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COMBINING ABILITY STUDIES FOR YIELD AND YIELD ATTRIBUTING CHARACTERS IN CUCUMBER (*CUCUMIS SATIVUS* L.)

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ABSTRACT

Estimation of combining ability pattern among the eleven local cucumber types crossed in line x tester (3 x 8) pattern were done and it was observed that both additive and non-additive gene actions were operating for all the characters under study because variance due to general combining ability (*gca*) and specific combining ability (*sca*) were highly significant. Variance due to *sca* were higher than *gca* for all the traits except vine length indicating the predominance of non-additive genes effects (which can be utilized for hybrid developement) on governing the expressions of most of the characters.The line, BGM (0.170) was found to be the best general combiner for yield per vine along with testers like PCO-2 (0.1261), PCL-1 (0.122), White Long (0.101) and Priya (0.069). So these local types can be used as parents for hybrid development. The hybrids HS x DWD-1 (0.449), BGM x PCL-1 (0.428), BGM x Priya (0.378) and HYD x Pusa Sanyog (0.359) were showing best *sca* effects for fruit yield per vine respectively. These crosses were also showing significant positive *sca* effects for directly yield attributing character of number of fruits per vine hence these crosses can be directly advanced in hybrid development programme.

INTRODUCTION

Cucumber (*Cucumis sativus* L.) is one of the most important and popular vegetables of the family Cucurbitaceae, with chromosome number 2n = 14. Low fruiting ability and yield suppression due to its inherent fruiting habits are major factors limiting fruit yield in slicing and processing cucumbers. Development of high yielding varieties chiefly depends upon genetically superior parents, along with appropriate breeding methodology. Combining ability analysis is one of the important and powerful tools available for the estimation of combining ability effects as reported by Rabou and Hameed(2011), Mule *et al.* (2012), Krishna Reddy *et al.* (2014) and Golabadi *et al.* (2015) in cucumber. Selection of parents for hybridization has to be based on the complete genetic information and potential of suitable parents. Identification and selection of flexible parental lines are required to be used in any hybridisation programme to produce genetically modified and potentially rewarding germplasm by assembling fixable gene effects more or less in a homozygous line (Singh *et al*., 2013 and Potla *et al*., 2013).The combining ability analysis gives an indication of the variance due to *gca* and *sca*, which represent a relative measure of additive and non-additive gene actions, respectively. It is an established fact that dominance is a component of non-additive genetic variance (breeding value). This also thus helps in selecting superior parents and crosses for further exploitation of heterosis. Such studies in cucumber are very few.

Especially in Northern Karnataka, lots of local type cucumbers are grown which are popular among the people as compared to other types of cucumbers. But these varieties are having very higher sex ratio of 20-30:1 and very late female flower emergence. So there is an urgent need for improving these local cultivars through use of breeding program to boost the yield of this crop. Therefore the experiment was conducted to identify the best combiners among the existing germplasm for different quantitative characters in (3 x 8) line x tester set for formulation of a sound breeding programme in local type cucumbers form North Karnatakafor exploiting heterosis.

MATERIALS AND METHODS

The experiment was conducted at Main Agricultural Research Station (MARS), Dharwad farm under University of Agricultural Sciences, Dharwad during 2015. The experimental materials consisted of eleven genotypes selected from vegetable block of Division of Horticulture, College of Agriculture, Dharwad based on their performance in the previous seasons. Out of eleven genotypes, three were used as lines (female parents) *viz.*Belgaum Local (BGM), Hot Season (HS) and Hyderabad (HYD) and eight were used as testers (male parents) *viz.* Pusa Sanyog, Priya, PCO-2, DWD-1, PCL-1, DWD-2, PCR-1 and White Long. Lines were crossed with testers to give rise to hybrids in line x tester model as suggested by Kempthorne (1957) to produce twenty four hybrids for studying combining ability of different characters under study. The parents and F_1 hybrids were grown during *Kharif* season of 2015-16 for further study.The seeds were sown in a randomized complete block design (RCBD) with two replications. The distance between plants to plant was kept at 90 cm whereas row to row distance was 2 m. All recommended agronomic and intercultural practices were carried out thoroughly. During crop growth, the data for different characters such as days for first female flower,node number of first female flower,days to first fruit picking,number of total fruits per vine,total fruit yield per vine, fruit yield per hectare, average fruit weight,vine length, number of branches per vine,internodal length and sex ratio were recorded. Combining ability analysis for the F_1 hybrids was based on the procedure developed by Kempthorne (1957).

