Journal of Pharmacognosy and Phytochemistry

Available online at www.phytojournal.com

E-ISSN: 2278-4136
P-ISSN: 2349-8234
www.phytojournal.com
JPP 2020; 9(2): 1218-1221
Received: 22-01-2020
Accepted: 26-02-2020

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Studies on combining ability for fruit yield and quality attributing characters in ridge gourd (*Luffa acutangula* (L.) Roxb.)

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Abstract
The present study was taken up at College of Horticulture, Dr. Y. S. R. Horticultural University, Venkataramannagudem, Andhra Pradesh, India during 2018-2019, to study the combining ability of ten different lines of ridge gourd. They were mated diallel fashion excluding reciprocals and their forty five crosses were evaluated along with ten parents and two checks in Randomized block design (RBD) for fruit yield and quality attributing characters. Significant differences of analysis of variances due to *GCA* and *SCA* were observed for all the characters, it indicates predominance of non additive and additive gene action, that provides ample scope for heterosis breeding or direct selection. Out of the ten parents studied VRG-25 and VRG-24 were found to be good general combiners for fruit yield and quality characters. The cross combinations, VRG-25 x Swarna Manjari, VRG-14 x VRG-16, VRG-23 x VRG-16 showed highest significant positive heterosis as well as *sca* effects for number of fruits per vine. The cross combinations, VRG-24 x VRG-13, VRG-24 x VRG-16, Swarna Manjari x Arka Prasan and Swarna Manjari x VRG-16 exhibited significant *sca* effects and high *per se* performance for fruit yield per vine. The knowledge of combining ability helps in identifying good combiners for hybridization.

Keywords: Ridge gourd, randomized block design, gene action, fruit yield per vine

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) [10]. The genus *Luffa* derives its name from the product 'loofah' which is used in bathing sponges, door mats, pillows and also for cleaning utensils. It is one of the important cucurbitaceous vegetable grown throughout India. It is considered to be the old world species and is native of tropical Africa and South-East Asian region including India.

During recent years, the commercial exploitation of hybrid vigour and selection of parents on the basis of combining ability have expanded a new alley in crop improvement. The concept of combining ability for the evaluation of parents in a crossing programme is of immense importance. Hybridization is one of the most important technique for breaking yield barriers and evolving varieties having high yielding potential. The selection of suitable parents is one of the most important step in heterosis breeding. Selection of parents on the basis of phenotypic performance alone is not a sound procedure, since phenotypically superior lines may not lead to expected degree of heterosis. Thus, one of the potential tool for identifying prospective parents for hybridization and shifting productive hybrids from a set of crosses in F_1 generation is the analysis of combining ability (Griffing, 1956) [5].

Materials and Methods
The experimental material consisted of ten parental lines *viz*., VRG-11, VRG-23, VRG-24, VRG-25, Swarna Manjari, Arka Prasan, VRG-13, VRG-14, VRG-15 and VRG-16 of these were crossed in diallel fashion excluding reciprocals during *Rabi*, 2018. The resultant 45 F_1 hybrids along with ten parents and two checks were evaluated in randomized block design with two replications with spacing of 1.2 x 1.0 m during *Summer*, 2019. Observations were recorded on five randomly selected plants from each plot for fruit yield and quality characters *viz.*, number of fruits per vine, fruit diameter (cm), fruit length (cm), fruit flesh thickness (mm), average fruit weight (g), number of seeds per fruit, fruit yield per vine (kg),

total soluble solids (^{O}B), ascorbic acid content (mg/100g), carotene content (µg/100g), total sugars (%), reducing sugars (%), non reducing sugars (%) and fiber content (g/100g).

Results and Discussion

The analysis of variances for general combining ability are highly significant for the characters like number of fruits per vine, fruit diameter, fruit length, fruit flesh thickness, average fruit weight, number of seeds per fruit, fruit yield per vine, total soluble solids, ascorbic acid content, carotene content, total sugars, reducing sugars, non reducing sugars and fiber content. The variance for specific combining ability are highly significant for all the characters, studied indicating the importance of both additive and non-additive genetic components for most of the characters. Further, the estimates of *gca* and *sca* variances and their ratios are presented in (Table-1). General combining ability is associated with additive gene action, while specific combining ability is due to dominance and epistasis. In the present investigation, it was observed that *sca* variances were higher than *gca* variances for all the characters which indicated that predominance of non additive gene action.

