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Heterosis and Combining Ability in Onion (*Alliumcepa* L. Var. *aggregatum* Don.)*

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Ten aggregatum onion lines (*Allium cepa* L. Var. *aggregatum* Don) a were crossed with three testers in the line×tester method to get 30 crosses and to choose suitable combiners and best hybrid combination for exploitation of hybrid vigour. The study revealed that the lines P^1 and P^{10} and tester T^1 were found to exhibit high mean expression and high *gca* effect for yield and yield components indicating their use as appropriate parents in a crossing programme for further accumulation of favourable genes through recombinations. The hybrids $P^1 \times T^1$ and $P^{10} \times T^1$ were found to be desirable for the purpose of exploitation of hybrid vigour because of combined expression of high mean, heterotic expression, sca effect and also the parents involved possessed high expression of gca effects. Plant height, number of leaves, number of bulbs, weight of plant, shape index and Tss were governed by non-additive genetic factors suggesting that these traits could be improved through heterosis breeding. The role of additive genetic factors was observed for weight of bulbs and days to maturity.

The hybrid vigour in plants is exploited for higher production in several crops. Heterotic expression as exhibited by various economic plant characters is reflected on the production potential of a hybrid. The magnitude of general and specific combining ability variances is helpful in the selection of suitable parents and hybrids for designingan efficient breeding schedule. The investigations reported herein relate to the extent and nature of heterosis and to have an insight into the importance of the general and specific combining ability in the selection of suitable parents and hybrids in onion (*Allium cepa* L. Var. *aggregatum* Don).

MATERIAL AND METHODS

A set of thirty crosses involving ten aggregatum onion lines and three testers in a line x tester method was grown along with their parents at the Faculty of Horticulture, Tamilnadu Agricultural University, Coimbatore. The material comprising 43 entries (13 parents and 30 crosses) was raised in single row plots in randomised block design with five replications in bulb to bulb generation. In seed to bulb generation the parents were not compared with the F1's. The observations on plant height, number of leaves, number of bulbs, weight of plant, weight of bulbs, day of maturity

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TABLE I Anaylsis of variance for combining ability (Seed to Bulb)

Source	Mean sum of squares							
	Morphological characters							
	Plant height (cm)	No. of leaves	No. of bulbs	Weight of plant (g)	Weight of bulb (g)	Days to maturity	Shape index	Bulb density
Hybrids	56.4393**	32.0983**	1.0534**	134.9546**	82.5678**	283.8742**	0.007929**	0.007072
Lines	44.0733**	32.7586**	0.6995*	261.7934**	153.9387**	290.4562**	0.005756**	0.009403
Testers	345.8550**	32.6830**	2.9293**	180.6470**	152.4780**	2460.2881**	0.010693**	0.008569
Line × Tester	30.4650**	31.7032**	1.0219**	66.4582**	39.1146**	38.7594**	0.008708**	0.005741
Error	1.9131	3.1376	0.1859	5.2361	3.2177	2.7281	0.001374	0.029306
Variance								
σ^2 GCA	5.0615	0.0313	0.0239	4.7619	3.5106	41.1265	—0.000015	0.000099
GCA lines	0.9072	0.0704	— 0.0235	13.0223	7.6549	16.7798	—0.005422	0.000244
GCA Testers	6.3078	0.0196	0.0381	2.2838	2.2673	48.4306	0.000040	0.000056
σ^2 SCA	5.7104	5.0971	0.1693	12.2445	0.4786	8.2972	0.001467	—0.004713
GCA/SCA	0.8864:1	0.0061:1	0.1412:1	0.3889:1	7.355:1	4.9567:1	0.0102:1	0.0210:1

shape index and bulb density were recorded on randomly selected 30 plants per replication and T. S. S. on the composite sample having one bulb from each of the selected plants. The magnitude of heterosis was worked out as per cent deviation over the estimated mid-parent (di), better parent (dii) and best parent (diii) values for bulb to bulb generation respectively. The mean of each cross was computed and the data were subjected to line×tester analysis. General combining ability effects of parents and specific combining ability effects of hybrids were worked out as suggested by Kempthorne (1957) for both seed to bulb and bulb to bulb generations. In the present paper the *gca* effects and *sca* effects of bulb to bulb generation alone were furnished.