RESULTS AND DISCUSSION

Analysis of variance for combining ability was carried out for all the characters and results are presented in Table 1. The variances due to female parents were significant for nine characters out of fifteen characters. The variances due to male parents were significant for only one character. The variances due to line x tester were significant for thirteen characters out of fifteen characters studied. The estimates of *gca* effects for parents are presented in Table 2and *sca* effects are presented in Table 3**.**

From the analysis of combining ability estimates, it was observed that both additive and non-additive gene actions were operating for all the characters under study because variance due to general combining ability (*gca*) and specific combining ability (*sca*) were highly significant. Further it was observed that variance due to *sca* were higher in magnitude than *gca* for all the traits except vine length. Thus, it supports the predominance of non-additive genes effects on governing the expressions of most of the characters. (Table 1)

The line Belgaum Local (0.17) and tester PCO-2 (0.126) were found to be the best general combiners for fruit yield per vine among the lines and testers respectively. The line Belgaum Local (2.148) and tester White Long (1.084) showed highest significant positive *gca* effects for number of fruits per vine among the lines and testers respectively. The hybrid HS x DWD-1 (0.449) was found to be showing best *sca* effects for the trait fruit yield per vine, followed by BGM x PCL-1 (0.428), BGM x Priya (0.387) and HYD x Pusa Sanyog (0.359). These crosses were also showing significant positive *sca* effects for directly yield attributing character of number of fruits per vine. All of these crosses except BGM x PCL-1 were showing significant positive *sca* effects for number of branches per vine. HS x DWD-1 and HYD x Pusa Sanyog were showing significant negative *sca* effects for sex ratio (Table 3). These reasons may be the causes of high *sca* effects shown by these crosses for fruit yield. Among the parents involved in these crosses BGM, Priya and PCL-1 were found to be the good general combiners for traits like number of fruits per vine, fruit yield and sex ratio (Table 2), which might be contributing to the superior *sca* effects for yield shown by the crosses involving these parents. DWD-1 was showing superior *gca* effects for fruit yield which might be the reason of superior *sca* effect shown by the cross HS x DWD-1. These are in accordance with the results shown by Hanchinamani and Patil (2009), Singh *et al.* (2010), Kumar *et al.* (2011), Kushwaha *et al.* (2011), Rabou and Hameed (2011), Mule *et al.* (2012), Krishna Reddy

Table 1: ANOVA for combining ability study in cucumber

Characters	Mean sum of squares			σ^2 *gca*	σ^2 *sca*	σ^2 *gcal*	σ^2 *sca*
Sources	Line effect	Tester effect	L x T effect	Error			
Degrees of freedom	2	7	14	23			
Days to first male flower	125.17**	4.786	14.672 **	3.13	5.600**	5.648**	0.992
Days to first female flower	259.013*	16.874	43.212 **	7.486	11.961*	18.420**	0.649
Node number of first male flower	1.418	0.26	0.669	0.319	0.05	0.188*	0.264
Node number of first female flower	1.634	1.367	1.156**	0.251	0.119	0.481**	0.247
Days to first fruit picking	108.063*	40.247	21.193 **	0.935	6.665**	10.177**	0.655
Number of total fruits per vine	64.243*	13.45	13.095 **	0.459	3.485**	6.291**	0.554
Total fruit yield per vine	0.362	0.133	0.207**	0.043	0.019	0.085**	0.225
Fruit yield per hectare	1121.523	411.84	641.759 **	131.213	59.432	264.413**	0.225
Fruit length	71.504*	12.855	14.528 **	2.012	3.669**	6.356**	0.577
Fruit girth	16.762*	2.096	2.77**	0.664	0.808**	1.119**	0.722
Average fruit weight	6597.664*	3340.993	1683.007 **	11.045	450.727**	835.837**	0.539
Vine length	26510.56**	5794.908*	1880.743 **	537.42	1415.473**	649.107**	2.181
Number of branches per vine	168.35**	11.2	23.844 **	4.474	7.819**	10.035**	0.779
Internodal length	1.145	0.503	0.431	0.31	0.053*	0.095	0.559
Sex ratio	17.366	11.571	4.91**	1.378	1.196**	1.799**	0.665

