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Combining ability studies for yield, quality and storage in onion

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ABSTRACT

Combining ability effects were estimated for different characters in a line × tester crossing programme comprising 96 onion hybrids produced by crossing of 3 male sterile lines and 32 testers. Parents and hybrids differed significantly for gca and sca effects, respectively. Among the lines, 30A and 97A and among the testers CT-1201, CT-1202, CT-1204, CT-1205, CT-1207 and CT-1217 were found to be the good general combiners. Five cross combinations, *viz*., 65A × CT-1213, 65A × CT-1227, 97A × CT-1230, 65A × CT-1209 and 97A × CT-1220 were found to be best specific crosses for bulb yield and most of the important traits including keeping quality. Results showed that non-additive variation is an integral component of the genetic architecture of different traits in onion.

Key words: Combining ability, diversity, line × tester, onion.

INTRODUCTION

Onion (*Allium cepa* L.) is most important vegetable for domestic needs and export in India. India is the third largest exporter of onion after the Netherlands and Spain. Even after restrictions, onion earns foreign exchange more than Rs. 3,170 crores annually, which is about 55% of the fresh vegetables, and 36% of total vegetables and fruits (Anon, 2). The increase in productivity and production can enhance export and stabilize onion prices in the country. The productivity of onion in India is very low (16.1 MT ha^{-1}) than USA (53.9), Spain (52.05), Japan (47.55) and the Netherlands (43.12). A major share of F_1 hybrids is one of the reasons for high productivity in USA (81%), Japan (73%) and Europe (50%) (Kik *et al*., 10). F_1 hybrids have the advantage of high yield, size uniformity, earliness and storage attributes. A potential range of heterosis for yield in onion has been reported between 40-160% (Sypein *et al*., 15; Suciv *et al*., 14; Arold, 3; El-Sayed *et al*., 5; Sato *et al*., 12; Gowda *et al*., 6). However, hybrids are cultivated on negligible area (<1%) in India and non-availability of male sterile lines in diverse genetic backgrounds adapted to variable geographic regions is one of the reasons for this cause. Punjab Agricultural University (PAU) has developed CGMS lines from adapted populations of north-western India and can be utilized for hybrid development. To proceed for hybrid development, we must have the knowledge of good combining parents and gene action of different traits. Therefore, present investigation was planned to study the combining ability effects for growth, yield, quality and storage attributes of onion.

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MATERIALS AND METHODS

Experimental material comprised of three male lines, *viz.,* 30A, 65A and 97A and 32 testers. Among male sterile lines 30A and 97A were developed at PAU, Ludhiana and 65A at IIHR, Bengaluru, whereas, testers were developed by four generations of recurrent selection. Crosses were made in line × tester mating design during *rabi* season of 2011-12. All the 96 F_1 along with their parents evaluated during *rabi*, 2012-13 in randomized block design with three replications. Each genotype was represented by 77 plants in a plot spaced at 15 cm × 10 cm. All recommended cultural practices were followed during experimentation to raise a healthy crop. Observations were recorded on plant height, leaf length, number of leaves, leaf thickness (cm), pseudo-stem thickness (cm), five bulb weight (g), polar and equatorial bulb diameter (cm), marketable bulb yield (kg), neck thickness of bulb (cm), total soluble solids (°Brix), pyruvic acid content (%) and lachrymatory factor (%). The analysis of GCA and SCA for the above characteristics was calculated as per the model suggested by Kempthorne (9).

RESULTS AND DISCUSSION

The results pertaining to the analysis of variance for combining ability have been given in Table 1. Total genetic variability among hybrids was further partitioned into different components corresponding to lines in hybrids, testers in hybrids and lines × testers in hybrids. The significant mean squares due to lines in hybrids, tester in hybrids and lines × testers in hybrids indicated the role of both additive and non-additive gene effects in inheritance of all the traits under study. Such findings were also

Table 1. Analysis of variance for combining ability for different traits in onion.

