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Combining ability studies in cucumber (*Cucumis sativus* L.) in mid hills of Himachal Pradesh

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Abstract
For the development of superior hybrids, estimates of general combining ability of parents and specific combining ability of the crosses help in proper selection of parents for hybridization. The high estimates of gca were exhibited by K-90, G_2 and Gyn_1 for most of the characters. In general, there was a close agreement between gca effects and per se performance but in certain cases, it did not hold good which may be due to higher degree of gene action involved. The superior cross combinations which recorded high sca estimates and per se performance for yield and number of fruits were K-90 x G_2 and K-90 x Gyn_1 and hence, may be exploited for the development of F_1 hybrid (s) after testing their performance at multi-locations for 2-3 years.

Keywords: Cucumber, *Cucumis sativus*, gca, sca, hybrids

Introduction
Cucumber (*Cucumis sativus* L.), a member of family Cucurbitaceae is grown as summer and rainy season crop in low and mid hills of North-Western Himalaya from April to August and fruits are available from June to October to the plains. The crop raised in the hills being of high quality and off-season brings good returns to the growers.
F_1 hybrids in cucumber as in many vegetable crops have several well known advantages over open-pollinated varieties and hence, provide a scope for the breeder to find out more appropriate combination to develop superior hybrids. The F_1's are early, vigorous, high yielding, tolerant to diseases and insect-pests and more efficient in the use of water and fertilizers. Currently, the farmers are purchasing hybrid seeds from the private firms, who are charging exorbitantly. To tide over the situation, there is a need to make concentrated efforts to develop F_1 hybrids and making their seed available to the farmers at a reasonable price. For the development of superior hybrids, estimates of general combining ability of parents and specific combining ability of the crosses help in proper selection of parents for hybridization. Moreover, use of gynoecious lines for developing cucumber hybrids makes the production of F_1 seed more cost effective.

Materials and Methods
The present investigations were carried out at Experimental Farm of the Department of Vegetable Crops, Dr Y S Parmar University of Horticulture and Forestry, Nauni, Solan (HP) which is 1276 m a.m.s.l. All the parents except two gynoecious lines were of monoecious type. Crosses among eight parents were attempted in a half-diallel fashion. The material comprised of eight parents, twenty eight F_1s and one check (Pusa Sanyog) was sown in Randomized Block Design with three replications. Spacing was 1.25x1.00 m. Data were recorded on randomly selected plants for yield and horticultural characters. Griffing's [7] method II model I was used for deriving general and specific combining ability estimates. The analysis of variance for combining ability was based on following mathematical model:

$$P_{ijk} = m + g_{ii} + g_{jj} + s_{ij} + b_k + e_{ijk}$$

Where,
P_{ijk} = phenotypes of the hybrids between i th and j th parents in k th plots
m = population mean
g_{ii} = GCA effects of i th parent
g_{jj} = GCA effects of j th parent
s_{ij} = SCA of the crosses between i th and j th parents
b_k = block effects
e_{ijk} = environmental effect associated with ijk th observation

Results and Discussion

Analysis of variance (Table 1) for combining ability revealed that importance of gca (σ^2g) was more than sca (σ^2s) indicating the preponderance of additive gene action for days to first female flower appearance and days to marketable maturity. However, in all the other traits, sca component was higher in magnitude than gca one's indicating the preponderance of non-additive gene effects in conformity with the findings of Naik *et al.* [12]. However, mean sum of squares for gca and sca were highly significant for all the characters except TSS suggesting the importance of both additive and non-additive genetic variance in consonance with the findings of Ene *et al.* [5]; Om *et al.* [13]; and Pradhan *et al.* [14].

