids	1	0.39	3.57	0.03	0.92	2.54	3.11
Check *vs.* Hybrids	1	0.59	18.79	0.38	0.00	3.68*	18.44
Error	56	11.09	17.71	0.20	0.27	0.78	10.49

Source of variation	d.f.	Main vine length	Fruit weight	Fruit length	Fruit girth	Fruits per plant	Fruit yieldper plant
Replications	2	2.38**	268.89**	17.25	1.46*	4.95	0.25**
Genotypes	28	3.02**	1059.89**	26.02**	2.04**	7.46**	0.08
Parents	6	6.40**	409.02**	29.13**	1.00*	2.69	0.05
Hybrids	20	2.13**	1345.41**	27.21**	2.53**	9.50**	0.09*
Parents *vs.* Hybrids	1	3.40**	30.31	6.56	0.18	0.00	0.12
Check *vs.* Hybrids	1	0.13	284.24*	3.14	0.48	2.95	0.01
Error	56	1.24	51.71	6.21	0.32	1.94	0.05

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

Table 3: Analysis of variance for combining ability and variance component for various traits in ridge gourd.

Source of variation	d.f.	Days to first male flower	Days to first female flower	Primary branches per plant	Node number of first male flower	Node number of first female flower	Days to first picking
GCA	6	19.82**	37.83**	0.11	0.19	2.29**	49.64**
SCA	21	16.82**	13.52**	0.12*	0.24**	2.05**	12.63**
Error	54	3.80	6.10	0.06	0.08	0.25	3.55
Variance components							
$\sigma^2 gca$		1.78	3.52	0.004	0.01	0.22	5.12
$\sigma^2 sca$		13.01	7.42	0.05	0.15	1.79	9.07
$\sigma^2 gca / \sigma^2 sca$		0.13	0.47	0.08	0.07	0.12	0.56

Source of variation	d.f.	Main vine length	Fruit weight	Fruit length	Fruit girth	Fruits per plant	Fruit yieldper plant
GCA	6	1.76**	168.73**	9.69**	1.51**	2.03*	0.05**
SCA	21	0.83**	418.34**	8.74**	0.46**	2.69**	0.01
Error	54	0.10	16.60	2.13	0.09	0.67	0.01
Variance components							
$\sigma^2 gca$		0.18	16.90	0.83	0.15	0.15	0.004
$\sigma^2 sca$		0.73	401.73	6.60	0.36	2.01	0.002
$\sigma^2 gca / \sigma^2 sca$		0.25	0.04	0.12	0.42	0.07	2.33

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

Table 4: Estimates of general combining ability effects of parents for various traits in ridge gourd.

Sr. No.	Parents	Days to first male flower	Days to first female flower	Primary branches per plant	Node number of first male flower	Node number of first femaleflower	Days to first picking
1.	JDNRG-39	0.40	-1.99*	-0.11	0.03	-0.61**	-2.09**
2.	GRG-2	-0.41	-0.99	0.12	-0.17	0.56**	-0.68
3.	JDNRG-19	-2.08**	-2.66**	0.19*	-0.07	-0.30	-3.50**
4.	JDNRG-10	0.29	1.78*	-0.10	-0.14	-0.13	1.69**
5.	JDNRG-32	2.70**	3.04**	-0.02	-0.03	-0.00	3.50**
6.	IC-523892	-1.08	-0.03	-0.06	0.17	-0.32*	0.13
7.	JDNRG-15-27	0.18	0.86	-0.02	0.21*	0.80**	0.95
SE (gi)		0.60	0.76	0.08	0.09	0.15	0.58
Range		-2.08 to 2.70	-2.66 to 3.04	-0.11 to 0.19	-0.17 to 0.21	-0.61 to 0.80	-3.50 to 3.50