Source of variation	d.f.	Mean sum of squares															
		No. of leaves	Plant height	Leaf length	Leaf width	Pseudo stem thickness	Neck thickness	Yield	Bulb wt.	Polar dia.	Equator dia.	P:E dia.	Bolting	TSS	Pyruvic acid	Lachrymatory factor	Storage loss
Replication	2	2.24	194.81	21.46	0.41	0.022	0.018	0.04	8.61	0.13	0.03	0.003	0.70	1.29**	83.64**	18.58**	0.049*
Lines in hybrids	2	3.06**	2904.02**	1889.94**	0.09**	0.201**	0.047**	9.16**	2153.20**	7.33**	6.99**	0.030**	331.96**	3.49**	355.38**	408.71**	0.304**
Testers in hybrids	31	0.44	190.98**	181.46**	0.02	0.052*	0.010*	3.52**	724.73**	2.46**	1.82**	0.030**	117.69**	2.30**	1476.35**	663.86**	0.157**
Lines × testers	62	0.54	70.94	61.84	0.02	0.035	0.007	1.22**	332.44**	1.15**	0.75**	0.027**	29.64**	2.54**	165.50**	105.50**	0.091**
Error	190	0.57	40.65	32.33	0.02	0.022	0.003	0.04	1.68	0.04	0.03	0.002	1.16	0.23	9.06	8.27	0.002
Components of genetic variance																	
σ^2GCA		0.03	29.51	19.04	0.002	0.004	0.003	0.08	18.97	0.06	0.06	0.002	7.44	0.03	145.65	62.04	0.01
σ^2SCA		0.01	10.10	9.84	0.001	0.003	0.002	0.39	110.25	0.37	0.24	0.01	9.50	0.77	52.14	32.41	0.03
σ^2SCA/ σ^2GCA		0.33	0.34	0.52	0.50	0.75	0.67	4.88	5.81	6.17	4.00	5.00	0.78	25.67	0.36	0.52	3.00

* and ** significant at 5 and 1% levels, respectively

observed by Aghora and Pathak (1) in their study on onion. The ratio of σ^2SCA/ σ^2GCA was less than unity for plant height, number of leaves, leaf length, leaf width, pseudo-stem thickness, neck thickness, bolting, pyruvic acid content and lachrymatory factor, which indicated the greater role of additive gene effects in the inheritance of these traits. However, predominance of non-additive gene effects for traits like bulb yield, average bulb weight, polar diameter, equatorial diameter, bulb shape index, TSS and weight loss during storage was indicated by the ratio of genetic variance. Veere Gowda (16) and Divakar (4) were also of same view for yield contributing traits.

The GCA effects for different traits under study showed that for plant height 30A (6.11) was best general combiner and 65A (-4.56) was the poor. Among testers CT-1207 (7.64), CT-1211 (7.16), CT-1210 (6.90), CT-1208 (5.37), CT-1202 (5.06), CT-1204 (4.39), CT-1212 (4.18) and CT-1205 (3.92) exhibited highly significant and positive GCA effects and, were regarded as good general combiners. The SCA effects for plant height were significantly high in seven crosses and ranged from 6.12 to 10.99 in cross 30A × CT-1223 and 65A × CT-1217, respectively. For number of leaves per plant, lines 30A (0.18) and 97A (0.00) were average general combiners due to positive and non-significant GCA effect. Similarly in testers, majority were average general combiners. There were four crosses that showed significant and positive SCA effects for number of leaves per plant, which ranged from 0.53 (65A × CT-1203) to 1.05 (96A × CT-1206). The GCA effects for neck thickness was non-significant and negative in 65A (-0.01) and 97A (-0.01), hence, were average combiners. However, among testers CT-1221 (-0.05), CT-1222 (-0.05), CT-1229 (-0.04) and CT-1231 (-0.04) were significantly negative for this trait. The SCA value of twelve hybrids were found negative and significant with a range from -0.09 (30A × CT-1204) to -0.04 (65A × CT-1224). These findings are made as the observations by Divakar (4) and Veeregowda (16).

