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Combining ability analysis and correlation studies for yield and mineral nutrients in ridge gourd (*Luffa acutangula*)

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ABSTRACT

The current study was carried out to determine combining ability and association of yield and yield components in 7 × 7 half-diallel crosses of ridge gourd (*Luffa acutangula* Roxb.) at ICAR-IARI, New Delhi in the year 2016. Twenty one F_1 hybrids along with seven parental lines were grown in randomized block design in three replications. The mean square due to GCA and SCA were highly significant for all the characters indicating the importance of additive and non-additive genetic components for the traits under study. Further, SCA variance was more than GCA variance for all the characters which suggested the importance of non-additive variance for the improvement of these characters. The parental lines Pusa Nutan, DRG-7, DRG-71 and Pusa Nasdar were good combiners for most characters under study including yield and mineral nutrients. The hybrid combination of Pusa Nutan × Arka Sujat, Pusa Nasdar × Co-1 and Pusa Nasdar × Swarna Uphar were found to be most promising combinations for earliness, yield, mineral content and other economic traits of interest. Significant positive correlations were observed between yield and fruit length, average fruit weight and number of fruits per plant. The results indicated the importance of heterosis breeding for effective utilization of non-additive genetic variance in ridge gourd.

Key words: Combining ability, Correlation, Luffa, Minerals, Ridge gourd

Crop improvement necessitates techniques for increasing quality and inherent capacity of yield potential. For any effective breeding programme, identification of the best performing lines for commercial release and as parents in future crosses are important prerequisites (Oakey *et al*. 2006). In heterosis breeding, equally promising parents produce superior as well as inferior progeny, thus *per se* performance of parents may not necessarily suggest that it is a good or poor combiner. The choice of parents should therefore be based on their genetic value and performance. Combining ability studies reveal the nature of gene action and lead to the identification of parents with higher general combining ability (GCA) effects and the cross combinations with high specific combining ability (SCA) effects.

Ridge gourd (*Luffa acutangula* Roxb.) is a very popular vegetable grown throughout India both commercially as well as in kitchen garden. Combining ability which helps to estimate the combining ability effects, aids in selecting desirable parents and crosses for the exploitation of heterosis has been done by many researchers in ridge gourd (Ahmed *et al.* 2006, Prabhakar 2008, Tyagi *et al.* 2010, Karmakar 2011and Singh *et al.* 2017). Yield is polygenically inherited character, therefore selection on the basis of fruit yield along with its component characters could be more efficient and reliable. Consequently, information on the association between yield and its components and among the component characters themselves can improve the efficiency of selection in ridge gourd improvement (Rabbani *et al.* 2012 and Choudhary *et al.* 2014). Efforts on the improvement of ridge gourd have been very limited which is reflected from the presence of very few varieties and hybrids available for commercial cultivation. Therefore, the present study was undertaken to find out best general combiner(s) and best specific combinations for yield, its attributing characters and mineral nutrients following 7 × 7 half-diallel mating designs.

MATERIALS AND METHODS

The present study was carried out at the Research Farm of Division of Vegetable Science, ICAR-Indian Agricultural Research Institute, New Delhi during 2016. Seven genetically diverse inbred lines of ridge gourd, viz. Pusa Nutan (P_1), DRG-7 (P_2), DRG-71 (P_3), Arka Sujat (P_4), Pusa Nasdar (P_5), Swarna Uphar (P_6) and Co-1 (P_7) were crossed in 7 × 7 half diallel mating scheme to obtain 21 F_1 hybrids combinations. The hybrids along with seven

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parents were evaluated in randomized block design with three replications. The crop was sown in rows of 2.5 m with 75 cm spacing between the plants. Out of the 12 plants, 10 were marked at random for observations on individual plant basis, where nine quantitative characters, viz. days to first male flower anthesis, days to first female flower anthesis, days to first fruit harvest, fruit length (cm), fruit diameter (cm), average fruit weight (g), number of fruits per plant, vine length (m) and total fruit yield per plant (kg) were recorded. Apart from the quantitative characters, the hybrids along with the parents were also evaluated for minerals like Ca, K, Mn, Zn and Fe. Procedure for sample preparation, digestion and estimation of minerals were followed as per Tandon (1998) and Jones (2001) with minor modifications.