RESULTS AND DISCUSSION

The variances due to hybrids, lines, testers and line × tester interactions were significant for all the characters except bulb density in seed to bulb generation. In bulb to bulb generation all sources of variances are highly significant except variances due to testers for T.S.S. and that is due to line x tester interactions for bulb density (Table I and II).

High mean expression was observed in line P1 for weight of plant, weight of bulbs, plant height, T.S.S. and shape index. Simlarly high mean expression was observed in line P10 for plant height, number of leaves, weight of plant and weight of bulbs. These were followed by line P5 in the mean expression for bulb yield and yield components like number of bulbs, weight of plant and TSS and low mean for days to maturity (earliness). Among the testers T1 recorded high mean expression for number of leaves, number of bulbs, weight of plant, weight of bulbs, shape index and low mean for days to maturity (Table III).

The higher mean expression of lines P1, P5 and P10 and tester T1 for the characters referred above for each parent coincided with higher and significant *gca* effects observed for these lines for the respective traits (Table IV).

High mean expression was observed in the hybrids P1 × T1 and P10 × T1 for most of the characters studied (Table V).

Higher expression was observed for di and dii estimates most in of the characters. Higher expression of heterobeltiosis was evident in P1 × T1 for plant height (10.52 per cent), number of leaves (15.34 per cent), number of bulbs (24.92 per cent), weight of plant (50.98 per cent), weight of bulbs (41.20 per cent), T.S.S (13.11 per cent) shape index (22.94 per cent) and negative value for days to maturity (-5.70 per cent). Similarly higher expression of heterobeltiosis was observed for P10 × T1 for number of leaves (29.54 per cent), number

TABLE II Analysis of Variance for Combining Ability (Bulb to Bulb)

Source	Mean sum of Squarers								
	Chatacters								
	Plant height (cm)	No. of leaves	No. of bulbs	Weight of plant (g)	Weight of bulbs (g)	Days to maturity	T.S.S.	Shape index	Bulb density
Hybrid	22.4248**	121.2500**	3.8793**	459.2449**	311.0303**	55.6310**	2.9675**	0.006376**	0.002936**
Lines	33.5665**	63.5000**	3.3267**	516.5455**	380.1692**	96.7764**	6.6072**	0.008910**	0.002616*
Testers	113.1029**	108.5700**	27.7200**	887.2717**	799.2619**	317.9821**	1.8865 NS	0.11407 **	0.018316**
Line x Tester	6.7786**	51.5300**	1.8400**	383.0360**	222.2128**	5.908 **	1.2683**	0.004549**	0.001387NS
Error	1.5563	14.5480	0./017	42.9500	24.8808	2.4644	0.5569	0.001336	0.001179
Variance									
σ^2 GCA	2.0480	4.1390	0.375	9.811	11.308	6.119	0.092	0.000017	0.00028
GCA lines	1.7860	14.1310	0.099	8.901	10.530	6.058	0.356	0.000291	0.000082
GCA Testers	2.1260	1.1410	0.458	10.085	11.541	6.241	0.012	0.000137	0.000339
σ^2 SCA	1.0440	7.3950	0.287	65.156	39.465	0.689	0.141	0.000641	0.000043
GCA/SCA	1.9616:1	0.5597:1	1.3066:1	0.1506:1	0.2865:1	8.9977:1	0.6524:1	0.0265:1	6.488:1

of bulbs (13.53 per cent), weight of plant (21.06 per cent), weight of bulbs (22.10 per cent) and earliness (-8 52 per cent). The highest heterobeltiosis was observed in P1 × T3 for plant height (25.70 per cent), in P9 × T2 for number of leaves (35.76 per cent), in P2 × T1 for number of bulbs (26.46 per cent), in P1 × T1 for weight of plant (50.98 per cent), and weight of bulbs (41.20 per cent), in P5 × T3 for T.S.S. (13.78 per cent), in P1 × T1 for shape index (22.94 per cent) and earliness was observed in P2 × T1 (-14.01 per cent). Significant and positive *sca* effects were observed in P1 × T1 for plant height (1.968), number of leaves (4.535) number of bulbs (0.940), weight of plant (8.604), weight of bulbs (6.360) and shape index (0.074) and negative effect for days to maturity (-1.354). Similarly significant and positive *sca* effects were observed for P10 × T1 for number of leaves (4.415), weight of plant (7 810) and weight of bulbs (7.200). Next in order was P5 × T2 (Table VI).

