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Combining Ability Analysis for Yield and Processing Qualities in White Onion (*Allium cepa* L.)

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Abstract

Eight diverse white onions parents were selected and crossed in half diallel fashion in order to determine the combining ability to identify promising hybrids for nine traits including yield and processing quality. Analysis of variance for general and specific combining ability revealed that GCA and SCA variances were significant ($p<0.05$) for all characters. Among the parents exotics JV16 and JV12 was proved to be a good general combiner for yield and processing quality characters. Among the crosses AF x JV12, was best specific combination for bulb weight, bulb diameter, total soluble solids, percent bolting, percent doubles, pungency and yield. It is evident from present investigation that the hybrids combinations AF x JV12, PW x JV12, J16 x JV12 and PS x JV12 exhibited the high *per se* performance and SCA effect for bulb yield and processing quality characters could be advanced by selecting desirable segregants and recombinants in each generation for funneling the new genotype or using further advanced breeding programme.

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Introduction

Onion (*Allium cepa* L.) originated in Asia. The important species from the *Alliums* group are used for their flavour, aroma and taste. They are available in fresh and dehydrated forms. Pungent or mild and sweet which is depending on onion varieties. All over the world, onion ranks second in value in the list of cultivated vegetable crops and preferred as a commercial vegetable. India ranks second in onion bulb production (22.47 million tons) with second largest in area (1.30 million ha) FAO.[1]

Jain Irrigation Systems Ltd. (JISL) is the pioneer and India's biggest and world's second leading micro-irrigation company. As a forward integration, JISL expanded into food processing and custom-made world class food processing plant for dehydration of onion and vegetables. JISL is ranks

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third in the international market and in India the leading player in the organized onion dehydration market. The business accounts for nearby 40% of the total exports of dehydrated onions from India.

JISL initiated research based on the performance of imported and Indian white onion cultivars, promising varieties were short-listed for detailed investigations Balasubramanyam *et al.,*[2] Amongst the introduced varieties, white Creole, an OP variety was found suitable, and selected for multilocation trials. Balasubramanyam *et al.,*[3] while reviewing the development of OP varieties of white high solid onions in JISL concluded that JV12, a selection from white Creole, over the years had improved further in shape, TSS and important parameters, desirable for dehydration and also emphasized scope for further improvement by selection and systematic breeding.[3] Patil *et al.,*[4] another studied three cultivars of white creole with transplanting dates; it was observed that there is inverse correlation between yield and TSS content.

Most varieties grown by farmers in India are open pollinated use of hybrids for commercial cultivation has not been exploited (Lawande).[5] Diallel cross analysis is useful for systematically testing the performance of inbred lines in hybrid combinations. So, the present investigation was undertaken to know good combiners as well as specific combinations for yield and processing components.

Material and Methods

There are eight genotypes of white onion of indigenous and exotic origins were used. These parents namely AF (Agri found white), PW (Punjab White), GJ (Gujrat Local), UD102 (Udaipur white), J5 (JISL-5), PS (Phule Safed), JV12 (Jain White Creole 12) and JV16 (Jain White Creole 16) were selected based on phenotypic diversity of plants in respects of yield and processing qualities traits. Crosses were made between the eight parents following the scheme of 8 x 8 half diallel, excluding reciprocals to develop 28 F_1 hybrids. All the crosses along with parents were grown during Rabi 2012-13 in a randomized block design (RBD) with three replications at Jain R & D farm, Jain Hi-Tech Agricultural Institute, Agri Park, Jalgaon Maharashtra, India. All the recommended cultural practises were carried out to raise crop. Data were recorded on five unbiasedly selected plants per replication for all characters viz., Plant height, Number of leaves, Bulb weight, Bulb diameter, Percent Bolting, Percent Doubles or Splits, Total Soluble Solids (TSS), Pungency and Total Bulb Yield. The variation among the hybrids was partitioned into genetic components attributed to general combining ability (GCA) variances and specific combining ability (SCA) variances and effects were analysed by adopting Griffing's Model-I, Methods-II.[6] The analysis was carried out using 'Indostat' statistical software developed by Indostar services, Hyderabad. Indian corporation Ltd. Hyderabad.

