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Combining ability estimation of gynoecious and monoecious hybrids for yield and earliness in cucumber (*Cucumis sativus*)

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ABSTRACT

Twenty one F_1 hybrids developed from seven diverse inbred of cucumber through a half-diallel mating system. Among parents, gynoecious parent GPC-1 showed maximum GCA effects in desirable direction for node number of first female flower, days to first fruit harvest, number of fruits/plant and vine length. Whereas the another gynoecious parent PPC-2 showed maximum GCA effects in desirable direction for traits like, days to first female flower anthesis, days to fruit set from opening of first female flower, and yield/plant. The monoecious parent Pusa Uday exhibited highest positive GCA effect for fruit length, fruit diameter and average fruit weight. These two gynoecious (GPC-1 and PPC-2) and one monoecious (Pusa Uday) parents were good general combiners for earliness, yield and other yield related traits and could be used in cucumber breeding programmes to improve these traits for the accumulation of favourable genes present in them. In order of merit the gynoecious hybrids $P_1 \times P_2$ (GPC-1 × PPC-2), $P_1 \times P_7$ (PPC-2 × Pusa Uday), $P_1 \times P_6$ (GPC-1 × Punjab Naveen) followed by monoecious hybrid $P_3 \times P_7$ (DC-1 × Pusa Uday) which exhibited highest SCA effects for number of characters including total fruit yield/plant. Thus, gynoecious lines in combination with gynoecious and monoecious have enormous potential to breed ''suitable gynoecious genotypes for earliness, yield and yield contributing traits"

Key words: Cucumber, Combining ability, Gynoecious, Yield traits

Cucumber (*Cucumis sativus* L.) (2n=14), belongs to family cucurbitaceae, is grown in both spring as well as summer season in tropical and subtropical countries. It is mostly grown for its edible tender fruits, preferred as salad, pickles, dessert fruit and *rayata* preparation. It is considered an ideal vegetable for people suffering from jaundice and allied diseases and also very much useful in preventing constipation because of high water content and also good source of nutrients and minerals.

Monoecious is the primitive sex form in cucumber, although gynoecious varieties are gaining popularity among cucumber growers because of its high yield, earliness and best suited to protected cultivation. When gynoecious line used as one parent the successive generations shows very high percentage of pistillate flowers and it results in high yield potential. The most potential use of gynoecious sex form in increasing cucumber yield was studied by several workers. It was found that the number of pistillate flowers was positively correlated with yield in some population season combinations (Cramer and Wehner 1998). Moderate to highly significant positive correlations between percent pistillate nodes and yield were also found in cucumber and suggested that sex expression has play an important role in increasing cucumber yield through indirect selection (Cramer and Wehner 2000). A positive correlation was observed with the number of pistillate nodes on lateral branches and number of fruit/plant (Fazio 2001, Fan *et al.* 2006). In India very less number of hybrids developed in cucumber, therefore the development of hybrids using gynoecious lines or predominantly gynoecious lines would be highly useful for increasing yield potential.

Realizing the importance of cucumber as an important vegetable crop for protected cultivation, it is imperative to study the GCA and SCA effects for earliness, yield and yield contributing characters. For the development of superior hybrids, estimates of general combining ability (GCA) of parents and specific combining ability (SCA) of the crosses help in proper selection of parents for hybridization programme. Therefore, the present investigation was undertaken to determine combining abilities, i.e. GCA and SCA effect of the Indian gynoecious lines with other potent diverse inbred and also to identify the best combiners among the existing germplasm for yield and its contributing characters of different quantitative characters in 7 × 7 half diallel mating system to facilitate the formulation of a sound

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breeding programme utilizing Indian gynoecious cucumber lines.