The data pertaining to yield, its attributing traits and mineral content were analysed for combining ability estimates by following Griffing's Method-II of Model I (Griffing, 1956). Phenotypic correlation coefficient between all the traits was computed according to Know and Torrie (1964).

RESULTS AND DISCUSSION

The analysis of variance for combining ability of the yield characters and mineral content showed highly significant mean sum of square due to GCA and SCA for most of the characters under study (Table 1) thus, indicating the importance of both additive and non-additive components of heritable variance. Estimate of SCA variance was greater than that of GCA variance for all the traits suggesting the importance of non-additive gene action for the improvement of studied traits in ridge gourd. The values of σ^2D were higher than σ^2A and more than unity value of average degree of dominance also indicates the importance of non-additive gene action. This was further confirmed with predictability ratio values (<0.5) for all the characters studied.

Perusal of the data in Table 2 indicated that it is not feasible to select a good combiner line for all the characters studied due to non-consistency of parents' GCA. The parental line P_1 showed highest significant and positive GCA effects for total fruit yield per plant and five other characters, viz. days to first male flower anthesis, fruit length, fruit weight, number of fruits per plant and Mn content. P_3 was found to be good general combiner with highest significant and desirable GCA for days to first female flower anthesis, days to first fruit harvest, Ca, K and Fe content. P_7 recorded highest value for desired significant positive GCA estimates for fruit diameter, and P_5 for Zn content. Thus, on the basis of overall performance across 14 traits under study, the parental line P_1 followed by P_3 were identified as most promising combiner lines due to good GCA for earliness, yield, yield components and mineral content in ridge gourd. The association between higher GCA effects and mean performance are considered important criteria for selecting parental line to be used as superior parent in hybridization programme. A perusal of the result also revealed that in most of the cases, *per se* performance of the parents bear direct reflection of their respective GCA

Table 1 Analysis of variance for combining ability for yield and mineral content in ridge gourd

Source	d.f.	Mean sum of squares													
		DFMA	DFFA	DFFH	FL	FD	AFW	NFPP	VL	TYPP	Ca	K	Fe	Zn	Mn
GCA	6	17.68**	18.68**	24.37**	49.39**	0.28	256.70**	41.27**	0.41*	1.08**	21.99**	27.24**	1752.86**	8849.16**	605.38**
SCA	21	11.79**	13.64**	13.77**	6.71**	0.09	93.98**	15.40**	0.07	0.42**	11.30**	9.22**	610.66**	4402.37**	430.68**
Error	54	2.91	3.98	3.08	1.13	0.18	27.90	2.28	0.15	0.05	0.32	0.40	20.21	2.52	1.35
Variance components							*Estimates of variance components*								
σ 2GCA		0.28	0.38	0.29	0.11	0.02	2.66	0.22	0.01	0.004	0.03	0.04	1.93	0.24	0.13
σ 2SCA		2.35	3.20	1.78	0.91	0.15	22.47	1.83	0.12	0.04	0.26	0.33	16.28	2.03	0.79
σ 2A		0.56	0.76	0.58	0.22	0.04	5.32	0.44	0.02	0.01	0.06	0.08	3.86	0.48	0.26
σ 2D		2.35	3.20	1.78	0.91	0.15	22.47	1.83	0.12	0.04	0.26	0.33	16.28	2.03	0.79
PR		0.19	0.19	0.25	0.19	0.21	0.19	0.19	0.14	0.17	0.19	0.20	0.19	0.19	0.25
ADD		4.20	4.21	3.07	4.14	3.75	4.22	4.16	6.00	5.00	4.33	4.13	4.22	4.23	3.04