*→Significant at 5% level, **→Significant at 1% level

Table 2: General combining ability of male and female parents for 15 characters in cucumber

	Days to first male flower	Days to first female flower	Node no. of first male flower	Node no . of first female flower	Days to first fruit picking	No. of fruits/ vine	Fruit yield / vine	Fruit yield per hectare	Fruit length	Fruit girth	Fruit weight	Vine length	No. of branches /vine	Intern-odal length	Sex ratio
LINES (FEMALE PARENTS)															
BGM	-2.813 **	-4.619 **	-0.265 **	-0.347 **	-2.688 **	2.148 **	0.170 **	9.468	-1.022 **	-0.815 **	-23.435 **	36.837	2.174 **	-0.204 **	-0.248 **
HS	2.781 **	2.744 *	0.322 **	0.283 **	0.188	-1.819 **	-0.116 **	-6.425 **	-1.409 **	1.149 **	12.402 **	-43.701 **	-3.729 **	-0.099 **	-0.895 **
HYD	0.031	1.875 *	-0.058 **	0.064 *	2.500 **	-0.329 **	-0.054 **	-3.040 **	2.431 **	-0.334 **	11.032 **	6.864	1.555 *	0.303 **	1.144 **
CD@5%	0.95	1.305	0.279	0.227	0.473	0.37	0.099	5.49	0.696	0.38	1.741	12.481	1.004	0.254	0.592
TESTERS (MALE PARENTS)															
PusaSanyog	0.542	1.35	-0.082 **	-0.257 **	-3.813 **	-2.816 **	-0.274 **	-15.23 **	0.333	1.154 **	28.656 **	-39.430 **	-1.619 **	0.221 *	2.544 **
Priya	0.625	1.733	0.098	0.360 **	-0.896 **	0.646 *	0.069 **	3.867	2.540 **	-0.270 **	21.861 **	-1.003 **	2.058	-0.229 **	-0.385 **
PCO-2	1.292	1.9	0.253 *	-0.057 **	-1.313 **	1.181 **	0.126 **	7.034	1.115	-0.095 **	-7.850 **	-3.403 **	0.648	0.084	-1.431 **
DWD-1	-1.542 **	-2.450 **	-0.247 **	-0.857 **	4.354 **	-0.879 **	0.042 *	2.329	0.388	0.177	-3.902 **	-11.963 **	-0.998 **	-0.571 **	0.889
PCL-1	-0.542 **	-1.817 **	-0.331 **	-0.385 **	-1.563 **	1.852 **	0.122 **	6.77	-1.112 **	-0.885 **	-32.932 **	-33.480 **	-1.094 **	0.071	-1.296 **
DWD-2	-0.708 **	0.683	0.219 *	0.243 *	-0.479 **	-0.564 **	-0.004 **	-0.263 **	0.06	0.195	27.363 **	26.587	1.806	0.232 *	-0.026 **
PCR-1	0.208	-1.200 **	0.031	0.476 **	2.688 **	-0.503 **	-0.181 **	-10.08 **	-2.039 **	0.129	-24.894 **	56.42	-0.303 **	-0.098 **	0.93
White Long	0.125	-0.200 **	0.059	0.476 **	1.021 *	1.084 **	0.101 **	5.572	-1.284 **	-0.405 **	-8.302 **	6.27	-0.498 **	0.291 *	-1.223 **
CD@5%	1.551	2.131	0.456	0.371	0.773	0.605	0.161	8.97	1.138	0.62	2.843	20.38	1.64	0.415	0.967

*→Significant at 5% level, **→Significant at 1% level;BGM – Belgaum local ; HS – Hot season ;HYD - Hyderabad

et al. (2014) and Golabadi *et al.* (2015) in cucumber.