MATERIALS AND METHODS

The present investigation was carried out at experimental farm of the Division of Vegetable Science, Indian Agricultural Research Institute, New Delhi during 2012 (*Kharif* season) and 2013 (summer season). Seven genetically diverse inbreds of cucumber developed in different parts of the country showing considerable amount of morphological variation, viz. P_1 (Gynoecious Pickling Cucumber-1), P_2 (Pant Parthenocarpic Cucumber-2), P_3 (DC-1), P_4 (Kalyanpur Green), P_5 (Swarna Poorna), P_6 (Punjab Naveen), and P_7 (Pusa Uday) were crossed. Twenty one F_1 hybrids developed from 7 diverse inbred including 2 gynoecious were used for present study. Flowers were hand pollinated to produce F_1 hybrids without the reciprocals. Twenty eight genotypes (21 F_1 and 7 parental lines) were grown under open field condition in a randomized block design, and were replicated three times. The crop was sown in rows of 1.5 m apart with spacing of 60 cm between the plants. Each treatment comprised twenty hills. Two plants were allowed to grow in each hill and finally one plant was retaining for final observations. Standard and uniform agronomic practices recommended under irrigated conditions were followed throughout the growing seasons to raise a healthy and successful crop for better phenotypic and morphological expression. Ten plants were randomly selected for taking observations after discarding the border plants at both the ends. The fruits were harvested at marketable stage. Observations on individual plant were recorded on ten economically important quantitative characters (Table 3). Griffing (1956b) method II, model I was used for deriving general (GCA) and specific combining ability (SCA) estimates, where parents and F_1s were included but not the reciprocals.

RESULTS AND DISCUSSION

Mean performance of parents and their crosses for earliness

Earliness in cucumber is judged through appearance of female flower at lower node and number of days required to first harvest of fruits at marketable stage. Based on node number of first female flowers appearance, the gynoecious inbred P_1 and P_2 (GPC-1 and PPC-2) was found to be earliest (i.e. 3.44th node; Table 1). The gynoecious parents GPC-1 and PPC-2 were also earliest parents (40.22 and 41.00 days respectively (Table 1) for days to first female flower anthesis. Both parents also took less number of days for fruit setting from opening of first female flower. Among the parental lines the gynoecious lines, GPC-1 and PPC-2 took only 46.07 and 47.89 days respectively (Table 1) for first picking and were considered as the best parents. The gynoecious hybrids $P_1 \times P_2$ (gynoecious × gynoecious), $P_1 \times P_7$ (gynoecious × monoecious), $P_2 \times P_7$ (gynoecious × monoecious) had female flower at lower node (2.54th, 3.37th, 3.41st node respectively (Table 2). The top three hybrid combinations produced early fruits (<47 days after sowing) compared to other hybrids are $P_2 \times P_7$ (PPC-2 × Pusa Uday), $P_2 \times P_6$ (PPC-2 × Punjab Naveen) and $P_1 \times P_6$ (GPC-1 × Punjab Naveen) (Table 2). The top three hybrid combinations for days to first female flower anthesis (<40 days after sowing) compared to other hybrids are $P_1 \times P_7$ (GPC-1 × Pusa Uday), $P_2 \times P_7$ (PPC-2 × Pusa Uday) and $P_1 \times P_6$ (GPC-1 × Punjab Naveen) (Table 2). The cultivation of gynoecious based hybrids in cucumber at high plant densities

Table 1 Mean performance of parents for earliness traits in cucumber

Parents	NNFFF	DFFFA	DFSFFF	DFFH
GPC-1 (P_1)	3.44	40.22	3.50	46.07
PPC-2 (P_2)	3.44	41.00	3.49	47.89
DC-1 (P_3)	5.23	47.64	3.61	56.85
KG (P_4)	4.98	45.49	3.81	55.70
SP (P_5)	5.12	48.55	3.89	57.13
PN (P_6)	5.38	49.61	4.22	60.19
PU (P_7)	5.43	50.52	4.16	58.66
Mean	4.72	46.15	3.81	54.64
Range	3.44-5.43	40.22-50.52	3.49-4.22	46.07-60.19
CD (P=0.05)	0.67	4.60	0.68	4.88

GPC-1-Gynoecious Pickling Cucumber-1, PPC-2-Pant Parthenocarpic Cucumber-2, KG-Kalyanpur Green, SP-Swarna Poorna, PN-Punjab Naveen, PU-Pusa Uday

