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Combining ability analysis in ridge gourd [*Luffa acutangula* (Roxb.) L.] for yield attributing traits

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Abstract
Combining ability studies carried out through half-diallel method (excluding reciprocals) using eight parents in ridge gourd for yield and yield components. F_1's and parents were evaluated under two season *i.e*. rainy 2016 and summer 2017. This analysis revealed that GCA and SCA variance were significant for all the indicating the importance of both additive and non additive genetic control of all the characters studied. The GCA variances lower than the SCA variances indicating the predominance of non-additive gene effects. Two parents *viz.,* Pusa Nasdar and Pusa Nutan were found to be good general combiners for yield and yield components. The crosses Swarna Manjari X Konkan Harita and Pusa Nutan X Arka Sumeet found to be good for most of the characters whereas, in respect to fruit weight and total fruit yield per vine, good specific combiner was identified as Pusa Nutan X Konkan Harita, Pusa Nasdar X Pusa Nutan and Pusa Nutan X Arka Sumeet. The crosses exhibiting high SCA effect involved either good x poor general combiners for majority of characters indicating the presence of additive x dominance type of gene interactions.

Keywords: Combining ability, GCA and SCA effects, yield attributes

Introduction
Ridge gourd [*Luffa acutangula* (Roxb.) L.] belongs to family cucurbitaceae and tropical vegetable grown throughout South East Asiaan countries. It is a popular vegetable both spring summer and rainy season. It is also known as "Ribbed gourd", "Angled gourd", "Angled loofah", "Vegetable gourd', "Koshataki", "Chinese okra" and "Flucted loofah". Green immature fruits of ridge gourd are cooked as vegetable and used in preparation of curries. Fruit is demulcent, diuretic and nutritive. It is beneficial for jaundice patients and cure for tetanus. Distinct variability in fruit characters impart a great opportunity for developing desirable variety/ hybrids in ridge gourd. Despite the performance of wide variability a very little work has been done in improving the existing cultivars of ridge gourd (Varalakshmi and Reddy, 1994; Karuppaiah *et al*., 2002 and Samadia, 2011) [14, 4, 10]. Combining ability analysis helps to choose suitable parents for hybridization, which can be utilized for future hybridization programme or to accumulate fixable genes through selection. Diallel cross designs are frequently used in plant breeding to obtain information on genetic effects for fixed set of parental lines or to estimate general combing ability and specific combining ability, which play an important role in control of yield related components (Virk, 1988) [15]. Hence, the present investigation was undertaken to determine the mechanism of gene action involved in inheritance of yield components in ridge gourd.

Method and Material
Eight divers ridge gourd parent *viz.***,** Swarna Manjari (P_1), Pusa Nasdar (P_2), AHRG-29 (P_3), Pusa Nutan (P_4), Arka Sujat (P_5), Arka Sumeet (P_6), Swarna Uphar (P_7) and Konkan Harita (P_8) were selected and crossed with all possible combinations (28 F_1) excluding reciprocals. The F_1's and parents evaluated under complete randomized block design, which was replicated three times during rainy 2016 and summer 2017. Observation were recorded for male female ratio, number of fruit per vine, fruit length, fruit girth, fruit weight (g) and fruit yield per vine (g). The combining ability variances and their effects were worked out according to Griffing (1956) (Model I method II) and heterosis was worked out over mid parent, over better parent and over standard check (Kaveri).

Results and Discussion

Analysis of variance on pooled basis showed that GCA and SCA variances were significant for most of the traits under the study indicating the importance of both additive and non-additive gene action. The ratio of GCA and SCA variances was less than unity which is showing the preponderance of non-additive gene effects (Table 1). These results were close conformity with result of Naliyadhara *et al*. (2010) [8] and Sonwane *et al*. (2013) [13] in sponge gourd and Narasannavar *et al*. (2015) [9] and Bairwa *et al*. (2015) [2] in ridge gourd. This indicated the huge scope of heterosis breeding for these characters.