In the present material, the line P1 and P10 exhibited high *gca* effects and high mean expression for yield and yield components. Currence *et al* (1944) and Singh and Joshi (1966) have stressed the importance of *gca* effects for selection of parents. Kalloo *et al*. (1974) stated that array mean itself is enough to choose suitable combiners. But lines P1 and P10 combine both high *gca* effect and high mean, indicating their superiority as better combiners than other lines and testers.

The combination P1 × T1 exhibited positive values for all the three heterosis parameters namely di, dii and diii for the traits like plant height, number of bulbs, weight of plant, weight of bulbs, T. S. S. and shape index. The hybrid P10 × T1 exhibited positive values for the three heterosis parameters for number of leaves, weight of plant, number of bulbs and weight of bulbs. Exploitation of hybrid vigour in onion was common as reported by several workers like B"chvarov and Trifonov (1976) & Hosefield *et al*. 1976a, b and 1977 b Kazakova and Yakovlev (1974) Meer Vander and Van Bannikom (1973) and Peterson (1975). In the present material also hybrid vigour expression for yield and yield components even over the best parent available was exploited clearly, in general for most of the hybrids and P1 × T1 and P10 × T1, in particular.

A moderate Heterosis for earliness was observed in these two hybrids P1×T1 and P10×T1 (better than better parent only). But P5 × T1 and P5 × T2 were outstanding for their earliness recording negative values up to diii estimates. Similar results were reported for hybrids of common onion (Hosefield *et al*. 1977b and Todorov 1977). Both negative and positive heterosis were reported in F1 hybrids of onion (B"chvarov and Trifonov 1976) as was the case in the present material also.

TABLE III. Mean Performance of Parents

Parents		Number of leaves	Plant height (cm)	Number of bulbs	Weight of plant (g)	Weight of bulbs (g)	Days to maturity	TSS	Shape index	Bulb density
Lines										
CS 856-8	(P1)	31.22	30.60	5.40	58.10	53.78	75.4	15.6	0.424	0.910
CS 675-3	(P2)	39.04	36.20	5.92	66.36	49.04	83.8	14.6	0.427	0.921
CS 872	(P3)	34.62	34.04	6.46	59.80	49.88	81.8	17.2	0.427	0.879
CS 463	(P4)	33.96	33.32	5.88	54.00	46.16	84.0	15.3	0.455	0.916
CS 396	(P5)	39.32	36.46	6.26	62.20	54.12	75.2	15.6	0.421	0.893
CS 856-13	(P6)	31.68	31.22	6.40	61.68	52.98	85.0	16.4	0.424	0.911
CS 1094-34	(P7)	28.08	32.56	7.04	59.78	47.40	76.6	15.8	0.440	0.915
CS 421	(P8)	29.52	34.38	6.36	60.78	54.10	69.4	15.7	0.374	0.887
CS 854	(P9)	30.36	31.46	6.84	69.06	52.64	71.0	16.6	0.467	0.918
CS 665-51	(P10)	37.92	35.00	5.74	68.96	56.02	84.8	15.9	0.371	0.895
Testers										
Co 1	(T1)	34.16	34.02	6.50	61.24	50.14	84.0	14.8	0.449	0.921
CS 522	(T2)	32.44	28.96	7.00	62.98	55.76	70.2	16.0	0.448	0.942
F 1 of Co 1 × CS 522	(T3)	40.54	30.66	7.14	68.50	56.50	69.9	15.4	0.461	0.908

The estimate of *sca* effects is yet another way of assessing the value of hybrids apart from mean expression and heterotic performance. Hybrids which combine high expression of mean, hybrid vigour and high *sca* effects are reliable for considering them as hybrids with potential heterotic influence. Suc an analysis in this investigation indicated that significant and positive *sca* effects were observed in hybrids with high heterotic performance. Further these crosses involved parents with high expression of *gca* effect and high mean.