DFMA, Days to first male flower anthesis; DFFA, Days to first female flower anthesis; DFFH, Days to first fruit harvest; FL, Fruit length (cm); FD, Fruit diameter (cm); AFW, Average fruit weight (g); NFPP, Number of fruits per plant; VL, Vine length (m); TYPP, Total fruit yield per plant (kg); Ca, Calcium (mg/100g); K, Potassium (mg/100g); Fe, Iron (µg/100g); Zn, Zinc (µg/100g); Mn, Manganese (µg/100g). Predictability ratio (PR) = 2 σ2g/ 2 σ2g + σ2s; Average degree of dominance (ADD) = σ2s / 2σ2g. *Significant at P = 0.05, **Significant at P = 0.01.

Table 2 GCA effects for yield and mineral content in ridge gourd

Parent	DFMA	DFFFA	DFFH	FL	FD	AFW	NFPP	VL	TYPP	Ca	K	Fe	Zn	Mn
P1	-2.11**	-1.51*	-1.62**	3.07**	-0.05	6.73**	3.90**	0.12	0.62**	0.86**	0.41*	11.08**	27.45**	10.07**
P2	-0.53	-0.77	-0.22	0.62	0.04	3.01*	1.20*	0.04	0.19*	0.67**	2.18**	10.10**	11.97**	-6.34**
P3	-0.72	-2.00**	-1.90**	2.19**	-0.1	3.44*	1.24*	0.2	0.21**	2.35**	2.19**	14.78**	-18.05**	10.04**
P4	2.61**	2.51**	3.19**	-0.98**	-0.21	-3.37*	-1.14*	-0.40**	-0.16*	-0.91**	-0.19	-0.32	-12.34**	1.29**
P5	0.83	0.29	0.83	1.24**	0.1	2.16	-1.48**	-0.03	-0.16*	0.58**	-1.57**	1.02	51.71**	0.44
P6	-0.16	0.46	-0.36	-3.16**	-0.1	-2.71	-2.27**	0.2	-0.34**	-2.29**	-2.34**	-23.46**	-28.55**	-12.19**
P7	0.07	0.17	0.07	-2.98**	0.33*	-9.27**	-1.44**	-0.13	-0.36**	-1.25**	-0.68**	-13.20**	-32.18**	-3.30**
SE(g1)	0.57	0.62	0.54	0.33	0.13	1.63	0.47	0.11	0.07	0.18	0.19	1.39	0.49	0.36

DFMA, Days to first male flower anthesis; DFFFA, Days to first female flower anthesis; DFFH, Days to first fruit harvest; FL, Fruit length (cm); FD, Fruit diameter (cm); AFW, Average fruit weight (g); NFPP, Number of fruits per plant; VL, Vine length (m); TYPP, Total fruit yield per plant (kg); Ca, Calcium (mg/100g); K, Potassium (mg/100g); Fe, Iron (µg/100g); Zn, Zinc (µg/100g); Mn, Manganese (µg/100g). *Significant at P =0.05, **Significant at P =0.01

effects. The results are in conformity with the findings of Ahmed *et al.* (2006), Prabhakar (2008), Tyagi *et al.* (2010) in ridge gourd. The parental lines with high GCA effects indicate potent evidence for desirable gene flow from parents to offspring at high frequency attributed to additive or additive × additive gene effects (Franco *et al.* 2001). Thus, crosses involving genotypes with high GCA value should be potentially superior for the selection of lines in advanced generation which may be released as conventional varieties or used as one of the promising parents for F_1 hybrid development in ridge gourd.