The information regarding GCA effect of the parent is revealed that Pusa Nasdar and Pusa Nutan emerged as good general combiner for most of the yield attributes. Arka Sujat was superior for fruit length. The parent Swarna Manjari was good for number of fruit per vine, Swarna Uphar and Konkan Harita was good general combiner for fruit weight (Table 2 & 3). Hence they may be use intensively in the hybridization programme to develop parents with several desirable traits and yield improvement in ridge gourd. Similar findings were reported by Singh *et al*. (2018) [12] in sponge gourd, Bairwa *et al*. (2015) [2] and Muthaiah *et al*. (2017) [7] in ridge gourd, Acharya *et al*. (2019) [1] in bitter gourd and Shinde *et al*. (2016) [11] in bottle gourd. On the basis of high SCA effects in desirable direction the promising cross combinations among 28 crosses for total fruit yield per vine were Pusa Nutan X Konkan Harita, Pusa Nasdar X Pusa Nutan and Pusa Nutan X Arka Sumeet over the pooled. Pusa Nutan X Konkan Harita and Pusa Nutan X Arka Sumeet for male female ratio, Swarna Manjari X Konkan Harita and Arka Sujat X Konkan Harita for fruit length, Arka Sujat X Arka Sumeet and Pusa Nutan X Arka Sumeet for fruit girth were found good specific combiner as they showed high positive SCA effect for these traits (Table 4). Furthermore Table 5 revealed that Arka Sujat X Arka Sumeet and Swarna Manjari X Konkan Harita for fruit weight and Pusa Nutan x Konkan Harita and Pusa Nutan x Arka Sujat for number of fruits per vine, were good specific combiner as these crosses had significant SCA effects for these traits. These crosses could be of immense potential in ridge gourd for improvement programme. These findings are in accordance with results of earlier workers Lodam *et al*. (2009) [5], Muthaiah *et al*. (2017) [7], Bairwa *et al*. (2015) [2] and Mole *et al*. (2001) [6] in ridge gourd.

Table 1: Mean squares due to general and specific combining abilities and their interactions with seasons for different characters

Source of Variation	d.f.	MF	NFV	FL	FG	FW	TFYV
GCA	7	15.488**	8.527**	8.174**	2.124**	953.371**	254492.1**
SCA	28	5.761**	2.510**	6.075**	1.136**	723.455**	83396.52**
Seasons	1	114.742**	56.341**	89.617**	18.676**	34099.210**	7917475.00**
GCA x Seasons	7	0.066	0.345	0.149	0.033	42.087	12486.88**
SCA x Seasons	28	0.078	0.271	0.11	0.022	24.53	6426.491**
Error	140	0.404	0.289	0.771	0.179	46.44	3437.937
σ^2gca		0.745	0.411	0.37	0.097	45.346	12552.71
σ^2sca		2.678	1.11	2.651	0.478	338.507	39979.29
σ^2gca/ σ^2sca		0.281	0.37	0.139	0.203	0.133	0.313

* Significant at p=0.05 and ** significant at p=0.01

MF=Male female ratio, NFV= Number of fruit per vine, FL= Fruit length, FG=Fruit girth, FW=Fruit weight, TFYV=Total fruit yield per vine

Table 2: Estimates of general combining effect of parents for male female ratio, fruit length and fruit girth in ridge gourd under different season

Parents ↓ Seasons→	Male female ratio			Fruit length			Fruit girth		
	S_1	S_2	S_3	S_1	S_2	S_3	S_1	S_2	S_3
Swarna Manjari (P_1)	-0.030	-0.214	-0.122	-0.192	0.005	-0.094	-0.090	-0.068	-0.079
Pusa Nasdar (P_2)	-1.682**	-1.701**	-1.691**	0.720*	0.672**	0.696**	0.691**	0.534**	0.612**
AHRG-29 (P_3)	0.130	0.244	0.187	-1.174**	-1.028**	-1.101**	-0.300	-0.229*	-0.264**
Pusa Nutan (P_4)	-0.475*	-0.495*	-0.485**	0.512	0.322	0.417*	0.248	0.191*	0.219*
Arka Sujat (P_5)	1.092**	1.108**	1.100**	0.722*	0.778**	0.750**	-0.547**	-0.434**	-0.491**
Arka Sumeet (P_6)	0.948**	0.884**	0.916**	-0.611*	-0.472*	-0.542**	-0.023	-0.025	-0.024
Swarna Uphar (P_7)	-0.266	-0.304	-0.285*	-0.158	-0.454*	-0.306	0.048	0.047	0.047
Konkan Harita (P_8)	0.283	0.478*	0.381**	0.180	0.179	0.180	-0.027	-0.014	-0.021
S.E. (gi)	0.179	0.195	0.132	0.289	0.226	0.183	0.152	0.090	0.088
S.E. (gi- gj)	0.271	0.296	0.200	0.437	0.342	0.277	0.530	0.136	0.133