The *gca* effects of parents were significant for most of the characters studied which indicated the existence of variability among the parents selected for hybridization (Table-2). Information regarding *gca* effect of the parent is of prime importance as it helps in successful prediction of genetic potentiality of crosses. The parent VRG-24 had highest mean values for fruit length, fruit flesh thickness, average fruit weight, fruit yield per vine, carotene content, total sugars and reducing sugars. Hence, VRG-24 can be used in ridge gourd breeding programme. The parents with good *gca* for the characters also exhibited good *per se* performance. Similar results for some of the characters were reported by Laxuman *et al*., (2012) [7] in bitter gourd, Umamaheswari and Haribabu, (2005) [12] in pumpkin and Naliyadhara *et al*., (2007) [11] in sponge gourd.

Estimation of *sca* effects for 45 crosses has resulted in identification of good specific combiner for various characters as given in (Table-3). Among these 45 cross combinations, the cross combination, VRG-25 x Swarna Manjari exhibited maximum and significant *sca* effects for number of fruits per vine. Similar results were also observed by Bairwa *et al*., (2015) [2], Divya *et al*., (2018) [4] and Jadhav *et al*. (2018) [6] for number of fruits per vine in ridge gourd. The best cross combinations, showing positive significant *sca* effects for different characters were VRG-24 x VRG-13 followed Swarna Manjari x VRG-16 for fruit length and average fruit weight, VRG-24 x VRG-13 followed by VRG-24 x VRG-16, Swarna Manjari x Arka Prasan and Swarna Manjari x VRG-16 for fruit yield per vine. Similar results are conformity with the findings of Bairwa *et al*., (2015) [2], Muthaiah *et al*., (2017b) [9], Divya *et al*., (2018) [4] in ridge gourd.The cross combinations VRG-11 x VRG-13, VRG-14 x VRG-16, VRG-23 x VRG-16exhibited maximum and significant *sca* effects for total soluble solids, ascorbic acid content and carotene content respectively, VRG-11 x Arka Prasan for total and reducing sugars. Similar results were also observed by Mallikarjunarao *et al*., (2018) [8], Acharya *et al*., (2018) [1] and Daleep *et al*., (2018) [3] in bitter gourd. Hence, cross combinations, with higher specific combining ability effects are useful to derive high performing hybrids.Similar results were also reported by Muthaiah *et al*., (2017b) [9] and Divya *et al*., (2018) [4] in ridge gourd.

Conclusion

The present investigation indicates that combining ability helps in identifying good combiners and cross combinations for hybridization and to exploit heterosis. Among ten parents studied VRG-24 is identified as good general combiner as it made significant contribution towards fruit yield and quality attributing characters. The cross combination, VRG-25 x Swarna Manjari exhibited highest *SCA* effect for number of fruits per vine. The cross combination, VRG-24 x VRG-13 for fruit length, average fruit weight and fruit yield per vine. The cross combinations VRG-11 x VRG-13, VRG-14 x VRG-16, VRG-23 x VRG-16for total soluble solids, ascorbic acid content and carotene content respectively and VRG-11 x Arka Prasan for total and reducing sugars. These studies were prerequisite for breeding programmes.