The hybrid P1 × T1 exhibited significant and positive sca effects for yield and yield components like number of leaves number of bulbs and shape index in bulb to bulb generation. The bybrid P10×T1 recorded significant *sca* effects for number of leaves, weight of plant and weight of bulbs. Next in order was P5 × T2 for *sca* effects.

Both *gca* and *sca* effects are important in the choice of desirable combinations (Gill *et al.* 1973). Again the combination P1 × T1 and P10 × T1 could be selected as the best as these hybrids involved parents with high mean expression and high *gca* for yield and important yield components. Similar results were reported for yield components in onion (Hosefield et *al.* 1976a, c 1977a and b).

The analysis of variances for combining ability indicated that, there existed significant differences among hybrids, lines, testers and line × tester interactions for the characters studied. The estimates of combining ability variances showed that the characters plant height, number of leaves, number of bulbs, weight of plant, shape index and T. S. S. were governed by non-additive genetic factors (SCA variance more than GCA variance) suggesting that these could be improved through heterosis breeding. The role of non-additive genetic factors for plant height was reported in common onion (Singh and Joshi 1966). The role of additive genetic factors was observed for weight of bulbs (yield) and days to maturity. Similar result was reportad in onion (Hosefield *et al.* 1977a). Hence improvement of these traits could also be possible by pedigree breeding. It was observed that, the *sca* effects of different crosses exhibited varying performance between seed to bulb and bulb to bulb generations for the characters studied, indicating the possibility of existing both additive and non-additive genetic factors in deciding these characters depending upon the parents involved.

The change in the magnitude of SCA variance for plant height, number of bulbs and bulb density between seed to bulb and bulb to bulb generations was reasoned to be due to genotype × environmental interactions (Hosefield *et al.* 1977 a). Similarly such change in GCA variance for weight of bulb (yield) between these two generations was due to

TABLE IV General Combining Ability Effects of Parents (Blub-Bulb)

Parents	Plant height (cm)	No. of leaves	No. of bulbs	Weight of plant (g)	Weight of bulbs (g)	Days to maturity	T.S.S.	Shape index	Bulb density
Lines									
P1	1.988**	—4.753**	0.060**	9.346**	9.226**	—0.348	0.575**	0.036**	—0.002
P2	0.742*	—1.893	—0.700**	—1.587	0.739	—0.501	—0.412*	0.011	0.007
P3	—0.672*	—4.873**	0.053	9.246**	4.066**	1.606**	0.466*	0.022*	0.020*
P4	0.068	—4.963**	0.040	—3.307	—4.408**	1.412**	—1.375**	0.099**	—0.008
P5	—1.698**	0.490	0.873**	—0.647	0.999	—4.806**	0.975*	0.019	0.005
P6	1.275**	0.077	—0.367*	—6.834**	—4.768	1.352**	0.382	—0.028	—0.024**
P7	—0.118	0.247	—0.573**	2.960	2.159	0.466	—0.405*	0.005	—0.007
P8	—1.545**	6.157**	—0.380*	—2.627	—4.341**	—2.168**	—0.285	—0.022*	0.013
P9	—2.052**	4.427**	—0.353*	—7.714**	6.961**	1.574**	0.035	—0.036**	0.009
P10	2.015**	5.087**	—0.053	1.160	3.286*	4.559**	0.048	-0.020	—0.010
SE (gi)	0.322	0.985	0.164	1.692	1.288	0.405	0.193	0.009	0.009
Testers									
T1	—0.861**	1.335*	0.520**	4.829**	4.613**	—0.779**	0.157	0.014**	0.018**
T2	—0.875**	0.247	0.280**	—2.957**	-2.459**	—2.041**	0.061	0.001	0.002
T3	1.737**	—1.581**	—0.800**	—1.867*	-2.155**	2.819**	—0.217*	0.015**	-0.020**
SE (gj)	0.176	0.539	0.090	0.927	0.705	0.222	0.106	0.005	0.005