* Significant at p=0.05 and ** significant at p=0.01 S_1 =Rainy 2016, S_2=Summer 2017 S_3=Pooled

Table 3: Estimates of general combining effect of parents for number of fruit per vine, fruit weight and total fruit yield per vine in ridge gourd under different season

Parents ↓ Seasons→	Number of fruit per vine			Fruit weight			Total fruit yield per vine		
	S_1	S_2	S_3	S_1	S_2	S_3	S_1	S_2	S_3
Swarna Manjari (P_1)	0.502**	0.424**	0.463**	-6.974**	-7.735**	-7.355**	-3.292	-31.213*	-17.253
Pusa Nasdar (P_2)	0.933**	0.840**	0.887**	9.784**	6.856**	8.320**	266.080**	173.015**	219.548**
AHRG-29 (P_3)	0.435**	0.183	0.309**	-10.429**	-6.658**	-8.543**	-36.828	-44.045**	-40.436**
Pusa Nutan (P_4)	0.628**	0.226	0.427**	-2.351	0.566	-0.892	78.609**	49.959**	64.284**
Arka Sujat (P_5)	-1.199***	-0.856**	-1.028**	3.629	-0.203	1.713	-162.511**	-114.385**	-138.448**
Arka Sumeet (P_6)	-0.308	-0.264	-0.286*	-8.124**	-5.140**	-6.633**	-137.245**	-80.754**	-108.860**
Swarna Uphar (P_7)	-0.186	0.149	-0.019	6.751**	6.428**	6.589**	33.896	71.694**	52.795**
Konkan Harita (P_8)	-0.805**	-0.702**	-0.754**	7.714**	5.887**	6.800**	-38.708	-24.550	-31.629*
S.E. (gi)	0.162	0.155	0.112	2.442	1.469	1.425	19.675	14.645	12.264
S.E. (gi- gj)	0.246	0.213	0.169	3.693	2.222	2.154	29.746	22.142	18.541

* Significant at p=0.05 and ** significant at p=0.01 S_1 =Rainy 2016, S_2=Summer 2017 S_3=Pooled

Table 4: Estimates of specific combining effect of parents for male female ratio, fruit length and fruit girth in ridge gourd under different season