Sr. No.	Parents	Main vine length	Fruit weight	Fruit length	Fruit girth	Fruits per plant	Fruit yieldper plant
1.	JDNRG-39	-0.46**	-1.64	-0.36	-0.02	-0.55*	-0.12**
2.	GRG-2	0.51**	-3.75**	1.13*	-0.76**	0.91**	0.10*
3.	JDNRG-19	0.68**	9.43**	0.10	0.55**	-0.05	0.09*
4.	JDNRG-10	-0.28**	-1.43	1.63**	0.23*	0.27	0.04
5.	JDNRG-32	-0.08	-2.11	-0.48	-0.19	-0.31	-0.04
6.	IC-523892	-0.39**	0.02	-0.81	-0.00	-0.20	0.00
7.	JDNRG-15-27	0.02	-0.52	-1.22**	0.19	-0.08	-0.07
SE (gi)		0.10	1.25	0.45	0.09	0.25	0.04
Range		-0.46 to 0.68	-3.75 to 9.43	-1.22 to 1.63	-0.76 to 0.55	-0.55 to 0.91	-0.12 to 0.10

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

Table 5: Summary of general combining ability effects of the parents for various traits in ridge gourd.

Parents	Days to firstmale flower	Days to first female flower	Primary branches per plant	Node number of first male flower	Node number of first female flower	Days to first picking	Main vine length	Fruit weight	Fruit length	Fruit girth	Fruits per plant	Fruit yield per plant
JDNRG-39	A	**G**	A	A	**G**	**G**	P	A	A	A	P	P
GRG-2	A	A	A	A	P	A	**G**	P	G	P	**G**	**G**
JDNRG-19	**G**	**G**	**G**	A	A	**G**	**G**	**G**	A	**G**	A	**G**
JDNRG-10	A	P	A	A	A	P	P	A	**G**	**G**	A	A
JDNRG-32	P	P	A	A	A	P	A	A	A	A	A	A
IC-523892	A	A	A	A	**G**	A	P	A	A	A	A	A
JDNRG-15-27	A	A	A	P	P	A	A	A	P	A	A	A

G = Good general combiner having significant gca effect in desired direction
A = Average general combiner having either positive or negative but non-significant effects
P = Poor general combiner having significant gca effect in undesirable direction

Table 6: Estimates of specific combining ability effects associated with each hybrid for various ridge gourd characters.

Sr. No.	Hybrids	Days to first male flower	Days to first female flower	Primary branches per plant	Node number of first male flower	Node number of first female flower	Days to first picking
1.	JDNRG-39 × GRG-2	11.13**	7.87**	0.32	-0.10	-0.69	7.96**
2.	JDNRG-39 × JDNRG-19	-0.20	0.87	0.09	-0.73**	-0.03	1.78
3.	JDNRG-39 × JDNRG-10	-3.24*	0.09	-0.16	-0.40	-0.43	0.26
4.	JDNRG-39 × JDNRG-32	3.35*	5.50**	-0.51*	-0.15	-0.40	5.11**
5.	JDNRG-39 × IC-523892	-1.87	-0.43	0.17	-0.01	0.19	-3.52*
6.	JDNRG-39 × JDNRG-15-27	-6.46**	-2.31	-0.07	0.79**	0.20	-3.67*
7.	GRG-2 × JDNRG-19	-1.39	0.20	-0.24	1.13**	-1.10**	-0.96
8.	GRG-2 × JDNRG-10	-1.09	-1.57	-0.09	0.40	0.23	-2.48
9.	GRG-2 × JDNRG-32	0.83	1.50	-0.90**	-0.52*	2.50**	2.04
10.	GRG-2 × IC-523892	-2.39	-0.76	0.08	-0.34	-2.02**	-2.26
11.	GRG-2 × JDNRG-15-27	0.35	-0.31	0.10	0.05	-0.33	-0.74
12.	JDNRG-19 × JDNRG-10	-1.76	-2.91	-0.12	0.17	-1.41**	-3.00*
13.	JDNRG-19 × JDNRG-32	-0.83	-3.83*	0.03	0.00	-1.54**	-4.48**
14.	JDNRG-19 × IC-523892	0.61	0.24	0.28	0.06	-0.65	1.22
15.	JDNRG-19 × JDNRG-15-27	-0.31	-0.98	-0.03	-0.15	1.53**	-0.93
16.	JDNRG-10 × JDNRG-32	-1.20	-2.28	0.58**	0.59*	1.33**	-1.67
17.	JDNRG-10 × IC-523892	6.24**	6.13**	-0.04	-0.07	1.24**	3.70*
18.	JDNRG-10 × JDNRG-15-27	3.31*	1.91	-0.15	0.22	2.26**	3.56*
19.	JDNRG-32 × IC-523892	2.50	0.87	0.55**	-0.15	0.01	1.89
20.	JDNRG-32 × JDNRG-15-27	-3.43*	-2.02	0.30	-0.19	-0.30	-2.59
21.	IC-523892 × JDNRG-15-27	-4.98**	-5.28**	0.05	0.68**	1.51**	-3.56*
S.E.(Sij) ±		1.48	1.88	0.19	0.22	0.38	1.44
Range		-6.46 to 11.13	-5.28 to 7.87	-0.90 to 0.58	-0.73 to 1.13	-2.02 to 2.50	-4.48 to 7.96
No. of positive significant		4	3	2	4	6	4
No. of negative significant		4	2	2	2	4	5
Total significant		8	5	4	6	10	9