TABLE V Mean performance of Hybrids

Cross	Plant height (cm)	No. of leaves	No. of bulbs	Weight of plant (g)	Weight of bulbs (g)	Days to maturity	T. S. S.	Shape index	Bulb density
P1 × T1	37.60	39.40	8.12	92.46	75.94	71.10	17.60	0.552	0.913
P2 × T1	33.58	33.40	8.22	70.58	56.94	72.06	16.40	0.427	0.839
P3 × T1	32.32	33.36	6.88	86.10	66.74	75.02	17.72	0.475	0.821
P4 × T1	32.10	32.04	6.72	68.04	53.40	74.98	15.12	0.446	0.895
P5 × T1	34.88	39.40	7.72	61.20	53.32	67.60	17.82	0.456	0.890
P6 × T1	34.94	40.36	6.84	72.38	58.30	75.80	17.84	0.389	0.875
P7 × T1	32.90	36.40	6.50	83.20	68.76	73.08	16.08	0.456	0.820
P8 × T1	30.68	43.60	6.42	67.32	52.22	70.04	16.92	0.404	0.915
P9 × T1	31.38	44.10	6.40	60.34	47.08	71.50	17.28	0.402	0.902
P10×T1	36.06	49.12	7.38	83.48	70.84	76.84	16.84	0.413	[illegible]
P1 × T2	33.35	29.34	5.52	74.20	61.20	73.32	17.90	0.395	0.888
P2 × T2	35.22	37.70	7.64	68.00	56.64	71.16	16.76	0.441	0.900
P3 × T2	33.44	35.34	6.78	70.22	52.58	73.40	16.32	0.450	0.899
P4 × T2	32.56	36.72	7.46	60.84	47.38	72.94	15.60	0.455	0.874
P5 × T2	32.32	40.00	8.64	83.86	66.76	66.16	17.68	0.459	0.916
P6 × T2	35.56	36.45	6.42	50.88	41.92	70.50	17.04	0.427	0.844
P7 × T2	33.94	36.98	6.28	65.40	51.92	71.80	17.00	0.458	0.861
P8 × T2	32.18	44.02	6.24	61.96	48.12	69.68	16.28	0.408	0.891
P9 × T2	31.14	44.04	6.96	57.90	[illegible]	69.76	16.56	0.385	0.913
P10×T2	36.60	44.72	6.86	74.04	59.72	76.66	17.52	0.409	0.890
P1 × T3	38.54	31.86	6.34	70.44	57.76	75.28	16.64	0.448	0.849
P2 × T3	36.94	33.08	6.04	65.72	55.86	76.00	16.02	0.443	0.877
P3 × T3	35.74	31.54	6.30	80.48	60.10	77.14	17.78	0.425	0.864
P4 × T3	33.76	31.20	5.74	70.26	53.22	77.03	15.56	0.411	0.861
P5 × T3	36.52	36.92	6.08	62.06	50.14	72.56	17.84	0.425	0.864
P6 × T3	36.94	38.28	5.44	65.30	52.70	78.50	16.98	0.383	0.863
P7 × T3	36.32	42.20	5.30	69.34	53.02	77.26	16.12	0.386	0.853
P8 × T3	36.02	45.70	6.00	71.90	53.66	74.5[illegible]	16.36	0.406	0.890
P9 × T3	34.34	33.98	5.33	67.68	52.68	74.70	16.68	0.380	0.867
P10×T3	[illegible]	36.26	5.40	56.02	46.52	80.92	16.20	0.400	0.831

TABLE VI Specific Combining Ability Effects of Hybrids (Bulb to Bulb)