In the present investigation, none of the crosses exhibited high SCA effects for all the characters. The top three specific combiners exhibiting significant SCA effects in desirable direction and the GCA effects of their parents are presented in Table 3. Of the various high specific combiners

Table 3 Top three specific combiners with GCA effects of parents for yield and mineral content in ridge gourd

Character	Cross	SCA effect	GCA effect of its parents		Character	Cross	SCA effect	GCA effect of its parents	
			Female	Male				Female	Male
DFMA	P5 × P7	-4.88**	0.83 (Low)	0.07(Low)	TYPP	P1 × P4	1.44**	0.62**(High)	-0.16**(Low)
	P1 × P7	-3.67**	-2.11**(High)	0.07(Low)		P2 × P5	0.50*	0.19**(High)	-0.16**(Low)
	P3 × P6	-3.64*	-0.72(Low)	-0.16(Low)		P1 × P6	0.42*	0.62**(High)	-0.34**(Low)
DFFFA	P5 × P7	-5.57**	0.29 (Low)	0.17(Low)	Ca	P5 × P6	5.60**	0.58**(High)	-2.29**(Low)
	P5 × P6	-4.83**	0.29 (Low)	0.46(Low)		P5 × P7	4.83**	0.58**(High)	-1.25**(Low)
	P2 × P7	-3.50*	0.77(Low)	0.17(Low)		P3 × P6	4.69**	2.35**(High)	-2.29**(Low)
DFFH	P5 × P7	-6.22**	0.83 (Low)	0.07(Low)	K	P2 × P5	4.35**	2.18**(High)	-1.57**(Low)
	P5 × P6	-4.79**	0.83 (Low)	-0.36(Low)		P4 × P7	4.33**	-0.19(Low)	-0.68**(Low)
	P3 ×P7	-3.29*	-1.90**(Low)	0.07(Low)		P3 × P5	3.51**	2.19**(High)	-1.57**(Low)
FL	P1 × P4	4.61**	3.07**(High)	-0.98**(Low)	Fe	P3 × P5	42.68**	14.78**(High)	1.02(Low)
	P2 × P7	3.64**	0.62(Low)	-2.98**(Low)		P2 × P4	33.71**	10.10**(High)	-0.32(Low)
	P4 × P5	3.04**	-0.98** (Low)	1.24**(High)		P2 × P3	27.28**	10.10**(High)	14.78**(High)
AFW	P1 × P4	18.09**	6.73**(High)	-3.37*(Low)	Zn	P1 × P5	190.68**	27.45**(High)	51.71**(High)
	P5 × P6	13.28**	2.16(Low)	-2.71(Low)		P4 × P5	67.51**	-12.34**(Low)	51.71**(High)
	P2 × P3	9.61*	3.01*(High)	3.44**(High)		P3 × P6	56.78**	-18.05**(Low)	-28.55** (Low)
NFPP	P1 × P4	7.86**	3.90**(High)	-1.14**(Low)	Mn	P1 × P4	35.51**	10.07**(High)	1.29** (High)
	P1 × P7	2.96*	3.90**(High)	-1.48**(Low)		P4 × P7	31.22**	1.29**(High)	-3.30** (Low)
	P3 × P7	2.87*	1.24**(High)	-1.44**(Low)		P3 × P6	56.78**	-18.05**(Low)	-28.55** (Low)

DFMA,Days to first male flower anthesis; DFFFA, Days to first female flower anthesis; DFFH, Days to first fruit harvest; FL, Fruit length (cm); FD, Fruit diameter (cm); AFW, Average fruit weight (g); NFPP, Number of fruits per plant; VL, Vine length (m); TYPP, Total fruit yield per plant (kg); Ca, Calcium (mg/100g); K, Potassium (mg/100g); Fe, Iron (µg/100g); Zn, Zinc (µg/100g); Mn, Manganese (µg/100g). *Significant at P = 0.05, **Significant at P = 0.01