Crosses↓	Male female ratio			Fruit length			Fruit girth		
Seasons→	S_1	S_2	S_3	S_1	S_2	S_3	S_1	S_2	S_3
P_1 X P_2	0.112	0.434	0.273	0.729	0.233	0.481	0.290	0.256	0.273
P_1 X P_3	0.020	-0.161	-0.071	1.030	1.013	1.022	-0.243	-0.271	-0.257
P_1 X P_4	1.375*	1.578*	1.477**	0.071	0.383	0.227	-0.698	-0.581*	-0.639*
P_1 X P_5	1.938**	2.025**	1.981**	-0.639	-0.575	-0.606	-0.369	-0.176	-0.272
P_1 X P_6	1.042	0.699	0.870*	1.541	1.527*	1.534**	-0.879	-0.565	-0.722**
P_1 X P_7	-0.164	-0.523	-0.343	-0.299	0.119	-0.090	0.186	0.243	0.214
P_1 X P_8	-1.703**	-2.445**	-2.074**	2.856**	2.736**	2.796**	0.881	0.674*	0.777**
P_2 X P_3	-1.398*	-1.524*	-1.461**	0.098	0.326	0.212	0.689	0.597*	0.643*
P_2 X P_4	-1.480*	-0.638	-1.059*	-0.668	-1.004	-0.836	0.151	0.157	0.154
P_2 X P_5	0.237	-0.038	0.099	1.762	1.710*	1.736**	-0.550	-0.428	-0.489
P_2 X P_6	2.004**	1.886**	1.945**	-1.085	-0.850	-0.967	-1.314**	-1.077**	-1.195**
P_2 X P_7	-0.312	-0.776	-0.544	0.442	-0.138	0.152	-0.082	-0.089	-0.085
P_2 X P_8	-1.771**	-1.885**	-1.828**	1.860*	2.029**	1.945**	-0.160	-0.188	-0.174
P_3 X P_4	-1.755**	-1.680**	-1.717**	2.459**	1.576*	2.018**	-0.605	-0.540	-0.572*
P_3 X P_5	-1.162*	-1.133	-1.147**	-1.621	-1.500*	-1.560**	-0.843	-0.695*	-0.769**
P_3 X P_6	1.361*	-1.309*	-1.335**	1.096	1.130	1.113	0.387	0.146	0.266
P_3 X P_7	1.237*	2.049**	1.643**	-2.690**	-2.218**	-2.454**	-0.962*	-0.696*	-0.829**
P_3 X P_8	1.598**	2.097**	1.847**	0.524	0.699	0.612	0.520	0.515	0.518
P_4 X P_5	-1.577**	-1.624*	-1.600**	0.037	0.260	0.149	0.963*	0.735*	0.849**
P_4 X P_6	-1.763**	-2.040**	-1.901**	1.110	0.230	0.670	1.479**	1.116**	1.298**
P_4 X P_7	-0.435	-0.682	-0.558	-2.923**	-2.018**	-2.470**	0.364	0.254	0.309
P_4 XP_8	-2.607**	-2.974**	-2.791**	1.379	0.639	1.009	-0.188	-0.065	-0.126
P_5 X P_6	-1.420*	-1.133	-1.276**	1.347	1.224	1.286*	2.321**	1.791**	2.056**
P_5 X P_7	0.775	0.415	0.595	0.551	-0.134	0.208	0.409	0.379	0.394
P_5 X P_8	1.356*	1.283*	1.319**	2.122*	2.143**	2.133**	-0.499	-0.390	-0.444
P_6 X P_7	-1.431*	-1.511*	-1.471**	-0.333	0.146	-0.093	0.196	0.030	0.113
P_6 X P_8	0.580	0.507	0.543	-2.198*	-2.017**	-2.107**	0.097	0.171	0.134
P_7 X P_8	-0.696	-0.305	-0.501	1.489	1.145	1.317*	0.516	0.339	0.427
S.E. (sii)	0.478	0.522	0.407	0.771	0.604	0.563	0.405	0.241	0.271
S.E. (sij)	0.550	0.600	0.354	0.886	0.694	0.489	0.466	0.277	0.236
S.E. (sij- sjj)	0.665	0.725	0.492	1.070	0.839	0.680	0.563	0.335	0.327
S.E. (sij- sik)	0.814	0.888	0.602	1.311	1.028	0.833	0.690	0.410	0.401
S.E. (sij- skl)	0.767	0.837	0.568	1.236	0.969	0.785	0.650	0.387	0.378

* Significant at p=0.05 and ** significant at p=0.01 S_1 =Rainy 2016, S_2=Summer 2017 S_3=Pooled

Table 5: Estimates of specific combining effect of parents for number of fruit per vine, fruit weight and total fruit yield per vine in ridge gourd under different season