The maximum negative *gca* effects were observed in line Belgaum Local (-4.619) and testers DWD-1 (-2.450) for days to first female bloom. The maximum negative *gca* effects was observed in DWD-1 (-0.857) and Belgaum Local (-0.347) for node of first female bloom, among the lines and testers respectively. For days to first fruit picking, maximum negative *gca* effects was observed in tester Pusa Sanyog (-3.813) followed by the line Belgaum Local (-2.688). For earliness character of days to first fruit picking, hybrids BGM x Pusa Sanyog (-7.063) followed by HS x DWD-1 (-3.354), HYD x DWD-2 (-3.333) and BGM x PCL-1 (-2.063) showed the best *sca* effects. These crosses were found to be the good specific combiners for days to first female flower which is also an indirect contributor of earliness (Table 3). The parents involved in these crosses BGM, Pusa Sanyog and PCL-1 were found to be good general combiners for almost all the earliness characters like days to male and female flower, node number of first male and female flower and days to first fruit picking and this might be the reason of the superior *sca* effects shown by crosses involving them. In the other two crosses *i.e.* HS x DWD-1 and HYD x DWD-2, the male parents DWD-1 and DWD-2 were found to good general combiners for different earliness characters thus contributing to the superior combinations of the hybrids (Table 19). The results are in accordance with the results shown by Hanchinamani and Patil (2009), Kumar *et al.* (2011) and Krishna Reddy *et al.* (2014) in cucumber.

For all the characters studied, the best general combiner among the lines was BGM. Among the testers Priya, PCO-2, PCL-1 and DWD-1 were found to be the best general combiners for overall characters (Table 4). Likewise the crosses that showed high specific combining ability overall for different characters studied, include BGM xPriya[H(Higher) x H(Higher)], BGM x PCO-2(H x H), HS x DWD-1[L(Lower) x H(Higher)], HS x PCR-1[L(Lower) x L(Lower)], HS x White Long(L x L), HYD xPusa Sanyog(L x L), HYD x PCO-2(L x H), HYD x PCR-1(L x L) and HYD x White Long(L x L).Significant *sca* effect may be due to the involving the parents showing H x H, L x H, L x H and L x L status (Table 5). Heterosis (high *sca*) in the crosses involving high x high general combiners might be due to additive x additive type of interaction which is partially fixable. High *sca* effects in the crosses involving low x low combining parents were possibly due to intra and inter allelic interactions.The *sca* involving H x H combination could be used in developing of the varieties to exploit additive gene action by pedigree whereas, the crosses involving the combination of L x L could be used for exploitation of heterosis by recurrent selection. According to Rawlings and Thompson (1962) *sca* effect is due to genes with dominance and epistatic effect. A comparison of the *sca* effects of the crosses and the *gca* effects of the parents were not related to the *sca* effects of their crosses. Higher *gca* of parent does not necessarily confer higher *sca* and the *gca* and *sca* were independent (Khan *et al*., 2007b).

A comparison of *sca* effects of the crosses and *gca* effects of the parents involved indicated that in most of the cases, *gca* effects were reflected in the *sca* effects of the cross combination. The F_1 hybrids showed promising results when at least one of the parental lines exhibiting high *gca* effect for yield and its