Table 1: Analysis of variance and gene action of combining ability analysis for fruit yield and quality attributing characters in 10x10 half diallel of ridge gourd

Source of variation	Mean sum of squares			σ^2gca	σ^2sca	*gca/sca*
	GCA	SCA	Error			
Degrees of freedom	09.00	45.00	54.00			
Characters						
Yield parameters						
Number of fruits per vine	3.84	5.04 *	1.28	-0.10	3.76	-0.02
Fruit diameter	1.70 **	1.94 **	1.14	-0.01	0.79	-0.02
Fruit length	31.33 **	17.10 **	4.77	1.18	12.32	0.09
Fruit flesh thickness	2.74 **	6.45 **	0.00	-0.30	6.44	-0.04
Average fruit weight	2365.52 **	2113.89 **	149.80	20.96	1964.09	0.01
Number of seeds per fruit	3.84 **	5.04 **	1.28	-0.10	3.76	-0.02
Fruit yield per vine	0.05 **	0.45 **	0.04	0.00	0.40	0.02
Quality parameters						
Total soluble solids	0.54 **	0.44 **	0.06	0.00	0.37	0.02
Ascorbic acid content	0.55 **	0.27 **	0.10	0.02	0.17	0.13
Carotene content	17124.76 **	35967.80 **	1188.02	-1570.25	34779.77	-0.04
Total sugars	0.44 **	1.04 **	0.01	-0.04	1.02	-0.04
Reducing sugars	0.29 **	0.77 **	0.01	-0.03	0.75	-0.05
Non reducing sugars	0.17 **	0.28 **	0.04	-0.00	0.24	-0.03
Fiber content	0.23 **	0.20 **	0.03	0.00	0.17	0.01

* and ** indicates Significance at p=0.05 and p=0.01, respectively.

GCA - General combining ability, SCA - Specific combining ability, σ^2gca - Variance due to GCA, σ^2sca - Variance due to SCA

Table 2: Estimates of general combining ability effects for fruit yield and quality attributing characters in 10x10 half diallel of ridge gourd

Parent	Yield parameters							Quality parameters						
	NFV	FD	FL	FFT	AFW	NSF	FYV	TSS	AC	CC	TS	RS	NRS	FC
VRG-11	-1.05 *	0.35	-2.20 **	-0.04 *	-0.09	-1.04 *	0.12 *	0.07	0.20 *	-15.92	-0.09 *	0.02	-0.09	-0.24 **
VRG-23	0.23	-0.13	-1.95 **	0.02	-19.42 **	0.22	-0.34 **	-0.31 **	-0.34 *	45.60 *	0.23 *	0.09 *	0.21 *	0.06
VRG-24	0.39	0.00	1.47 *	0.56 *	22.03 **	0.38	0.19 **	-0.02	-0.33 *	68.13 *	0.08 *	0.23 *	-0.18 *	0.00
VRG-25	0.86 *	-0.37	-1.53 *	0.00	-14.35 **	0.86 *	-0.27 **	-0.40 **	-0.14	-5.67	-0.22 **	-0.24 *	-0.00	0.19 **
Swarna Manjari	-0.37	0.26	-0.04	0.28 *	7.49 *	-0.37	0.23 **	-0.02	0.18 *	35.47	-0.05	-0.11 *	0.04	-0.10
Arka Prasan	-0.34	0.24	0.29	-0.14 *	-4.11	-0.33	0.02	-0.01	-0.07	-31.55 *	0.13 **	0.15 *	-0.01	0.03
VRG-13	0.40	-0.19	1.67 **	-0.91 *	10.75 **	0.39	0.13 *	0.06	0.07	-2.91	0.29 **	0.17 *	0.08	-0.10
VRG-14	-0.53	0.53	0.49	0.33 *	-4.21	-0.53	0.11	0.22 **	0.05	-11.45	-0.20 **	-0.10 *	-0.07	-0.02
VRG-15	0.40	-0.73 *	-0.78	0.55 *	-14.82 **	0.39	-0.30 **	0.13	0.29 *	-48.08 *	0.09 **	-0.09 **	0.13 *	0.24 **
VRG-16	0.02	0.04	2.58 **	-0.64 *	16.73 **	0.02	0.11	0.28 **	0.08	-33.61 *	-0.27 **	-0.12 *	-0.09	-0.06
SE (gi)	1.04	0.98	2.01	0.06	11.30	1.04	0.20	0.23	0.29	31.83	0.11	0.11	0.18	0.16
SE (gi-gj)	1.50	1.42	2.90	0.08	16.23	1.50	0.28	0.33	0.42	45.72	0.16	0.16	0.26	0.24

* and ** indicates Significance at p=0.05 and p=0.01, respectively.