Crosses↓	Number of fruit per vine			Fruit weight			Total fruit yield per vine		
Seasons→	S_1	S_2	S_3	S_1	S_2	S_3	S_1	S_2	S_3
P_1 X P_2	1.292*	0.105	0.698*	-17.750*	-23.430**	-20.590**	-33.016	-243.648**	-138.332**
P_1 X P_3	-0.053	0.572	0.260	-5.381	-4.217	-4.799	-77.268	16.916	-30.176
P_1 X P_4	0.424	-0.031	0.197	-21.372**	-16.974**	-19.173**	-211.605**	-185.461**	-198.533**
P_1 X P_5	-0.679	-0.729	-0.704*	-12.725	-8.871	-10.798*	-194.905**	-128.314**	-161.610**
P_1 X P_6	-1.020	-0.361	-0.690*	-1.865	-2.434	-2.150	-138.571*	-52.928	-95.749*
P_1 X P_7	0.538	0.766	0.652	-7.501	3.712	-5.606	26.559	64.928	45.550
P_1 X P_8	-0.943	-0.823	-0.883*	38.803**	34.319**	36.561**	249.413**	201.281**	225.347**
P_2 X P_3	0.286	-0.384	-0.049	16.178*	12.392*	14.285**	236.996**	76.078	156.537**
P_2 X P_4	-1.187*	0.206	-0.490	37.513**	23.202**	30.357**	222.503**	264.221**	243.362**
P_2 X P_5	0.730	1.315**	1.022**	-17..037*	-10.942*	-13.989**	-60.024	49.814	-5.105
P_2 X P_6	-0.941	-0.737	-0.839*	-15.673*	-13.025**	-14.349**	-316.890**	-215.542**	-266.216**
P_2 X P_7	0.397	-0.230	0.083	2.114	7.407	4.761	105.046	59.199	82.123*
P_2 X P_8	0.546	0.571	0.558	14.338	11.938*	13.138**	264.740**	189.776**	227.258**
P_3 X P_4	2.452**	0.230	1.341**	-1.615	-1.258	-1.437	307.311**	-30.096	138.607**
P_3 X P_5	0.929	0.992*	0.960**	-5.638	-4.448	-5.043	100.500	86.518	93.509*
P_3 X P_6	0.128	0.360	0.244	14.006	10.989*	12.497**	165.185*	150.518**	158.070**
P_3 X P_7	-0.694	-0.303	-0.499	5.296	-7.579	-6.438	-144.456*	-97.317*	-120.887**
P_3 X P_8	-0.915	-0.792	-0.854*	-8.683	-8.288	-8.486	-219.362**	-158.404**	-188.883**
P_4 X P_5	1.656**	1.629**	1.642**	-5.953	2.328	-1.813	207.474**	212.487**	209.980**
P_4 X P_6	0.125	0.977*	0.551	17.391*	13.965**	15.678**	214.488**	241.294**	227.891**
P_4 X P_7	-1.027*	-0.216	-0.622	18.122*	10.947*	14.534**	42.737	70.609	56.673
P_4 XP_8	2.242**	1.755**	2.008**	1.226	6.018	6.362	371.391**	264.426**	317.908**
P_5 X P_6	-1.778**	-1.651**	-1.715**	50.858**	32.665**	41.761**	167.148**	53.548	110.348**
P_5 X P_7	-1.650**	-2.284**	-1.967**	23.513**	16.767**	20.140**	-60.363	-160.404**	-110.384**
P_5 X P_8	-0.931	-1.253*	-1.092**	3.353	1.708	2.530	-139.469*	-140.997**	-140.233**
P_6 X P_7	1.649**	1.414**	1.531**	-4.247	-1.296	-2.772	219.491**	163.603**	191.547**

P_6 X P_8	1.078*	0.825	0.951**	-24.514**	-18.305**	-21.140**	-83.055	-74.637	-778.846*
P_7 X P_8	-0.884	-0.028	-0.456	28.001	15.237**	21.619**	103.425	132.508**	117.966**
S.E. (sii)	0.434	0.413	0.344	6.513	3.919	4.369	52.468	39.055	37.594
S.E. (sij)	0.498	0.475	0.299	7.487	4.505	3.801	60.314	44.896	32.704
S.E. (sij- sjj)	0.602	0.574	0.416	9.046	5.442	5.278	72.864	24.238	45.417
S.E. (sij- sik)	0.738	0.703	0.509	11.079	6.666	6.464	89.240	66.427	55.625
S.E. (sij- skl)	0.695	0.663	0.480	10.445	6.284	6.095	84.136	62.628	52.443

* Significant at p=0.05 and ** significant at p=0.01 S_1 =Rainy 2016, S_2=Summer 2017 S_3=Pooled

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