The parents *viz.* G_2, Gyn_1 and Poinsette had negative estimates for days to first female flower appearance and node at which first female flower appears showing earliness in fruit bearing and were good general combiners for these characters. Among F_1's, the sca effects were significantly negative in 12 and 15 crosses, respectively for these two traits. The crosses LC-11 x Gyn_1 (poor x high) and EC 173934 x LC-40 (poor x poor), respectively had highest sca effect for these traits. The parents *viz.* G_2 and Gyn_1 with significantly high gca estimates (with negative value) were good general combiners for days to marketable maturity. Crosses *viz.* LC-11 x Gyn_1, EC 173934 x LC-40, K-90 x G_2 and K-90 x EC 173934 had high sca estimates involving poor x high, medium x high and medium x poor general combining parental lines, respectively. El-Shawaf and Baker [3]; Om *et al.* [13]; and Wang and Wang [16] also reported greater additive genetic variance for days to marketable maturity. However, Malav *et al.* [11] reported the preponderance of non additive genes for this trait. The parents *viz.* G_2 and Gyn_1 may be used in the hybridisation programme for developing early hybrids. LC-11 x Gyn_1 and EC 173934 x LC-40 may be exploited as early hybrids after further multilocational testing. These crosses may also be exploited to produce transgressive segregants in advanced generations.

For fruit length, the parents Gyn_1, LC-11 and K-90 were good general combiners which was evident from their high gca estimates. 14 crosses exhibited significant sca effects. The sca effects were high in crosses Poinsette x LC-40 and G_2 x Poinstte involving poor x poor general combiners. K-90, K-75 and EC 173934 had highest gca with respect to fruit width and hence were good general combiners. The sca effect was maximum in G_2 x Gyn_1 involving poor x poor general combining parental lines. Hormuzdi and More [9]; and Kupper and Staub [10] reported contrasting results for fruit length and width.

The best general combiners for TSS in order of merit were EC 173934 and LC-40. Among 28 specific combinations, 16 crosses exhibited positive sca effects being maximum in K-90 x Poinsette and Poinsette x K-75 involving poor x poor general combiners. For flesh to seed cavity ratio, the best general combiners were Poinsette, EC 173934 and Gyn_1. Cross combination K-90 x K-75 had maximum sca among seven significant and positive specific combinations. In contradiction to the present results, importance of additive gene action for flesh to seed cavity was reported Dogra [1].

The parents LC-11, K-90 and K-75 depicted high *per se* performance w.r.t. fruit weight as evident from their high gca effect. These parents had maximum concentration of favourable genes for increasing fruit weight. Eleven specific cross combinations were having significantly positive sca effects being maximum in K-90 x LC-11 (high x high) and K-90 x EC 173934 (high x poor). Non-additive gene action for fruit weight was also obtained Ghaderi and Lower [6]; Malav *et al.* [11] in consonance with the present findings. However, Gyn_1 and G_2 were identified as good general combiners for number of fruits per plant. The top specific combination in order of merit were K-90 x G_2, K-90 x Gyn_1 and K-75 x Gyn_1 involving medim x high, medium x high and poor x high general combiners, respectively. Importance of non additive gene action for number of fruits per plant was also reported Dogra [1]; Ghaderi and Lower [6]; and Om *et al.* [13]. However, the present results w.r.t fruit weight and number of fruits are contrary to the findings of El Hafeez *et al.* [3] which may be due to difference in the parental material used for making diallel crosses.

For yield per plant, K-90 was the best general combiner in addition to Gyn_1 and G_2. The sca effects were high for K-90 x G_2 (high x high), K-90 x Gyn_1 (high x high) and LC-11 x Gyn_1 (poor x high). Present results on yield per plant were similar to the earlier findings of Dolgibh and Sidorova [2]; Ghaderi and Lower [6]; Om *et al.* [13]; and Wang and Wang [16] but in contradiction to the Gu *et al.* (8). F_1 hybrid exhibited promising results when at least one of the parents with high gca for yield and contributing traits have been used in crosses thereby indicating the strong tendency of transmitting high potential from parents to off-springs Pradhan *et al.* [14]. The parents such as G_2, Gyn_1 and LC-40 had negative gca effects and were considered good general combiners for internodal length. Nine specific combinations had significant negative value being maximum in K-90 x Poinsette and Poinsette x EC 173934 involving poor x poor general combiners.

K-90, G_2 and Gyn_1 may be used in hybridisation for developing high yielding hybrids with more number of fruits per vine, long fruits and high TSS. Apparently, parents with good gca effect may be presumed to possess more favourable genes for the concerned traits. [Tiwari and Singh] [15]. The crosses *viz.* K-90 x G_2 and K-90 x Gyn_1 can be released as hybrids after further testing.