Cross	Plant height (cm)	No. of leaves	No. of bulbs	Weight of plant (g)	Weight of bulbs (g)	Days to maturity	TSS	Shape index	Bulb density
P1 × T1	1.968**	4.535**	0.940**	8.604**	6.360**	—1.354**	0.063	0.074**	0.012
P1 × T2	—2.268**	—4.437**	—1.420**	—1.876	—1.308	2.126**	0.459	—0.070**	0.003
P1 × T3	0.300	—0.089	0.480	—6.726*	—5.052*	—0.772	—0.522	—0.004	—0.014
P2 × T1	—0.806	0.675	0.400	—2.343	—4.153	—0.241	—0.150	—0.026	—0.011
P2 × T2	0.848	1.063	0.060	2.857	2.619	0.141	0.306	0.001	0.006
P2 × T3	—0.044	—1.729**	—0.460	—0.513	1.535	0.101	—0.156	0.025	0.005
P3 × T1	—0.652	—1.385*	—0.233	2.344	2.320	0.512	0.290	0.011	—0.002
P3 × T2	0.482	1.633**	—0.153	—5.756	—4.768*	0.254	—1.014**	—0.001	—0.008
P3 × T3	0.170	—0.289	0.447	3.414	2.448	—0.863	0.724*	—0.009	0.011
P4 × T1	1.168*	—2.615**	—0.440	—3.163	—2.546	0.765	—0.464	—0.005	0.000
P4 × T2	—1.378*	3.153**	0.540	—2.583	—1.494	—0.012	0.112	0.017	—0.005
P4 × T3	0.210	—0.539	—0.100	5.747	4.042	—0.752	0.351	—0.011	0.005
P5 × T1	0.154	—0.708	—0.273	—12.663**	—8.033**	—0.394	—0.117	0.015	—0.018
P5 × T2	0.628	0.980	—0.887**	17.777**	12.479**	—0.572	—0.161	—0.011	0.024
P5 × T3	—0.784	—0.272	—0.613*	—5.113	—4.445	0.968	0.277	—0.006	—0.006
P6 × T1	0.021	0.665	0.087	4.704	2.714	1.646*	0.496	—0.025	—0.004
P6 × T2	0.655	—2.167**	—0.093	—9.016**	—6.594**	—2.392**	—0.208	0.026	—0.019
P6 × T3	—0.677	1.501**	0.006	4.314	3.882	0.748	—0.209	—0.001	0.022
P7 × T1	—0.626	—3.465	—0.047	5.730	6.247**	—0.188	—0.477	0.009	0.024
P7 × T2	0.428	—1.793**	—0.027	—4.290	—3.521	—0.206	0.539	0.024	—0.019
P7 × T3	0.196	5.251**	0.075	—1.440	—2.725	0.394	—0.063	—0.031	—0.005
P8 × T1	—1.419*	—2.175**	—0.320	—4.563	—3.793	—0.584	0.243	—0.015	—0.001
P8 × T2	0.095	—0.627	—0.260	—2.413	—0.821	0.308	—0.301	0.001	—0.009
P8 × T3	1.323*	2.841**	0.580*	6.707*	4.615*	0.288	0.057	0.016	0.010
P9 × T1	—0.212	0.055	—0.367	—6.456*	—6.313**	0.272	0.283	—0.004	—0.010
P9 × T2	—0.438	1.083*	0.433	—1.116	0.259	—0.206	—0.341	—0.008	0.017
P9 × T3	0.650	—1.149*	—0.067	7.574*	6.055**	—0.066	0.057	0.013	—0.007
P10 × T1	0.401	4.415**	0.313	7.810*	7.200**	—0.521	—0.170	—0.009	0.010
P10 × T2	0.955	1.103*	0.033	6.150	3.152	0.561	0.606	0.000	0.013
P10 × T3	—1.357*	5.529**	—0.347	—13.980**	—10.352**	—0.039	—0.436	0.008	—0.024
SE (ij)	0.558	0.539	0.283	2.931	2.231	0.702	0.334	0.016	0.015

** Significant at 1% level. * Significant at 5% level.

GCA × year interactions as these two generations were raised in different seasons (Hosefield *et al.* 1977 a).