Table 2 Mean performance of hybrids for earliness traits in cucumber

Crosses	NNFFF	DFFFA	DFSFFF	DFFH
$P_1 \times P_2$	2.54	40.19	3.37	47.54
$P_1 \times P_3$	3.87	43.35	3.38	52.67
$P_1 \times P_4$	3.78	42.16	3.57	51.45
$P_1 \times P_5$	3.95	43.15	3.56	54.17
$P_1 \times P_6$	3.41	39.24	3.11	46.72
$P_1 \times P_7$	3.37	38.27	3.06	46.82
$P_2 \times P_3$	3.90	41.57	3.25	52.35
$P_2 \times P_4$	3.97	41.76	3.45	53.07
$P_2 \times P_5$	3.92	42.22	3.56	53.38
$P_2 \times P_6$	3.46	39.77	3.14	46.52
$P_2 \times P_7$	3.41	38.47	3.05	46.49
$P_3 \times P_4$	4.63	42.21	3.52	55.36
$P_3 \times P_5$	4.68	42.37	3.56	56.09
$P_3 \times P_6$	4.80	44.49	3.77	53.18
$P_3 \times P_7$	4.72	42.14	3.67	52.67
$P_4 \times P_5$	4.24	45.38	3.83	56.13
$P_4 \times P_6$	4.44	43.35	3.31	53.44
$P_4 \times P_7$	4.40	45.57	3.34	52.93
$P_5 \times P_6$	4.24	47.45	3.83	55.04
$P_5 \times P_7$	4.21	44.77	3.43	54.12
$P_6 \times P_7$	4.19	43.47	4.52	54.37
Mean	4.01	42.45	3.49	52.12
Range	2.54-4.80	38.27-47.45	3.05-4.52	46.49-56.13
CD (P=0.05)	0.71	3.43	0.56	4.24

Table 3 Analysis of variance for general and specific combining ability using half-diallel cross in cucumber

Character	Source of variation of gca			Source of variation of sca			Error		$\sigma^2 g$	$\sigma^2 s$
	DF	MSS	F	DF	MSS	F	DF	MSS		
NNFFF	6	1.63**	22.93	21	0.18*	2.49	54	0.07	0.05	0.06
DFFFA	6	23.58**	14.31	21	6.91**	4.20	54	1.65	0.16	1.33
DFSFFF	6	0.179**	4.05	21	0.11**	2.46	54	0.04	0.05	0.08
DFFH	6	46.32**	18.50	21	6.96**	2.78	54	2.50	0.24	2.20
NF/P	6	36.39**	53.95	21	3.68**	5.45	54	0.67	0.07	0.55
FL (cm)	6	25.18**	23.31	21	1.69**	1.56	54	1.08	0.11	0.88
FD (cm)	6	2.00**	29.36	21	0.08	1.23	54	0.07	0.07	0.08
AFW (g)	6	3550.9**	85.49	21	66.38	1.60	54	41.54	3.96	33.47
VL (cm)	6	1125.18**	77.76	21	22.36	1.55	54	14.47	1.38	11.66
Y/P (g)	6	219542.9**	30.73	21	66203.2**	9.27	54	7144.7	680.46	5755.46

has an opportunity to provide high yield potential in once over mechanical harvesting operations (Cantliffe 1977).

GCA effects of cucumber parental genotypes

The estimated effect for the GCA of the parents revealed that among seven parental lines, the line GPC-1 exhibited highest negative GCA effects in desirable direction for node number of first female flower (-0.63). The parental line PPC-2 exhibited highest negative GCA effects in desirable direction for days to first female flower anthesis (-2.33) and days to fruit set from opening of first female flower (-0.19). In order of merit the parental line GPC-1 exhibited highest negative GCA effects in desirable direction for days to first fruit harvest (-3.39) and was considered as one of the best parent followed by parental line PPC-2 (-2.98). The parent GPC-1 exhibited highest GCA effects for number of fruits/plant (2.73) followed by parent PPC-2 (2.69). The gynoecious parents GPC-1 and PPC-2 produced early fruits compared to monoecious parents. The parental line Pusa Uday exhibited highest GCA effects (1.69, 0.53 and 21.04) for traits like fruit length, fruit diameter and average fruit weight respectively, followed by Punjab Naveen. The parental line GPC-1 exhibited significant negative GCA effects in desirable direction for vine length (-24.58) followed by the parental line PPC-2. The parental line PPC-2 exhibited significant positive GCA effects in desirable direction for yield/plant (162.95) followed by Pusa Uday. It is observed that either one or two parental lines involved in crosses with high GCA effects for yield and its attributing characters, the F_1 hybrids showed promising results in terms of yield traits. In the present experiment, the gynoecious parent GPC-1 exhibited highest significant GCA effects in desirable direction for characters like node number of first female flower, days to first fruit harvest, number of fruits/plant and vine length followed by PPC-2 for traits like days to first female flower anthesis, days to fruit set from opening of first female flower and yield/plant. The monoecious parent Pusa Uday exhibited significant GCA effects in desirable direction for characters like fruit length, fruit diameter and average fruit weight. It was found that SCA components of variance were higher than GCA components of variance for all the traits studied indicating the preponderance of non-additive variance of gene action. Hence, heterosis breeding is rewarded for the improvement of these traits. Since the parents P_1, P_2 and P_7 had high GCA effects and yield components attributes as well; they could be used to breed high yielding gynoecious cucumber hybrids and may be tested for multi-location trials.