*, ** indicate the level of significance at 5% and 1%, respectively.

Table 6 *Cont..*

Sr. No.	Hybrids	Main vine length	Fruit weight	Fruit length	Fruit girth	Fruits per plant	Fruit yield per plant
1.	JDNRG-39 × GRG-2	-1.88**	-30.50**	-4.39**	-0.38	-0.07	-0.21*
2.	JDNRG-39 × JDNRG-19	0.08	30.01**	3.17**	0.57*	-2.20*	0.08
3.	JDNRG-39 × JDNRG-10	-0.16	30.23**	0.72	0.63*	-3.02**	-0.08
4.	JDNRG-39 × JDNRG-32	0.58*	-41.85**	-2.62*	0.11	1.96**	-0.20
5.	JDNRG-39 × IC-523892	1.02**	-15.57**	-5.03**	0.06	0.42	0.04
6.	JDNRG-39 × JDNRG-15-27	1.25**	-14.52**	-2.07	-0.76**	2.64**	0.11
7.	GRG-2 × JDNRG-19	0.07	-17.27**	-1.04	-0.78**	2.92**	0.34**
8.	GRG-2 × JDNRG-10	-0.99**	-2.93	-1.58	-0.76**	0.03	-0.01
9.	GRG-2 × JDNRG-32	-0.25	22.27**	2.30*	-0.38	-1.64*	0.07
10.	GRG-2 × IC-523892	0.13	-2.62	2.69*	-0.39	0.45	0.10
11.	GRG-2 × JDNRG-15-27	-1.15**	-8.71**	1.95	0.59*	1.58*	-0.03
12.	JDNRG-19 × JDNRG-10	-0.97**	-12.74**	1.74	-0.68**	1.29*	-0.02
13.	JDNRG-19 × JDNRG-32	0.67**	25.97**	0.55	0.07	-1.45*	0.11
14.	JDNRG-19 × IC-523892	0.09	-9.08**	-2.36*	-0.18	1.02	-0.02
15.	JDNRG-19 × JDNRG-15-27	0.53*	21.67**	3.20**	1.28**	-2.14**	-0.06
16.	JDNRG-10 × JDNRG-32	-0.09	4.19	2.66*	0.09	0.02	-0.00
17.	JDNRG-10 × IC-523892	-0.24	-1.09	1.16	0.28	0.56	-0.02
18.	JDNRG-10 × JDNRG-15-27	0.51*	0.86	2.23*	-0.14	-1.17	0.02
19.	JDNRG-32 × IC-523892	-0.26	6.91*	1.93	0.30	-0.88	0.03
20.	JDNRG-32 × JDNRG-15-27	-1.03**	-1.49	0.15	-1.13**	-0.08	0.04
21.	IC-523892 × JDNRG-15-27	-0.35	8.97**	-1.97	1.03**	-0.23	0.16
S.E.(Sij) ±		0.24	3.11	1.11	0.24	0.62	0.09
Range		-1.88 to 1.25	-41.85 to 30.23	-5.03 to 3.20	-1.13 to 1.28	-3.02 to 2.92	-0.21 to 0.34
No. of positive significant		6	7	6	5	5	1
No. of negative significant		5	8	4	5	5	1
Total significant		11	15	10	10	10	2