Table 1: Analysis of variance for GCA and SCA and their ratio for various characters in white onion

Sr. No	Characters	MEAN SQUARES		Error (70 d. f.)	GCA/SCA
		General Combining ability (7 d. f.)	Specific combining ability (28 d. f.)		
1	Plant Height (cm)	43.305	71.286	1.855	0.060
2	Number of leaves	6.713	5.152	0.149	0.131
3	Bulb Weight (g)	788.567	150.929	3.005	0.531
4	Bulb Diameter (cm)	0.5737	0.3532	0.022	0.166
5	Percent Bolting	363.442	39.555	0.744	0.934
6	Percent Doubles	80.518	13.343	0.363	0.617
7	Total Soluble Solids (TSS)	5.929	1.951	0.022	0.306
8	Pungency(ppm)	93374.648	22012.917	118.214	0.425
9	Yield (t/ha)	109.466	15.939	0.0362	0.688

Results and Discussion

Analysis of variance revealed that both GCA and SCA variances were highly significant for all characters (Table1). These indicated the importance of additive as well as non-additive types of gene action in the inheritance of these traits. However, the magnitude of GCA mean square was higher for most of the characters except plant height. The variance due to GCA and SCA may not give us a correct picture of the gene action and therefore the ratio of estimates of variances due GCA and SCA were calculated .The ratio estimates of variances due to GCA to that to SCA indicated the preponderance of additive and additive x additive type of gene action for most of the characters.

Table 2: Estimates of general combining ability effects associated with each parent

Parents	Plant Height (cm)	Number of Leaves	Bulb Weight (g)	Bulb Diameter (cm)	Percent Bolting	Percent Doubles	Total Soluble Solids (TSS)	Pungency (ppm)	Yield (t/ha)
AF	-0.905*	-0.153	-0.787	-0.069	2.051*	1.064*	-0.493*	-18.412*	0.341*
PW	3.930*	0.192	3.473*	0.079	0.736*	-0.762*	-0.349*	16.033*	-0.002
GL	0.727	-0.586*	-5.937*	0.235*	4.716*	1.222*	-0.436*	-116.099*	-4.236*
UD-102	0.362	0.420*	-7.597*	-0.228*	3.107*	3.672*	-0.619*	-83.143*	-2.147*
J5	-3.448*	1.694*	-7.413*	-0.294*	1.183*	-0.012	-0.129*	-35.306*	-1.134*
JV16	-0.614	-0.713*	3.296*	-0.011	-8.211*	-4.533*	1.411*	108.288*	3.219*
PS	-0.775	0.007	-4.107*	-0.136*	6.651*	2.750*	-0.405*	-43.216*	-2.140*
JV12	0.722	-0.861*	19.070*	0.423*	-10.233*	-3.401*	1.020*	171.854*	6.189*
S.E Gi	0.402	0.114	0.512	0.044	0.255	0.178	0.043	3.216	0.056
S.E. + Gi-Gj	0.609	0.173	0.775	0.066	0.385	0.269	0.067	4.862	0.085

Analysis for combining ability of variances due to general and specific combining ability was significant for all the characters studied (Table 2 and 3) indicating the presence of adequate amount of variability and there is possibility of selection desirable plants for quality traits of interest. The parents showed significant high general combining ability for nine characters presented in Table 2. It can be concluded that none of the parent reported uniformity in high general combining ability for all characters.

The parent JV16 and JV12 exhibited highly significant gca for characters bulb weight, bulb diameter, percent bolting, percent doubles, Total Soluble Solids (TSS), pungency and yield and PW for plant height, bulb weight, bulb diameter, percent doubles, pungency. AF good combiner for yield and average combiner for no. of leaves, bulb weight and bulb diameter.

PW the only parent exhibited highly significant positive GCA effects and hence it is a good general combiner for plant height. Sundari *et al.,*[9] estimated the effects of general combining ability among the lines. They observed that L-2 was a good combiner for the plant height. Two parents viz., J5 (1.694) and UD-102 (0.420) exhibited significant positive GCA effect for the number of leaves per plant. Ningadalli[10] reported highest GCA effect by the line NRCOG-659 (1.05) and tester Arka Pragati (0.25) for the number of leaves character.