General combing ability effects for total yield were positive and significant for lines 30A (0.19) and 97A (0.17), however, among testers CT-1202 (1.27), CT-1207 (1.27), CT-1217 (0.86), CT-1204 (0.85), CT-1208 (0.85), CT-1205 (0.68), CT-1206 (0.65), CT-1212 (0.44), CT-1210 (0.41), CT-1224 (0.38), CT-1201 (0.35), CT-1203 (0.25) and CT-1209 (0.18) were found to be good combiners (Table 2). Thirty-six crosses exhibited positive and significant SCA effects ranged from 0.19 (65A × CT-1224) to 1.42 (65A × CT-1213). Among these 36, nine crosses (97A × CT-1205, 97A × CT-1206, 97A × CT-1207, 97A × CT-1212, 30A × CT-1204, 30A × CT-1207, 30A × CT-1208, 30A × CT-1210, 30A × CT-1211 and 30A × CT-1212) involved both the parents having significant and positive GCA. These crosses can be commercially exploited as F_1 hybrids or can be potential source material to derive breeding lines with higher bulb yield from the segregating populations. Similar results were found by the Netrapal and Singh (11) and Shashikanth *et al.* (13) in different genetic stocks used in their studies.

Estimates of general combining ability for bulb weight revealed the line 30A (4.02) exhibited significant and positive GCA effects and was therefore good general combiner for average bulb weight. This genotype can be utilized to develop hybrids with the bigger bulb size. Whereas, the line 97A (1.21) showed positive and non-significant GCA effect and regarded as average combiner for bulb weight. Among testers, CT-1202 (13.48), CT-1210 (12.43), CT-1205 (12.42), CT-1204 (11.55), CT-1214 (11.73), CT-1208 (10.95), CT-1203 (9.49), CT-1217 (8.92), CT-1206 (7.36), CT-1207 (6.49), CT-1212 (6.39), CT-1220 (6.09), CT-1209 (3.35) and CT-1216 (0.91) showed positive and significant GCA effects and were regarded as good combiners for average bulb weight. SCA effects were significant and positive in 42 crosses and were therefore, good specific combiners for average bulb weight (Table 3). It was observed that SCA effects were significant and positive in 42 crosses for bulb weight and ranged from 1.06 to 23.13 in cross 30A × CT-1216 and 97A × CT-1207, respectively. Our results corroborate the reports of Divakar (4), wherein, improvement in bulb weight through selection has been emphasized.

The equatorial and polar diameters were major contributors towards bulb size and yield in onion. In this study, line 30A (0.29) and testers CT-1203 (0.84), CT-1206 (0.70), CT-1205 (0.66), CT-1208 (0.66), CT-1204 (0.60), CT-1202 (0.56), CT-1212 (0.48), CT-1210 (0.46), CT-1211 (0.20), CT-1209 (0.13) and CT-1201 (0.13) showed positive and significant GCA effects and found good combiners for this trait. The SCA effects of 34 crosses ranged from 0.15 (97A × CT-1223) to 0.98 (65A × CT-1213). For polar diameter again line 30A (0.25) was best general combiner with positive and significant effect. The GCA effects were positive and significant in tester CT-1202 (1.15), CT-1204 (0.98), CT-1205 (0.81), CT-1203 (0.80), CT-1208 (0.77), CT-1216 (0.60), CT-1210 (0.46), CT-1212 (0.41), CT-1217 (0.33), CT-1206 (0.30) and CT-1220 (0.29). The SCA effects for polar diameter were significant and positive in 38 crosses with a range from 0.13 to 1.60 in cross 65A × CT-1217 and 65A × CT-1213, respectively. The induction of flowering in bulb crop is termed as bolting and cause direct loss in marketable yield of onion. Line 97A (-1.84) exhibited negative significant GCA effect for bolting losses. Whereas, among testers CT-1202 (-5.06), CT-1201 (-4.62), CT-1223 (-4.62), CT-1209 (-4.4) and CT-1222 (-3.95) had negative significant GCA effects for bolting losses. Estimation of SCA effects indicated that out of 96 F_1 hybrids, 31 exhibited negative and significant SCA values for bolting with a range of -10.82 to -0.97 in cross 97A × CT-1205 and 30A × CT-1209, respectively.