*, ** indicate the level of significance at 5% and 1%, respectively.

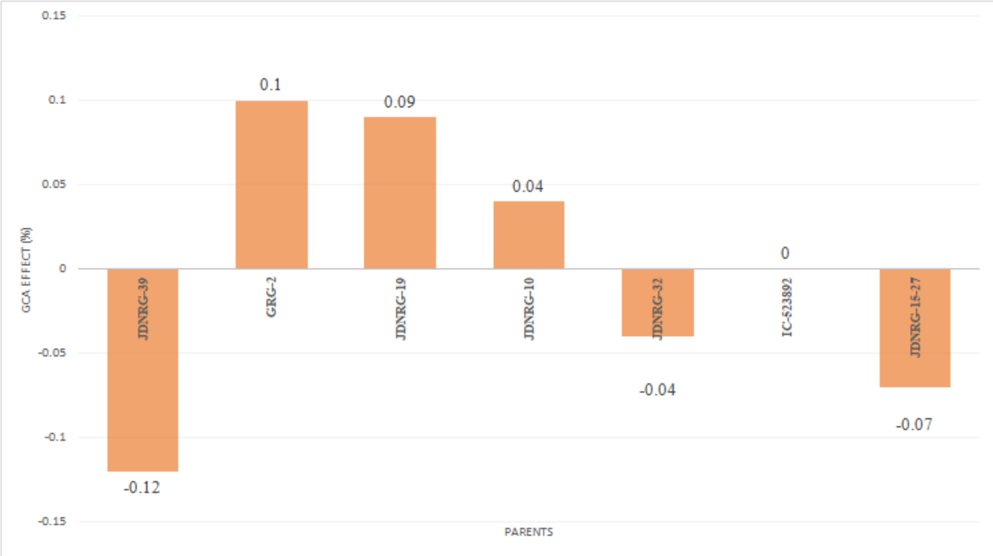
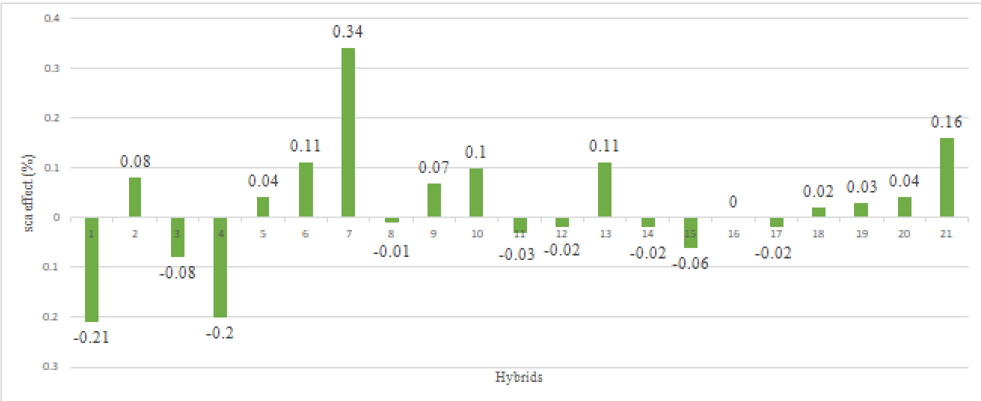


Fig. 1. Graphical representation of gca effect for fruit yield per plant.