Table 1: Analysis of variance for combining ability for different characters in F_1 cucumber

Source of variation	Df	Character										
		Days to first female flower appearance	Node of first female flower	Days to marketable maturity	Fruit length	Fruit width	TSS	Flesh to seed cavity ratio	Fruit weight	No. of fruits per plant	Yield per plant	Internodal length
gca	7	678.818*	27.997*	705.436*	6.425*	1.087*	0.005	0.001*	3787.657*	9.898*	0.735*	9.512*
sca	28	42.264*	3.049*	45.029*	3.237*	0.243*	0.021	0.0015*	693.149*	1.159*	0.193*	2.183*
Error	70	0.557	0.228	0.562	0.004	0.002	0.0013	0.00004	62.357	0.112	0.0013	0.272
σ^2g		67.826	2.777	70.487	0.642	0.108	0.0004	0.0001	372.53	0.979	0.073	0.924
σ^2s		41.707	2.821	44.467	3.0233	0.240	0.020	0.002	630.79	1.047	0.191	1.911
σ^2g/ σ^2s		1.626	0.984	1.585	0.199	0.451	0.021	0.068	0.591	0.934	0.383	0.483

* Significant at 5 per cent level of significance

Table 2: Estimates of general combining ability of parents for different characters in cucumber

Source of variation	Character										
	Days to first female flower appearance	Node of first female flower	Days to market-able maturity	Fruit length	Fruit width	TSS	Flesh to seed cavity ratio	Fruit weight	No. of fruits per plant	Yield per plant	Internodal length
K-90	0.000	0.367*	-0.550*	0.361*	0.364*	-0.016*	-0.0002	20.083*	0.017	0.276*	0.021
G_2	-12.133*	-2.567*	-12.217*	-1.404*	-0.041*	0.004	0.004*	-25.250*	1.317*	0.302*	-1.856*
Poinsette	-2.433*	-0.767*	-2.0183*	-0.105	-0.531*	-0.031	0.014*	-4.917*	-0.217*	-0.055*	1.048*
EC173934	8.167*	1.633*	8.517*	-0.390*	0.191*	0.037*	0.011*	7.417*	-0.617*	-0.346*	0.144
K-75	0.733*	0.733*	1.017*	-0.050*	0.320*	-0.004	0.017*	10.083*	-0.017	0.024*	1.084*
LC-11	6.600*	0.633*	6.583*	0.388*	0.136*	-0.022	0.007*	32.750*	-0.783*	-0.089*	0.604*
LC-40	9.800*	2.067*	9.950*	-0.225*	-0.008*	0.029*	0.005*	-8.417*	-1.283*	-0.379*	-0.593*
Gyn_1	-10.733*	-2.100*	-11.117*	1.425*	-0.433*	0.002	0.008*	-16.917*	1.583*	0.268*	-0.453
SE (gi)	0.221	0.141	0.222	0.019	0.013	0.011	0.0019	2.336	0.099	0.011	0.154
$CD_{0.05}$ (gi)	0.441	0.281	0.443	0.037	0.026	0.021	0.0038	4.658	0.197	0.022	0.307

* Significant at 5 per cent level of significance

Table 3: Estimates of specific combining ability of F_1 for different characters in cucumber