Total soluble solids (TSS), important quality parameter was positively significant in 97A for GCA effects. However, among testers none of the genotype showed significant and positive GCA effects, and regarded as average general combiners for this trait. SCA effects for TSS were ranged between 1.67 to 2.84, wherein, crosses 30A × CT-1217, 97A × CT-1209, 97A × CT-1202, 30A × CT-1211 and 65A × CT-1232 were

Table 2. General combining ability (GCA) effects of parents for different traits.

Trait	Significant No. of line(s)	Top general combiners (Line)	Significant No. of tester(s)	Top general combiners (Tester)
Plant height	1	30A (6.11**)	8	CT-1207, CT-1211, CT-1210, CT-1208
No. of leaves	0	30A (0.18)	0	CT-1211, CT-1205, CT-1210, CT-1216
Neck thickness	0	65A (-0.01), 97A (-0.01)	4	CT-1229, CT-1231, CT-1221, CT-1222
Bulb weight	2	30A (4.02**), 97A (1.21**)	14	CT-1202, CT-1210, CT-1205, CT-1214
Yield	2	30A (0.19**), 97A (0.17**)	13	CT-1202, CT-1207, CT-1217, CT-1204
Bolting	1	97A (-1.84*)	12	CT-1202, CT-1201, CT-1223, CT-1209
Polar dia.	1	30A (0.25**)	11	CT-1202, CT-1204, CT-1205, CT-1203
Equatorial dia.	1	30A (0.29**)	11	CT-1203, CT-1206, CT-1205, CT-1208
TSS	0	97A (0.16)	0	CT-1209, CT-1222, CT-1206, CT-1218
Pyruvic acid	0	97A (2.21)	8	CT-1231, CT-1219, CT-1202, CT-1228
Storage	1	30A (-0.06**)	13	CT-1223, CT-1226, CT-1230, CT-1221

* and ** significant at 5 and 1% levels, respectively

Table 3. SCA effects for yield, yield components and quality traits in onion.

Trait	Range (%)	No. of desirable heterotic hybrids	Best five hybrid combinations
Plant height	6.12** to 10.99**	7	65A × CT-1217, 97A × CT-1206, 30A × CT-1221, 30A × CT-1222, 97A × CT-1201
No. of leaves	0.53** to 1.05**	4	97A × CT-1206, 30A × CT-1209, 30A × CT-1206, 65A × CT-1203, 65A × CT-1225
Neck thickness	-0.09** to -0.04**	12	30A × CT-1204, 97A × CT-1205, 65A × CT-1209, 65A × CT-1220, 97A × CT-1202
Bulb weight	1.06** to 23.13**	42	97A × CT-1207, 65A × CT-1213, 30A × CT-1215, 97A × CT-1230, 97A × CT-1205
Yield	0.19** to 1.42**	36	65A × CT-1213, 65A × CT-1227, 97A × CT-1230, 65A × CT-1209, 97A × CT-1220
Bolting	-10.82** to -0.97**	31	97A × CT-1205, 30A × CT-1232, 97A × CT-1210, 97A × CT-1208, 97A × CT-1211
Polar dia.	0.13** to 1.60**	38	65A × CT-1213, 30A × CT-1210, 97A × CT-1220, 30A × CT-1225, 97A × CT-1205
Equatorial dia.	0.15** to 0.98**	34	65A × CT-1213, 97A × CT-1230, 65A × CT-1209, 30A × CT-1224, 65A × CT-1202
TSS	1.67** to 2.84**	2	30A × CT-1217, 97A × CT-1209, 97A × CT-1202, 30A × CT-1211, 65A × CT-1232
Pyruvic acid	6.80** to 27.27**	8	65A × CT-1227, 65A × CT-1207, 65A × CT-1230 , 65A × CT-1232, 65A × CT-1226
Storage	-0.34** to -0.03**	39	30A × CT-1207, 30A × CT-1229, 97A × CT-1213, 65A × CT-1224, 65A × CT-1202