The present study revealed that high mean expression, high *gca* effects were observed for parents P1, P10 and T1 for yield and important yield components indicating their use as appropriate parents in a crossing programme for further accumulation of favourable genes through recombinations. The hybrids P1 × T1 and P10 × T1 were found to be desirable for the purpose of exploitation of hybrid vigour because of combined expression of high mean, high heterotic performance, high *sca* effects and also the parents involved possessed high expression of *gca* effects.

The characters plant height, number of leaves, number of bulbs, weight of plant, shape index and TSS were appeared to be governed by non-additive genetic factors suggesting that these traits could be improved through heterosis breeding. The role of additive genetic factors was observed for weight of bulbs and days to maturity.

REFERENCES

B''CHAROV, S. and B. TRIFONOV. 1976. Breeding heterotic onion varieties for cultivation directly from seed in one year. *Gradinaisko i Lozarska Nauka* **13**: 75-82. *Pl. Breed. Abstr.* **47**: 790.

CURRENCE, T.M., R.E. LARSON and A.A. VITRA. 1944. A comparison of six tomato varieties as parents of F1 lines resulting from 15 possible crosses. *Proc. Amer. Soc. Hort. Sci* **45**: 349-52.

GILL, H. S., P. C. THAKUR and T. C. THAKUR. 1973. Combining ability in sweet pepper (*Capsicum annuum* L. Var. *grossum* Sendl.) *Indian J. agric. Sci.* **43**: 918-21.

HOSFIELD, G. L., G. VEST and C. E. PETERSON. 1976a. Heterosis and combining ability in a diallel cross of onion. *Hort. Sci.* **11**: 297.

HOSFIELD, G. L., G. VEST and C. E. PATERSON. 1976b. Comparative yields and environmental stability of F1 and 3 way crosses of onions. *Hort. Sci.* **11**: 298.

HOSFIELD, G. L., G. VEST and C. E. PETERSON. 1976c. A ten parent diallel cross to evaluate inbred line performance and combining ability in onions. *J. Amer. Soc. Hort. Sci.* **101**: 324-29.

HOSFIELD, G. L., G. VEST and C. E. PETERSON. 1977a. A seven parent diallel cross in onion to evaluate general and specific combining ability and their interactions with years and locations. *J. Amer. Soc. Hor. Sci.* **102**: 56-61.

HOSFIELD, G. L., G. VEST and C. E. PETERSON 1977b. Heterosis and combining ability in a diallel cross of onions. *J. Amer. Soc. Hort. Sci.* **102**: 355-60.

JOSHI, H.C. and J.P. TANDON 1976. Heterosis for yield and its genetic basis in onion. *Indian J. agric Sci.* **46**: 88-92.

KALLOO, R. K., SINGH and R. D. BUTANI. 1974. Combining ability studies in tomato. *Lycopersicon esculentum* Mill. *Theoret. Appl. Genet.* **44**: 358-63.

KAZAKOVA, A. A. and G. U. YAKOVLEV. 1974. Expression of heterosis in onion hybrids produced on male sterile basis. *Genetike i Selektsii* **49**: 268-80. *Pl. Breed. Abstr.* **44**: 221.

KEMPTHORNE, O. 1957. *Introduction to Genetical Statistics* John Wiley and Sons, Inc., New York, pp. 468-70.

MEER VANDER and J.L. VAN BANNIKOM. 1973. Parental lines for onion hybrids. *Zaadbelangen* **26** : 225-26. *Pl. Breed. Abst.* **43** : 4663.

PETERSON, C. E. 1973. Utilizing cytoplasmic male sterility in development of hybrid onions and carrots. *Eucarpia Section Horticole* **7**. 18. *Pl. Breed. Abst.* **43** : 717

SINGH, S. P. and A. B. JOSHI. 1966. Line × tester analysis in relation to breeding for yield in linseed. *Indian J. Genet. Pl. Breed.* **26** : 117-94.

TODOROV, I. 1977. Inheritance of length of growth period and keeping quality in some F1 hybrids of onion. *Genetike i Selektsii* **10** : 192-98. *Pl. Breed. Abst.* **48** : 1704.