Crosses	Characters										
	Days to first female flower appearance	Node of first female flower	Days to marketable maturity	Fruit length	Fruit width	TSS	Flesh to seed cavity ratio	Fruit weight	No. of fruits per plant	Yield per plant	Inter-nodal length
K-90x G_2	-7.422*	-1.059*	-7.252*	-2.481*	-0.411*	-0.082*	0.122*	-13.259*	2.685*	1.023*	-0.627*
K-90x Poinsette	-4.789*	-0.526*	-4.618*	-0.440*	0.086*	0.275*	-0.046*	-38.593*	0.848*	-0.324*	-2.530*
K-90x EC173934	-7.056*	-1.259*	-7.612*	-0.445*	-0.573*	-0.073*	-0.040*	40.574*	-0.752*	-0.059*	-1.894*
K-90x K-75	10.378*	1.974*	9.484*	1.382*	0.451*	0.011	0.012*	-35.259*	-0.352*	-0.543*	0.466
K-90x LC-11	9.178*	-0.259	9.948*	-0.406*	0.516*	-0.061*	-0.031*	55.407*	-0.252	-0.309*	2.246*
K-90x LC-40	-5.356*	-1.693*	-5.085*	1.324*	-0.794*	0.006	0.006*	-1.759	-0.085	-0.303*	2.043
K-90x Gyn_1	-4.489*	-0.526*	-5.352*	-1.343*	-0.182*	-0.051*	-0.013*	-23.259*	2.382*	0.509*	-0.030
G_2 xPoinsette	2.011*	1.074*	3.715*	2.334*	-0.393*	0.002*	-0.045*	0.074	-0.119	-0.316*	0.680*
G_2 x EC173934	3.411*	0.007	3.348*	1.819*	0.482*	-0.032	-0.029	-4.093	-1.052*	-0.398*	0.883*
G_2x K-75	0.178	-1.093*	0.515	2.113*	0.306*	0.112*	-0.009*	21.074*	1.348*	0.494*	1.143*
G_2 x LC-11	-3.356*	0.674*	-4.052*	-1.142*	-0.367*	0.043	-0.014*	24.074*	0.115	0.268*	-0.044
G_2 x LC-40	9.444*	0.574*	9.248*	0.638*	-0.240*	0.160*	0.003	-26.426*	-1.385*	-0.659*	0.453
G_2 x Gyn_1	-0.356*	0.741*	0.982*	1.421*	0.756*	0.093*	-0.023*	-14.593*	0.082	-0.140*	1.013*
Poinsette x EC173934	1.044*	-1.126*	1.315*	2.070*	0.192*	0.085*	0.080*	5.574	0.482*	0.065*	-2.387*
Poinsettex K-75	-0.522*	0.107	-1.185*	2.002*	0.343*	0.223*	-0.039*	16.407*	-0.118	0.201*	2.006*
Poinsettex LC-11	-5.056*	-1.126*	-5.418*	-0.325*	-0.527*	-0.023*	-0.035*	10.407*	0.648*	0.478*	1.419*
Poinsettex LC-40	-4.922*	-1.226*	-5.452*	2.622*	0.654*	-0.256*	0.032*	-28.426*	0.481*	0.088*	-1.517*
Poinsettex Gyn_1	14.944*	0.941*	15.615*	-1.995*	0.126*	0.120*	0.032*	18.407*	-0.385*	0.260*	1.109*
EC173934x K-75	-1.456*	1.041*	-2.885*	0.033	-0.276*	-0.205*	0.0006	-7.759*	-0.718*	-0.314*	1.009*
EC173934x LC-11	-0.322*	-2.526*	-0.785*	1.161	0.139*	-0.074*	0.044*	9.574*	0.048	0.189*	0.489*
EC173934x LC-40	-9.189*	-3.293*	-8.818*	1.174*	-0.525*	-0.107*	-0.002	-5.926	1.548*	0.446*	0.353
EC173934x Gyn_1	9.678*	3.541*	8.915*	-0.092*	-0.059*	0.036*	-0.018*	-14.093*	-1.985*	-0.602*	0.179
K-75x LC-11	3.778*	0.374	3.715*	1.238*	0.436*	0.020	-0.014	-36.259*	0.448*	-0.258*	-2.084*
K-75x LC-40	4.244*	-2.059*	4.682*	0.901*	-0.677*	0.134*	-0.013*	-0.093	-0.052	-0.028*	-1.954*
K-75x Gyn_1	-6.556*	-0.893*	-6.585*	-1.116	-0.379*	-0.213*	-0.020*	13.407*	1.415*	0.538*	0.006
LC-11x LC-40	4.044*	4.041*	4.115*	0.496*	-0.593*	-0.005	-0.003	22.241*	-0.285	0.049*	1.259*
LC-11x Gyn_1	-9.422*	-1.459*	-9.818*	-0.454*	-0.158*	0.128*	-0.030*	25.741*	0.181	0.518*	-0.614*
LC-40x Gyn_1	3.378*	-0.226	2.482*	-1.707*	0.173*	0.211	-0.019*	-16.426*	-1.318*	-0.352*	-2.084*
SE (ij)±	0.676	0.433	0.680	0.058	0.044	0.032	0.0057	7.160	0.303	0.033	0.472
$CD_{0.05}$	1.994	0.883	1.356	0.116	0.088	0.064	0.011	14.280	0604	0.066	0.941

* Significant at 5 per cent level of significance

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