* and ** significant at 5 and 1% levels, respectively

the promising. In respect to pyruvic acid content, line 97A (2.21) was the average general combiner and among testers CT-1201 (13.85), CT-1214 (4.96), CT-1215 (8.44), CT-1219 (28.70), CT-1227 (10.88), CT-1228 (22.14) and CT-1231 (34.80) exhibited positive and significant GCA effects. The SCA effects for pyruvic acid ranged from 6.80 to 27.27. Netrapal and Singh (11) and Divakar (4) also observed significant differences for quality traits in their studies.

In respect to storage loss, line 65A (-0.06) was best general combiner as it recorded negative and significant GCA effects. Among testers, CT-1215 (-0.16), CT-1218 (-0.05), CT-1219 (-0.17), CT-1221 (-0.18), CT-1222 (-0.06), CT-1223 (-0.20), CT-1224 (-0.14), CT-1225 (-0.08), CT-1226 (-0.20), CT-1227 (-0.18), CT-1228 (-0.11), CT-1229 (-0.06) and CT-1230 (-0.20) were good combiners for better storage with negative and significant GCA effect. The SCA effects for storage were negative and significant in 39 crosses. It ranged from -0.34 to -0.03 in cross 30A × CT-1207 and 65A × CT-1203, respectively. The findings are in conformation of Hosfield *et al.* (7), Madalageri (8), Suciv *et al.* (14) and Divakar (4).

The best ten hybrids based upon *per se* value of yield have been compared for SCA of crosses and GCA effects of parents for yield, quality and storage traits in Table 4. It was observed that crosses 97A × CT-1207, 30A × CT-1207, 65A × CT-1202, 97A × CT-1205, 30A × CT-1208, 30A × CT-1204 and 30A × CT-1212 were high in SCA effects, where, both the parents exhibited high GCA, except cross 65A × CT-1202. Therefore, crosses having parents with high SCA and GCA can be exploited in heterosis breeding, and those having both the parents with high GCA for deriving populations having high yield and other desirable traits in onion.

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Table 4. Performance of top ten onion hybrids (*per se*) based upon bulb yield.

Hybrid	Yield (q/ha)	SCA of hybrids	GCA of parents	Bulb wt. (g)	Polar dia. (cm)	Equatorial dia. (cm)	Bolting (%)	TSS (°Brix)	Pyruvic acid (mg/100 g)	Lachrymatory factor (mg/100 g)	Storage losses after 90 days (%)
97A × CT-1207	414.60	H	H × H	87.43	6.03	6.23	3.33	11.83	67.31	103.77	58.62
30A × CT-1207	413.97	H	H × H	76.64	5.28	5.61	1.34	10.67	64.14	100.77	35.05
65A × CT-1202	375.87	H	L × H	77.37	5.37	6.2	8.45	10.33	100.23	110.21	53.12
97A × CT-1202	368.25	M	H × H	74.47	5.53	5.77	7.19	12.67	111.87	108.12	70.00
97A × CT-1205	357.46	H	H × H	73.53	5.57	5.17	9.53	12.00	89.12	78.01	53.47
30A × CT-1208	354.29	H	H × H	73.57	5.38	5.21	10.67	10.67	72.67	90.18	39.47
30A × CT-1204	353.02	H	H × H	74.64	5.64	5.88	7.41	11.17	85.57	94.21	57.78
30A × CT-1212	351.75	H	H × H	71.64	5.74	5.34	4.67	12.33	86.05	93.28	48.79
97A × CT-1217	342.86	M	H × H	70.73	5.67	5.6	6.33	10.67	80.88	103.84	58.45
97A × CT-1204	340.95	M	H × H	73.4	5.81	5.69	7.82	10.67	88.74	97.21	53.03

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