Out of eight parents for bulb weight characters studied, three parents (JV12, PW and JV16) showed significant positive GCA effects. Netrapal and Choudhary[11] studied diallel analysis in onion and found that parent Sel. 102-1(3.302) gave highest GCA effects followed by Pusa White Flat (2.489) and Punjab Selection (1.873) for bulb weight. For percent bolting exotic parents namely, JV12 (-10.233) and

JV16 (-8.211), which needs cold treatment for bolting exhibited highly significant and negative (considered desirable for bulb production) GCA, whereas all other parents were poor combiners for this trait. Adsul[12] in above two cultivars as compared to most of the Indian genotypes.

Out of eight parents studied, for percent double two exotic and a indian parent, total three parents namely JV16 (-4.533), JV12 (-3.401), PW (-0.762) and J5 (-0.012) showed significant negative GCA effects is welcomed (considered desirable for bulb production) for percent double. Significant GCA estimates were recorded for all parents except J5. Though percent doubles are influenced by many agronomical factors but significant genotypic differences were also reported (Adsul).[12]

For important quality parameter like Total Soluble Solid (TSS) studied two parents namely JV16 (1.411) and JV12 (1.020) showed significant and positive GCA effects, meaning that they were good general combiners. Pavlovic *et al.,*[13] studied five parents in diallel analysis, among these three parents showed the significant GCA (one positive and two negative) values, however other two were positive but non-significant for TSS. Ningadalli[10] observed significant GCA for TSS, Bellary Red (2.52) among line and among tester Arka Kalyan (0.85) showed significantly positive GCA.

All parents gave significant GCA estimates, three parents viz., JV12 (171.854), JV16 (108.288) and PW (16.033) exhibited positive estimates for pungency.

Out of eight parents studied, three parents; JV12 (6.189), JV16 (3.219), and PW (0.341); showed significant positive GCA effects, indicating good general combiners for yield. PW (-0.020) was average combiner for yield. Netrapal and Choudhary[11] reported that parent Pusa White Flat, Sel. 102-1 (0.180) and Punjab Selection (0.145) gave higher GCA effects for bulb yield in a diallel analysis of onion.

Hosfield *et al.,*[8] in their subsequent studies on nine parent's diallel cross over two locations for yield observed that inbred lines B2190 and M728 showed highest GCA effects and transmitted large yield to the progeny. Havey and Randle 14 reported significant GCA effects for yield in open pollinated populations of onions. Sundari *et al.,*[9] reported L-2 among lines and T-14 among tester as best general combiners.

The hybrids showing best specific combinations with sca effects for different characters were presented in Table 3. Out of 28 crosses, Twelve crosses for plant height character had significant SCA in positive direction with highest value in cross PW x UD-102 (13.439) followed by UD-102 x J5 (13.284).similar result reported by Sundari *et al.,*[9] estimated the SCA effects and found that the cross L-3 x T-12 had good SCA for plant height. The best combination for number of leaves was AF x UD -102 (4.118) followed by PW x UD-102 (3.373) and J5 x JV16 (3.272), Sundari *et al.,*[9] observed the cross L-3 x T-14 was a good specific combiner for number of leaves. The best combination for Bulb weight was AF x JV12 (18.424) followed by JV16 x PS (15.882) and J5 x PS (14.561). 12 crosses having positive SCA effects suggesting that they were good combinations for bulb weight. Hosfield *et al.,*[8] studied in a seven parent diallel cross for two years at three locations and recorded significant SCA.

Out of 28 hybrids, 20 hybrids showed significant SCA effects for Bulb diameter. UD -102 x J5 (0.837), AF x PW (0.773) and JV16 x PS (0.610) showed high SCA. Sundari *et al.,*[9] reported significant SCA for bulb diameter while studied on Indian onions.

Fifteen hybrids showed significant SCA effects for percent bolting. Among these, 12 cross combinations exhibited in negative (as desirable) directions. Higher values were recorded in cross JV16 x PS (-13.250) followed by PS x JV12 (-9.187) and AF x JV12 (-6.377).The best combination for percent doubles was JV16 x PS (-6.466) followed by PW x JV16 (-6.340) and AF x JV12 (-4.708).

Percent doubles also followed pattern similar to percent bolting except few exception. Twenty five hybrids showed significant SCA effects and among these 15 crosses exhibited in positive direction and ten in negative direction.