Table 3: Specific combining ability of F_1 hybrids for 15 characters in cucumber

Crosses	Days to first male flower appearance	Days to first female flower appearance	Node number of first male flower	Node number of first female flower	Days to first fruit picking	No of fruits per vine	Fruit yield per vine	Fruit yield per hectare
BGM X PusaSanyog	-4.604 **	-7.931 **	-0.262	-0.920 **	-7.063 **	-2.250 **	-0.355 *	-19.818 *
BGM X Priya	0.313	-3.315	0.308	0.963 **	0.771	2.389 **	0.387 **	21.565 **
BGM X PCO-2	-2.354	-1.981	-0.182	-0.62	-1.313	1.084 *	0.22	12.348
BGM X DWD-1	1.979	4.369 *	0.738	0.18	3.271 **	-4.246**	-0.512 **	-28.447 **
BGM X PCL-1	-0.521	0.885	0.071	-0.127	-2.063 **	4.752 **	0.428 **	23.767 **
BGM X DWD-2	2.646	0.235	0.021	1.080 **	2.604 **	-1.181 *	0.025	1.365
BGM X PCR-1	2.229	4.119 *	-0.125	-0.653 *	1.438 *	-0.308	-0.143	-7.98
BGM X WHITE LONG	0.313	3.619	-0.569	0.097	2.354 **	-0.24	-0.05	-2.8
HS X PUSASANYOG	3.052 *	1.706	0.316	0.201	4.313 **	-0.048	-0.004	-0.135
HS X PRIYA	0.219	2.973	-0.144	-0.016	-0.604	-1.124 *	-0.223	-12.427
HS X PCO-2	1.302	0.156	-0.099	0.751 *	2.313 **	0.001	-0.014	-0.874
HS X DWD-1	-3.115 *	-4.244 *	-0.769	-0.449	-3.354 **	3.431 **	0.449 **	24.941 **
HS X PCL-1	-2.615	-4.127 *	-0.686	0.329	0.063	-3.131 **	-0.356 *	-19.775 *
HS X DWD-2	-0.448	5.023 **	0.414	-0.249	0.729	0.386	-0.054	-3.017
HS X PCR-1	0.885	-0.244	0.873 *	-0.283	-1.938 **	-0.526	0.017	0.973
HS X WHITE LONG	0.719	-1.244	0.094	-0.283	-1.521 *	1.012	0.186	10.313
HYD X PUSASANYOG	1.552	6.225 **	-0.054	0.719 *	2.750 **	2.297 **	0.359 *	19.954 *
HYD X Priya	-0.531	0.342	-0.164	-0.947 **	-0.167	-1.264 *	-0.164	-9.138
HYD X PCO-2	1.052	1.825	0.281	-0.131	-1	-1.084 *	-0.206	-11.475
HYD X DWD-1	1.135	-0.125	0.031	0.269	0.083	0.816	0.063	3.505
HYD X PCL-1	3.135 *	3.242	0.614	-0.202	2.000 **	-1.621 **	-0.072	-3.991
HYD X DWD-2	-2.198	-5.258 **	-0.436	-0.831 *	-3.333 **	0.796	0.029	1.652
HYD X PCR-1	-3.115 *	-3.875 *	-0.747	0.936 **	0.5	0.834	0.126	7.007
HYD X White Long	-1.031	-2.375	0.474	0.186	-0.833	-0.773	-0.136	-7.513
CD @ 5%	2.687	3.692	0.79	0.642	1.34	1.047	0.28	15.54

*→Significant at 5% level, **→Significant at 1% level;BGM – Belgaum local; HS – Hot season;HYD – Hyderabad

Table 3: Cont....

Crosses	Fruit length	Fruit girth	Fruit weight	Vine length	No of branches per vine	Internodal length	Sex ratio
BGM X PUSASANYOG	-0.706	1.023	26.401 **	-44.237 *	-5.524 **	-0.259	0.848
BGM X PRIYA	-0.093	0.887	-0.439	35.167	3.879 **	-0.494	-1.468
BGM X PCO-2	0.482	-0.533	7.708 **	-23.263	2.959 *	-0.268	0.368
BGM X DWD-1	-1.371	-0.540	-22.290 **	13.997	-0.646	0.212	1.948 *
BGM X PCL-1	0.174	-0.073	4.490	3.863	0.266	-0.289	-1.552
BGM X DWD-2	1.467	1.527 **	18.395 **	32.997	3.051 *	0.429	-0.952
BGM X PCR-1	-0.534	-0.407	-5.349 *	0.663	-3.091 *	0.474	1.047
BGM X WHITE LONG	0.581	-1.883 **	-28.915 **	-19.187	-0.896	0.196	-0.24
HS X PUSASANYOG	-2.735 **	0.245	-17.936 **	19.551	1.879	0.191	1.055
HS X PRIYA	-0.666	-0.672	4.409	-0.626	-2.748	0.071	0.709
HS X PCO-2	-3.036 **	-0.087	-24.499 **	-1.896	-2.088	0.682	-0.965
HS X DWD-1	5.435 **	-0.794	-14.302 **	22.084	4.757 **	-0.288	-2.850 **
HS X PCL-1	-1.095	-0.167	-14.212 **	16.001	0.684	0.531	-0.025
HS X DWD-2	1.499	-0.197	36.803 **	-23.466	-1.551	-0.616	0.605
HS X PCR-1	0.872	1.175 *	26.014 **	-21.299	-0.688	-0.151	0.409
HS X White Long	-0.273	0.498	3.723	-10.349	-0.243	-0.419	1.062
HYD X PUSASANYOG	3.441 **	-1.268 *	-8.466 **	24.686	3.645 *	0.069	-1.904 *
HYD X PRIYA	0.759	-0.215	-3.971	-34.541	-1.131	0.424	0.76
HYD X PCO-2	2.554 *	0.62	16.791 **	25.159	-0.871	-0.415	0.596
HYD X DWD-1	-4.064 **	1.334 *	36.593 **	-36.081 *	-4.111 **	0.075	0.901
HYD X PCL-1	0.921	0.24	9.723 **	-19.864	-0.950	-0.241	1.576
HYD X DWD-2	-2.966 **	-1.330 *	-55.197 **	-9.531	-1.500	0.187	0.346
HYD X PCR-1	-0.338	-0.768	-20.666 **	20.636	3.779 *	-0.323	-1.455
HYD X White Long	-0.308	1.385 *	25.193 **	29.536	1.139	0.224	-0.822
CD @ 5%	1.971	1.075	4.924	35.300	2.841	0.719	1.674