identified for each of the traits, the cross $P_1 \times P_4$ for yield and its contributing traits, viz. fruit length, fruit weight, number of fruits per plant and Mn content was the best. Out of 21 crosses studied, highest desired negative significant SCA effect for earliness was recorded in the cross $P_5 \times P_7$. The hybrid $P_5 \times P_6$ for calcium content, $P_2 \times P_5$ for potassium content, $P_3 \times P_5$ for iron content and $P_1 \times P_5$ for zinc content were identified as the best specific combiners. In most of the cases, *per se* performance of hybrids had a direct relation with respective SCA effects. This nature of relation was not always true as in case of days to first male flower anthesis, calcium and potassium content thus suggesting that selection of crosses on the basis of either mean performance or SCA effects alone has limited value in breeding programme. In general, a relatively higher magnitude of SCA effects was observed in many crosses, which may probably be due to the formation of superior gene recombinations. The negative SCA effects recorded in some of the crosses for traits studied might be due to the presence of unfavorable gene combinations in the parents for the respective traits. The best specific combiners having the highest magnitude of significant SCA effects in favorable direction are recommended for heterosis breeding.

Out of 21 crosses, the top three high specific combiners identified for marketable yield per plant had high × low general combiners as parents. For other yield associated traits and mineral content, the top three crosses exhibiting significant SCA effects in desirable direction involved high × high, high × low, and low × low general combiners as parents. Therefore, it is evident that superior cross combination may also occur in all types of parental combinations irrespective of GCA effects of parents thus indicating high GCA effects of parents alone may not be a reliable criteria for predicting higher SCA effects. High SCA effects resulting from crosses involved high × high general combiners as parents are may be ascribed to additive × additive gene. The high SCA effects derived from crosses including high × low general combiner parents may be attributed to favourable additive effects of the good general combiner parent and epistatic effects of poor general combiner, which fulfils the favourable plant attribute. High SCA effects manifested by low × low crosses may be due to dominance × dominance type of non-allelic gene interaction producing overdominance and thus being non-fixable (Fasahat *et al.* 2016). The superiority of cross combinations involving high × low, or low × low general combiners as parents may be attributed to the genetic diversity among parents, in the form of number of heterozygous loci of the parents involved in the cross combinations (Kumar *et al.* 2006). In some of the traits investigated, parents with high GCA effects produced hybrids with low SCA effects. This may be due to lack of complementation of the parental genes. On the other hand, parents with low GCA effects produced hybrids with high SCA effects which can be attributed to complementary