The best combination for TSS was PW x JV16 (2.302) followed by AF x JV12 (2.258) and J5 x JV16 (1.915). Pavlovic *et al.,*[13] studied five parents

in diallel analysis. Among cross combinations, the highest SCA effects were shown by Piroska x Bunkio beo parents (1.174) followed by Makoi bronzi x AC 101(0.526) for dry matter contents.

Out of 28 hybrids for pungency, Fourteen cross combinations possessed significant positive SCA effects and the best combinations were AF x JV12 (222.51) followed by AF x JV16 (191.39), J5 x PS (189.21) and JV16 x JV12 (150.86). Netrapal and Choudhary[11] studied an eight parent diallel analysis, for inheritance of pungency.

Table 3: Estimates of specific combining ability effects associated with each cross

Cross	Plant Height (cm)	Number of leaves	Bulb Weight (g)	Bulb Diameter (cm)	Percent Bolting	Percent Doubles	TSS	Pungency (t/ha)	Yield
AF X PW	-1.994*	-1.854*	-4.913*	0.773*	-1.736*	1.596*	0.507*	-198.455*	-1.747
AF X GL	4.546*	-1.075*	-3.169*	-0.117	-2.516*	2.546*	0.627*	56.601*	0.891*
AF X UD-102	5.174*	4.118*	-2.743*	0.079	-0.674	0.896*	-0.357*	101.85*	-3.485*
AF X J5	-23.416*	-2.622*	-17.293*	-0.655*	3.816*	-1.821*	-2.947*	-191.33*	-2.958*
AF X JV16	7.650*	2.185*	-4.869*	-0.631*	4.710*	2.734*	-0.487*	191.39*	2.942*
AF X PS	-10.888*	-0.135	0.535	0.388*	4.182*	-3.116*	0.363*	-6.749	-2.222*
AF X JV12	6.648*	-0.880*	18.424*	0.395*	-6.377*	-4.708*	2.258*	222.51*	4.412*
PW X GL	7.291*	-0.820*	2.704*	0.069	-2.567*	-1.762*	0.549*	69.93*	1.963*
PW X UD-102	13.439*	3.373*	11.564*	-0.669*	-3.758*	-0.212	0.342*	65.38*	-2.696
PW X J5	4.349*	2.500*	-4.487*	0.564*	-1.835*	-1.195*	-0.191*	-50.83	-0.466*
PW X JV16	-9.651*	-0.827*	3.738*	0.448*	-0.841	-6.340*	2.302*	39.36*	-2.969*
PW X PS	-0.957	-0.214	-21.025*	-1.760*	15.531*	7.010*	-3.248*	29.27*	-4.760*
PW X JV12	-0.0554	-0.292	9.897*	0.204*	-4.952*	1.261*	0.393*	148.35*	4.185*
GL X UD-102	-3.024*	-0.448*	3.374*	0.095	-0.905	-0.328	0.785*	132.41*	0.401*
GL X J5	1.886*	2.545*	-10.943*	0.241*	0.485	-4.512*	0.395*	130.49*	-3.565*
GL X JV16	-3.681*	-1.115*	-19.186*	-0.008	6.379*	2.110*	-0.511*	-216.92*	-5.504*
GL X PS	3.280*	-2.435*	-12.382*	0.190*	11.917*	-0.540	0.572*	-58.39*	-5.232*
GL X JV12	-7.984*	1.966*	-1.360	0.058	1.802*	1.977*	-1.420*	-177.32	-3.854*
U-102X J5	13.284*	1.205*	9.450*	0.837*	-1.072*	-2.095*	0.012	1.37	-0.517*
U-102 X JV16	1.217	0.212	1.108	0.421*	0.298	5.326*	-1.761*	-191.85	2.176*
U-102 X PS	-8.122*	-1.375*	-16.055*	0.446*	5.160*	3.010*	-0.045	8.61	-4.262*
U-102 X JV12	-7.252*	-0.707*	-2.700*	-0.586*	-1.689*	0.227	-1.203*	-303.45	-3.814*
J5X JV16	-12.106*	3.272*	-15.976*	-1.113	-3.355*	-1.824*	1.915*	-191.42	2.264*
J5X PS	1.058	3.152*	14.561*	0.146	2.083*	4.193*	-0.035	189.21*	-2.728*
J5X JV12	-0.109	-0.580*	2.423*	0.253*	6.668*	5.411*	1.807*	127.93*	1.11.*
JV16X PS	2.288*	-1.908*	15.882*	0.610*	-13.250*	-6.466*	1.492*	-36.82	5.239*
JV16X JV12	0.390	0.293	3.674*	0.344*	3.208*	4.799*	-1.167*	150.86*	-1.109*
PS X JV12	4.218*	-1.827*	5.708*	0.376*	-9.187*	-4.618*	1.150*	-87.80*	3.383*
SE mean Sij	1.235	0.350	1.571	0.134	0.782	0.546	0.133	9.858	0.172
SE mean Sij-Sik	1.827	0.519	2.325	0.199	1.157	0.808	0.198	14.587	0.255