1. JDNRG-39 × GRG-2
2. JDNRG-39 × JDNRG-19
3. JDNRG-39 × JDNRG-10
4. JDNRG-39 × JDNRG-32
5. JDNRG-39 × IC-523892
6. JDNRG-39 × JDNRG-15-27
7. GRG-2 × JDNRG-19
8. GRG-2 × JDNRG-10
9. GRG-2 × JDNRG-32
10. GRG-2 × IC-523892
11. GRG-2 × JDNRG-15-27
12. JDNRG-19 × JDNRG-10
13. JDNRG-19 × JDNRG-32
14. JDNRG-19 × IC-523892
15. JDNRG-19 × JDNRG-15-27
16. JDNRG-10 × JDNRG-32
17. JDNRG-10 × IC-523892
18. JDNRG-10 × JDNRG-15-27
19. JDNRG-32 × IC-523892
20. JDNRG-32 × JDNRG-15-27
21. IC-523892 × JDNRG-15-27

Fig. 2. Graphical representation of sca effect of hybrids for fruit yield per plant.

CONCLUSIONS

In the present investigation of analysis of variance, it was observed that the differences due to various genotypes were highly significant for all the characters under study except for the primary branches per plant and fruit yield per plant. Highly significant differences were observed among parents for all the characters except primary branches per plant, node number of first male flower, fruit girth, fruits per plant and fruit yield per plant. This indicated the existence of considerable variability in experimental material. Analysis of variance for combining ability revealed that GCA and SCA mean sum of square was significant for most of the traits indicating that both additive and non- additive gene actions were involved in the inheritance of these traits. However, for fruit yield per plant, non-significant SCA mean square values was observed. The *σ2sca* was higher than *σ2gca* for all characters except for fruit yield per plant denoting a preponderance of non-additive gene action for these characters and this was confirmed by the *σ2gca/ σ2sca* ratio which was less than unity. General combining ability effects revealed that the two parents possessing significant gca effect for fruit yield per plant were GRG-2 and JDNRG-19. Along with fruit yield, GRG-2 was found to be good general combiner for fruits per plant, node number of first female flower, main vine length and fruit length. Parent JDNRG-19 was good general combiner for days to first female flower, days to first male flower, vine length, fruit girth and days to marketable maturity. In general, the parents which gave the best *per se* performance were also the best general combiners indicating a positive association between the two parameters. These findings showed that, in addition to the effects of general combining ability, parents' individual performance may be taken into account when choosing which parents to include in a breeding program. There was not a clear trend in the sca implications for the parents' gca. All types of combinations of the parents, including Good × Good, Average × Good, Poor × Good, Average × Average,

Average × Poor, Poor × Poor were included in the crosses with desirable sca effects. Because of their significant gca impact and good per se performance for numerous yield-attributing and earliness traits, genotypes GRG-2 and JDNRG-19 can be recommended for utilization as one of the parents to produce high yielding and better-quality hybrids as well as in varietal development programs.

FUTURE SCOPE

High fruit yield per plant was reported by the hybrids GRG-2 × JDNRG-19, GRG-2 × IC-523892, and JDNRG-19 × JDNRG-32. They also observed good sca effects for fruit yield per plant and its contributing characteristics. In order to isolate good transgressive segregants for fruit yield per plant, this cross was determined to have the potential to produce good transgressive segregants for fruit yield per plant and its contributing characters. It was also recommended that this cross be further evaluated for generation advancement in the future breeding program. According to the current study, non-additive genetic variations were significant for the majority of the characteristics. Therefore, it was recommended to try heterosis breeding to increase the ridge gourd's potential for fruit production.

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Conflict of Interest. None.

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