NFV= Number of fruits per vine, FD= Fruit diameter, FL= Fruit length, FFT= Fruit flesh thickness, AFW= Average fruit weight, NSF= Number of seeds per fruit, FYV= Fruit yield per vine, TSS= Total soluble solids, AC= Ascorbic acid content, CC= Carotene content, TS= Total sugars, RS= Reducing sugars, NRS= Non reducing sugars, FC= Fiber content

Table 3: Estimates of specific combining ability effects for fruit yield and quality attributing characters in 10x10 halfdiallel of ridge gourd

Pedigee/Cross	Growth parameters							Quality parameters						
	NFV	FD	FL	FFT	AFW	NSF	FYV	TSS	AC	CC	TS	RS	NRS	FC
VRG-11 X VRG-23	-2.01	-0.41	2.71	-0.52 **	-2.33	-2.01	0.62 **	0.00	0.47	111.18 **	-0.17	-0.66 **	0.37	-0.27
VRG-11 X VRG-24	-3.87 **	0.31	-6.36 **	0.44 **	-34.25 **	-3.87 **	-0.09	-0.28	0.58	-206.44 **	-1.07 **	-0.67 **	-0.42 *	0.01
VRG-11 X VRG-25	-0.55	-0.68	3.99	-3.50 **	6.58	-0.55	-0.12	0.32	0.22	-227.62 **	-0.83 **	-0.74 **	-0.11	-0.23
VRG-11 X Swarna Manjari	0.89	1.55	-7.25 **	1.33 **	-21.76	0.89	-0.32	-0.51 *	0.03	196.24 **	0.90 **	0.90 **	0.10	0.50 **
VRG-11 X Arka Prasan	0.45	0.67	2.83	-0.54 **	13.47	0.45	0.22	0.29	0.04	-227.07 **	2.04 **	1.92 **	0.06	-0.07
VRG-11 X VRG-13	1.52	-1.34	-6.21 **	2.44 **	-47.04 **	1.52	-0.97 **	1.10 **	-0.07	-65.84 *	-0.26 *	-0.58 **	0.31	0.01
VRG-11 X VRG-14	-1.06	-1.03	-1.00	3.31 **	-39.31 **	-1.06	-0.24	-0.01	-0.85 *	108.68 **	0.97 **	0.93 **	-0.01	-0.52 **
VRG-11 X VRG-15	-2.08	-0.40	-1.16	-0.91 **	-20.73	-2.08	-0.02	-0.02	-0.28	78.46 *	0.94 **	-0.11	0.77 **	-0.14
VRG-11 X VRG-16	-2.80 *	0.64	-0.67	1.96 **	-57.87 **	-2.80 *	-0.14	-0.97 **	-1.22 *	-144.82 **	-0.53 **	0.03	0.00	0.32
VRG-23 X VRG-24	-1.05	1.99 *	-2.985	2.70 **	-27.05 *	-1.05	-0.18	-0.78 **	-0.26	-58.07	0.93 **	0.22	0.63 **	0.35 *
VRG-23 X VRG-25	-3.02 **	-3.70 **	1.029	-1.71 **	11.58	-3.02 **	0.70 **	0.89 **	-0.28	-199.16 **	0.89 **	0.94 **	-0.13	-0.33
VRG-23 X Swarna Manjari	-2.09	1.98	0.39	-0.45 **	2.24	-2.09	0.07	-0.61 *	-0.65 *	-175.30 **	1.43 **	1.79 **	-0.46 *	0.46 **
VRG-23 X Arka Prasan	-0.12	-0.75	-2.48	-2.59 **	-2.29	-2.04	0.18	-0.31	0.21	-193.51 **	-1.75 **	-1.01 **	-0.39 *	-0.06