Eleven crosses had shown significant positive SCA effects. The highest significant positive SCA effects were exhibited by JV16 x PS (5.239) followed by AF x JV12 (4.412), PS x JV12 (3.383) and AF x JV16 (2.942). Netrapal and Choudhary[11] studied diallel analysis in onion using eight inbred lines. Their results showed that high specific combining ability effects were present in cross combinations

Sel.102-1 x Sel.126 (0.957) followed by Sel.126 x Punjab Selection (0.838) and Sel.96 x Punjab Selection (1.045) for bulb yield. (Hosfield *et al.,*[7 & 8]) generated diallel crosses among inbred lines and reported moderate to low SCA estimates.

The relationship between *per se* performance and combining ability effects of top 6 hybrids for yield and quality parameters (Table 4) showed the relationship between gca and sca effects can occur in gca parents indicating the presence of higher order interactions in the expression of these traits and in addition to this, sca effects occurred because it all depends upon how well genes from two parents interaction.

Table 4: *per se* performance and combining ability effects of top 6 hybrids for yield and other characters

Best crosses	Mean yield (t/ha)	Combining ability for yield			Significant heterobeltiosis for other traits in desirable direction
		SCA	GCA		
			P1	P2	
AF x JV12	34.32	4.412*	0.341**	6.189**	BW,BD,TSS,BOL,DOU,PUN,YLD
PW x JV12	33.75	4.185*	-0.002	6.189**	BW,BOL,DOU,PUN,YLD
JV16 x JV12	31.59	-1.109*	3.129**	6.189**	BW,BD,TSS,PUN
PS x JV12	30.81	3.383*	-2.140**	6.189**	BD,TSS,BOL,DOU
AF x JV16	29.79	2.942*	0.341**	3.111**	NL,DOU,YLD
JV16 x PS	29.61	5.239*	3.129**	-2.140*	BD,BOL,DOU,YLD

Where: PH: Plant height NL: Number of leaves BW: Bulb weight (g)
BD: Bulb diameter (cm) Bol: Bolting percent DOU: Doubles/split bulbs (%)
PUN: pungency TSS: Total soluble solids (%) YLD: Bulb yield (t ha)

The occurrence of high sca effects in good x good parent might be due to cumulative effects of high combining loci and no mutual cancelation of gene effects between high general combining loci. On the other hand high sca effects in good x average or average x good, average x poor or poor x average parent might be due to suit of low, good and poor or average combining loci. Therefore, based on *per se* performance of selective parents and crosses in present study, can be concluded that desirable the better performing hybrids AF x JV12, PW x JV12, JV16 x JV12, PS x JV12 and JV16 x PS were identified as outstanding and could be used as donors to gets high yield and processing qualities traits could be utilized in future under breeding programme.

Conclusion

The present study was concluded at Jain R & D Farm, Jain Agri Park, Jalgaon for investigating the combining ability analysis for yield and processing abilities of white onion. This study has examined the combining ability effects of parents and hybrids. Genotype JV12, JV16 and PW were found to be good donor parents for per cent bolting, per cent doubles and pungency. On the basis of per se performance, AF x JV12 was found to be most promising in respect of bulb yield and its contributing traits and may be exploited in future onion breeding programme. If one of the parent could be made male sterile and if after favourably assessing its superiority in the performance with stability across locations/ years with processing abilities like pungency and TSS% this cross could be favourable for emerging very good marketable hybrid for processing.

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Conflict of Interest
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