Estimation of SCA effects of F_1 hybrids for different quantitative traits in cucumber

The hybrid $P_1 \times P_2$ (-0.41) exhibited highest negative

Table 4 Estimates of general combining ability (GCA) effects of parental lines for ten important quantitative traits of cuumber using half-diallel cross

Character	NNFFF	DFFFA	DFSFFF	DFFH	NF/P	FL	FD	AFW(g)	VL (cm)	Y/P (g)
P_1	-0.63**	-2.24**	-0.17*	-3.39**	2.73**	-3.44**	-0.74**	-30.80**	-24.58**	102.85**
P_2	-0.60**	-2.33**	-0.19*	-2.98**	2.69**	-0.64	-0.46**	-24.60**	-1.24	162.95**
P_3	0.40**	0.50	-0.02	1.56*	-1.57**	0.85	0.32**	8.84**	2.85*	-91.83**
P_4	0.22*	0.50	0.01	1.31*	-1.85**	0.36	0.03	6.28*	6.63**	-174.41**
P_5	0.22*	1.72**	0.11	2.35**	-1.88**	0.34	-0.10	3.78	4.03**	-209.63**
P_6	0.20*	1.11*	0.17*	0.85	-0.32	0.84*	0.42**	15.45**	5.99**	58.30*
P_7	0.19*	0.75	0.09	0.30	0.19	1.69**	0.53**	21.04**	6.33**	151.77**
SE (gi)	0.082	0.393	0.064	0.488	0.253	0.321	0.080	1.987	1.170	26.085
SE (gi-gj)	0.126	0.605	0.098	0.746	0.387	0.490	0.123	3.038	1.793	39.846
CD (P=0.05)	0.183	0.876	0.143	1.087	0.565	0.714	0.179	4.428	2.608	58.118

** Significant at 1%, * Significant at 5%

Table 5 Estimation of specific combining ability (SCA) effects of F_1 hybrids for ten important quantitative traits in cucumber using half-diallel cross

Crosses	NNFFF	DFFFA	DFSFFF	DFFH	NF/P	FL	FD	AFW(g)	VL (cm)	Y/P (g)
$P_1 \times P_2$	-0.41**	2.39*	0.16	1.17	1.11	-0.74	-0.17	11.86*	0.38	-197.71*
$P_1 \times P_3$	-0.08	1.73	0.00	1.75	-1.40	0.43	-0.22	3.16	-0.69	27.08
$P_1 \times P_4$	0.01	0.53	0.16	0.78	-1.42	0.29	0.23	3.99	-8.36*	39.33
$P_1 \times P_5$	0.17	0.30	0.05	2.46*	-1.29	0.25	0.18	7.15	-8.79*	60.46
$P_1 \times P_6$	-0.35**	-3.00*	-0.67**	-3.49*	2.37**	0.62	-0.02	-1.39	-4.37	324.11**
$P_1 \times P_7$	-0.40**	-3.61**	-0.43*	-2.85	3.15**	0.81	0.03	-3.51	-9.11*	345.99**
$P_2 \times P_3$	-0.08	0.03	-0.11	1.02	-0.94	0.70	-0.17	-0.91	-2.11	11.62
$P_2 \times P_4$	0.16	0.23	0.06	2.00	-0.49	0.67	-0.07	-3.20	2.78	9.67
$P_2 \times P_5$	0.11	-0.54	0.07	1.26	-0.15	1.03	-0.19	-1.03	8.12*	19.79
$P_2 \times P_6$	-0.33**	-2.38*	-0.60**	-4.10*	2.66**	1.57	0.02	-1.85	7.86*	365.18**
$P_2 \times P_7$	-0.36**	-3.66**	-0.62**	-3.57*	3.22**	0.95	0.00	-2.05	3.24	407.83**
$P_3 \times P_4$	-0.17*	-2.15*	-0.04	-0.25	1.48	0.85	0.46*	-1.20	-0.65	51.19
$P_3 \times P_5$	-0.13*	-3.21*	-0.10	-0.57	1.36	0.59	0.44*	0.22	0.84	80.65
$P_3 \times P_6$	0.01	-0.49	0.05	-1.98	0.23	-0.03	0.47*	2.08	1.01	130.27
$P_3 \times P_7$	-0.05	-2.48*	0.03	-1.94	0.78	0.94	0.48*	12.29*	2.49	225.05*
$P4 \times P_5$	-0.38	-0.21	0.14	-0.29	0.96	0.05	0.28	-2.10	-3.19	139.99
$P_4 \times P_6$	-0.16	-1.62	-0.44*	-1.47	0.39	0.86	-0.12	10.77	1.15	66.60
$P_4 \times P_7$	-0.18	0.95	-0.53*	-1.43	0.04	0.66	-0.21	11.80*	7.25*	83.41
$P_5 \times P_6$	-0.37**	1.25	-0.02	-0.92	0.44	0.05	0.16	6.69	-1.34	38.60
$P_5 \times P_7$	-0.39**	-1.07	-0.34	-1.29	-0.11	0.73	0.20	6.11	-0.52	4.32
$P_6 \times P_7$	-0.38**	-1.77	0.68**	0.47	-0.28	1.01	0.46	3.97	-0.78	-137.87
CD (P=0.05)	0.485	2.337	0.378	2.881	1.496	1.892	0.475	11.733	6.923	153.883