*→Significant at 5% level, **→Significant at 1% level;BGM – Belgaum local; HS – Hot season;HYD - Hyderabad

component traits were involved in the crosses. This indicated that there was strong tendency of transmitting the higher gain from parents to offspring. The results are in conformity with the findings of Batakurki *et al*. (2011), Brar *et al*. (2011), Chirani *et al*. (2011), Kumar *et al*. (2011), Sarkar and Sirohi (2010) and Singh *et al*. (2012).

Overall it could be concluded that among the 24 hybrids, the top four hybrids namely BGM x PCL-1 BGM x Priya, BGM x PCO-2 and HS x DWD-1 were regarded as superior F_1 hybrids for yield and yield contributing characters. Therefore these

Table 4: Overall analysis of general combining ability status of the parents

Parents	Number of characters for which *gca* is in Desirable direction	Undesirable direction	Overall *gca* status
BGM	10	3	H
HS	4	10	L
HYD	4	9	L
PusaSanyog	5	7	L
Priya	8	2	H
PCO-2	5	4	H
DWD-1	6	5	H
PCL-1	8	5	H
DWD-2	4	6	L
PCR-1	2	8	L
White Long	4	7	L

BGM – Belgaum local HS – Hot season HYD – Hyderabad, (A – Average, H – High, L – Low)

Table 5: Overall analysis of specific combining ability shown by crosses

Crosses	Number of characters for which *sca* is in Desirable direction	Undesirable direction	*sca* statusof crosses	Status of crosses (showing *gca* effects of parents involved)
BGM X PusaSanyog	5	5	A	H x L
BGM X Priya	4	1	H	H x H
BGM X PCO-2	3	0	H	H x H
BGM X DWD-1	0	7	L	H x H
BGM X PCL-1	1	3	L	H x H
BGM X DWD-2	3	3	A	H x L
BGM X PCR-1	1	3	L	H x L
BGM X White Long	0	3	L	H x L
HS X PusaSanyog	0	4	L	L x L
HS X Priya	0	1	L	L x H
HS X PCO-2	0	4	L	L x H
HS X DWD-1	9	1	H	L x H
HS X PCL-1	1	4	L	L x H
HS X DWD-2	1	1	A	L x L
HS X PCR-1	3	1	H	L x L
HS X White Long	1	0	H	L x L
HYD X PusaSanyog	6	5	H	L x L
HYD X Priya	1	1	A	L x H
HYD X PCO-2	2	1	H	L x H
HYD X DWD-1	2	3	L	L x H
HYD X PCL-1	1	3	L	L x H
HYD X DWD-2	3	3	A	L x L
HYD X PCR-1	3	2	H	L x L
HYD X White Long	2	0	H	L x L

BGM – Belgaum local ; HS – Hot season HYD – Hyderabad (A – Average, H – High, L – Low)

hybrids can be commercialized among the cucumber growers of this locality.

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