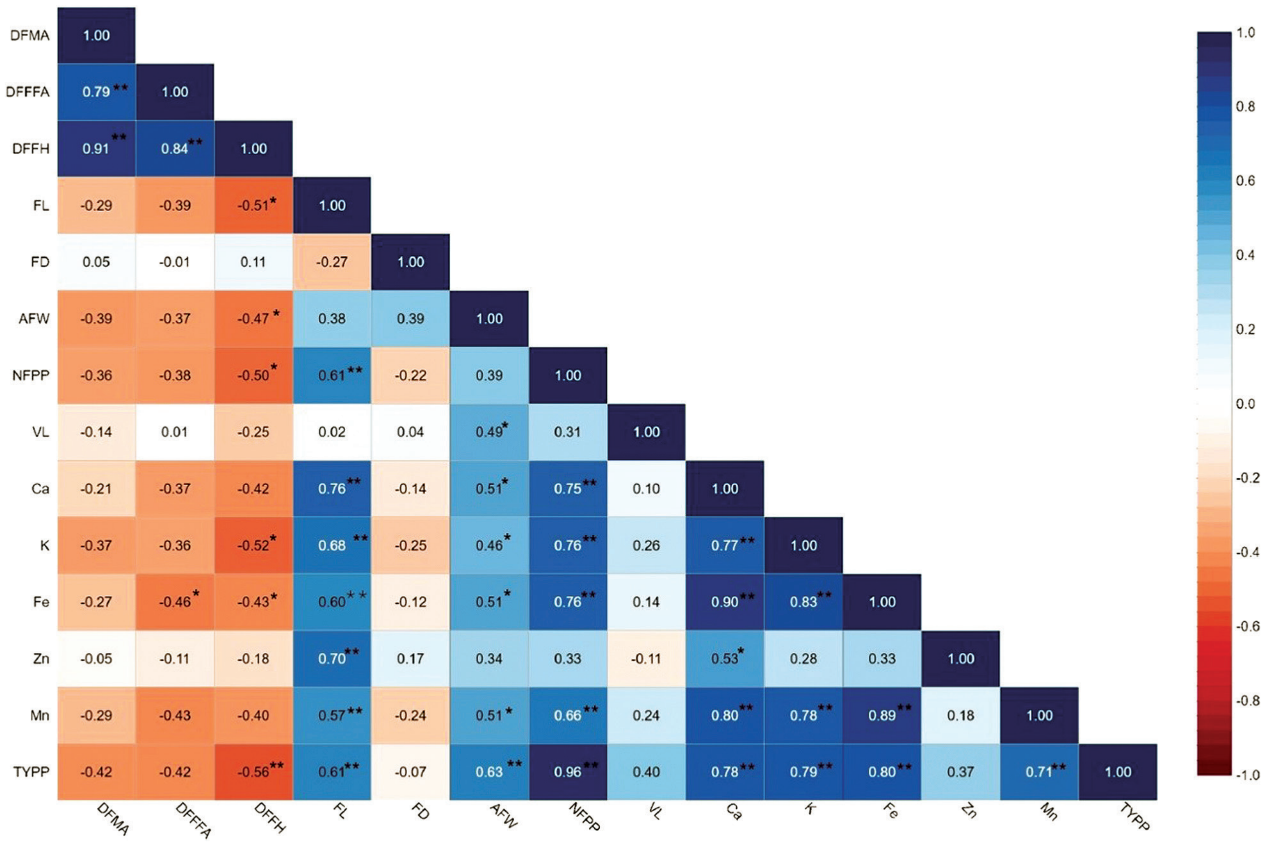

Fig 1 Correlation coefficient for pair wise comparison of yield and mineral content in ridge gourd (*Significant at P =0.05, **Significant at P =0.01).

gene effect. Therefore, crosses that recorded higher *per se* performance and desirable significant SCA effects with either both or at least one parent as good general combiner would be worthy for commercial exploitation. A comparison of the SCA effects of the crosses and GCA effects of the parents studied indicated that in most of the cases GCA effects were reflected in the SCA effects of the cross combination. It is apparent that in almost all the hybrids which showed the best SCA effects, the parental lines involved were at least one of the four outstanding parental lines, viz. P_1, P_2, P_3 and P_5 which also recorded high GCA effects for one or more characters contributing towards yield. This indicated that there was strong tendency of transmission of higher gain from the parents to the offspring.

Correlation co-efficient between yield and its components are presented in Fig 1. The marketable yield per plant had positive and highly significant correlation with fruit length, average fruit weight and number of fruits per plant. Fruit yield also recorded significant and it had positive correlation with Ca, K, Fe and Mn content of fruit. When correlations among yield components were considered, few of the characters showed significant and positive association. Fruit length was positively and significantly correlated with number of fruits per plant whereas average fruit weight has significant positive correlation with vine length. Results of this study indicated that selection might be directed towards number of fruits per plant, average fruit weight and fruit length which appeared to be the prominent characters for increasing fruit yield in ridge gourd. These results are in agreement with the findings of Choudhary *et al.* (2014) and Ramesh *et al.* (2018) in ridge gourd.

The results of the present study revealed that both additive and non-additive gene action were important in the inheritance of the yield characters and mineral content with predominance of non-additive gene action in ridge gourd. P_1 and P_3 were found to be the most promising parental lines which could be involved in heterosis breeding programs as evidenced by the higher GCA effects for most economic traits sought for improvement. In the order of merit, the most promising specific combinations $P_1 \times P_4$, $P_5 \times P_7$, $P_1 \times P_7$ and $P_5 \times P_6$ exhibited higher SCA effects for most characters including total fruit yield per plant which might be sent for multi-location trials for confirmation of their heterotic value.

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