VRG-23 X VRG-13	2.04	1.14	-4.47 *	3.57 **	-23.89 *	-1.63	-0.66 **	-1.02 **	-0.03	-32.03	0.19	-0.16	0.26	0.71 **
VRG-23 X VRG-14	-1.63	2.26 *	-1.536	2.18 **	-12.31	-0.06	-0.01	0.36	-0.49	41.55	0.90 **	1.31 **	0.02	0.09
VRG-23 X VRG-15	-0.06	-1.32	0.93	-2.76 **	0.22	2.71 *	0.01	-0.49 *	-0.63 *	83.14 *	0.34 **	-0.39 **	0.67 **	-0.13
VRG-23 X VRG-16	2.71 *	-0.25	4.42 *	1.52 **	-30.00 *	1.72	-0.67 **	0.53 *	-0.63 *	473.73 **	-1.68 **	-1.27 **	-0.22	-0.22
VRG-24 X VRG-25	1.72	1.39	2.37	-0.93 **	-9.87	1.35	-0.23	0.85 *	0.05	145.68 **	-0.21	-0.22	0.04	-0.22
VRG-24 X Swarna Manjari	1.35	0.85	-2.42	3.78 **	-11.51	1.62	-0.30	0.34	-0.49	-68.05 *	1.22 **	0.29 *	0.94 **	0.07
VRG-24 X Arka Prasan	1.62	0.07	1.40	0.64 **	-17.61	0.99	-0.59 **	0.02	-0.38	273.94 **	-0.07	0.28 *	-0.35	-0.24
VRG-24 X VRG-13	0.99	1.63	12.57 **	-5.11 **	156.86 **	0.41	2.14 **	-0.50 *	-0.29	-110.66 **	0.66 **	0.70 **	-0.01	-0.16
VRG-24 X VRG-14	0.41	0.12	-3.35	4.73 **	-47.96 **	-0.31	-0.65 **	-0.04	-0.03	58.31	0.01	-0.08	0.07	0.29
VRG-24 X VRG-15	-0.31	0.15	0.17	-1.49 **	55.63 **	-3.43 **	0.46 *	-0.45	-0.37	-6.43	-1.67 **	-0.48 **	-1.14 **	-0.62 **
VRG-24 X VRG-16	-3.43 **	0.17	2.56	-1.76 **	54.85 **	5.97 **	1.59 **	-0.22	0.26	-36.36	0.79 **	1.39 **	-0.66 **	-0.12
VRG-25 X Swarna Manjari	5.97 **	-1.27	1.12	-2.02 **	-35.08 **	-0.36	-1.22 **	-0.81 **	0.23	-175.20 **	-1.03 **	-0.95 **	-0.07	-0.51 **
VRG-25 X Arka Prasan	-0.36	-0.10	1.50	-2.38 **	26.94 *	-1.69	-0.05	-0.78 **	0.13	-212.44 **	-0.62 **	-0.56 **	-0.08	-0.59 **
VRG-25 X VRG-13	-1.69	0.39	-4.24 *	1.51 **	-18.46	0.12	-0.15	0.67 **	-0.12	48.97	-0.97 **	-0.32 **	-0.63 **	-0.42 *
VRG-25 X VRG-14	-0.16	2.30 *	-1.55	1.46 **	34.50 **	-0.16	0.40	-1.23 **	-0.67 *	-127.06 **	0.52 **	-0.22	0.72 **	0.86 **
VRG-25 X VRG-15	2.11 *	-2.00 *	-4.08 *	4.67 **	-16.52	2.11 *	-0.36	0.00	-0.13	98.68 **	-0.95 **	-0.59 **	-0.30	0.69 **
VRG-25 X VRG-16	-2.11 *	0.44	-4.05	3.35 **	-28.10 *	-2.11 *	-0.04	-0.56 *	0.16	-240.06 **	0.42 **	-0.13	0.49 *	-0.51 **
Swarna Manjari X Arka Prasan	-1.62	-0.54	4.76 *	-1.52 **	13.43	-1.62	1.19 **	-0.33	-0.34	78.84 *	-0.43 **	-0.49 **	0.04	0.84 **
SwarnaManjar X VRG-13	-1.76	0.80	-1.87	0.79 **	-16.35	-1.76	0.17	1.08 **	-0.38	-7.56	-0.66 **	-0.84 **	0.20	-0.78 **
Swarna Manjari X VRG-14	0.37	0.11	-5.04 *	1.61 **	4.03	0.37	-0.31	0.67 **	-0.62 *	212.63 **	-1.42 **	-1.27 **	-0.18	-0.66 **
Swarna Manjari X VRG-15	-2.06	0.94	-3.03	2.08 **	-1.76	-2.06	0.06	-0.27	-0.19	28.32	1.90 **	1.16 **	0.78 **	-0.60 **
Swarna Manjari X VRG-16	0.32	-1.90	5.57 **	0.12	105.34 **	0.32	1.07 **	-0.82 **	0.15	41.41	-0.33 **	-0.11	-0.28	0.18
Arka Prasan X VRG-13	-0.29	-0.14	-0.80	2.04 **	61.18 **	-0.29	0.19	0.54 *	-0.19	357.90 **	0.82 **	0.79 **	0.02	0.15
Arka Prasan X VRG-14	-0.06	-1.21	5.23 *	-2.83 **	20.03	-0.06	0.58 **	0.43	-0.11	-241.62 **	0.17	-0.53 **	0.64 **	0.12
Arka Prasan X VRG-15	-1.69	0.11	-2.00	1.14 **	-9.96	-1.69	0.10	0.08	0.70 *	-159.88 **	-0.10	-0.61 **	0.52 **	0.70 **
Arka Prasan X VRG-16	2.58 *	-0.59	-6.91 **	0.99 **	-55.64 **	2.58 *	-1.09 **	-0.52 *	-0.12	-164.37 **	1.65 **	0.99 **	0.56 **	-0.19
VRG-13 X VRG-14	-2.99 **	-1.98	-1.35	-0.95 **	-22.35	-2.99 **	0.51 *	0.19	0.48	194.74 **	-0.40 **	-0.64 **	0.22	-0.61 **
VRG-13X VRG-15	2.17 *	0.05	-1.24	-0.68 **	-36.62 **	2.17 *	-0.83 **	0.16	0.12	-243.61 **	1.18 **	1.38 **	-0.02	-0.02
VRG-13 X VRG-16	0.65	-0.48	-1.14	0.14 *	-16.81	0.65	-0.14	0.07	-0.10	92.14 **	0.31 *	1.13 **	-0.88 **	0.37 *
VRG-14 X VRG-15	2.10 *	-0.44	3.30	-2.25 **	5.20	2.10 *	-0.16	0.59 *	-0.23	120.13 **	-0.12	0.11	-0.22	-0.15
VRG-14 X VRG-16	4.37 **	1.38	-0.56	-0.48 **	76.04 **	4.377 **	-0.35	1.03 **	0.82 **	-74.50 *	-0.71 **	0.12	-0.93 **	-0.36 *
VRG-15 X VRG-16	0.85	0.05	-0.30	2.53 **	11.40	0.85	-0.10	0.59 *	-0.03	-23.03	-1.07 **	-0.72 **	-0.39 *	0.29
SE (sij)	3.09	2.92	5.96	0.18	33.39	3.09	0.59	0.69	0.86	94.05	0.33	0.33	0.55	0.50
SE (sij-sik)	4.12	3.90	7.96	0.24	44.61	4.12	0.79	0.92	1.15	125.64	0.45	0.45	0.74	0.66

* and ** indicates Significance at p=0.05 and p=0.01, respectively.

NFV= Number of fruits per vine, FD= Fruit diameter, FL= Fruit length, FFT= Fruit flesh thickness, AFW= Average fruit weight, NSF= Number of seeds per fruit, FYV= Fruit yield per vine, TSS= Total soluble solids, AC= Ascorbic acid content, CC= Carotene content, TS= Total sugars, RS= Reducing sugars, NRS= Non reducing sugars, FC= Fiber content

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