*Significant at 1%, **Significant at 5%. NNFFF- Node number of first female flower, DFFFA- Days to first female flower anthesis, DFSFFF- Days to fruit set from opening of first female flower, DFFH- Days to first fruit harvest, N/F- Number of fruits/plant, FL- Fruit length, FD- Fruit diameter, AFW- Average fruit weight, VL-Vine length, Y/P-Yield/plant

SCA effects in desirable direction for node number of first female flower followed by $P_1 \times P_7$ (-0.40).The hybrid $P_2 \times P_7$ (-3.66) was estimated maximum negative SCA effects value in desirable direction for days to first female flower anthesis followed by $P_1 \times P_7$ (-3.61). The hybrid $P_1 \times P_6$ (-0.67) showed maximum SCA effects for days to fruit set from opening of first female flower followed by $P_2 \times P_7$ (-0.62). The hybrid $P_2 \times P_6$ (-4.10) showed significant SCA effects in desirable direction for days to first fruit harvest followed by $P_2 \times P_7$ (-3.57).The hybrid combinations $P_1 \times P_2$, $P_1 \times P_7$, $P_2 \times P_7$, $P_1 \times P_6$, and $P_2 \times P_6$ are observed potential for earliness. Gynoecious based cucumber hybrids are early in flowering and produced concentrated fruit set (Dijkhuizen and Staub 2002). The crosses showed high specific combining ability (SCA) can be best utilized in heterosis breeding (Singh and Chaudhary 1979). The hybrid $P_2 \times P_7$ (3.22) showed highly significant SCA effects for number of fruits/plant followed by $P_1 \times P_7$ (3.15). The hybrid $P_2 \times P_6$ (1.57) revealed maximum SCA effect for fruit length followed by $P_2 \times P_5$ (1.03). The hybrid $P_3 \times P_7$ (0.48) exhibited significant SCA effects for fruit diameter followed by $P_3 \times P_6$ (0.47). The hybrid $P_3 \times P_7$ (12.29) revealed maximum SCA effect for average fruit weight followed by $P_1 \times P_2$ (11.86). The hybrid $P_1 \times P_7$ (-9.11) was estimated maximum negative SCA effects value but in desirable direction for days to first fruit harvest, followed by $P_1 \times P_5$ (-8.79). The hybrid $P_2 \times P_7$ (407.83) was found significant SCA effects for yield/plant followed by $P_2 \times P_6$ (365.18) and $P_1 \times P_7$ (345.99). In all crosses, the gynoecious lines, GPC-1 and PPC-2 were found to be good combiner. The most outstanding parental lines involved in all F_1 crosses which showed best SCA effects are GPC-1, PPC-2 and Pusa Uday. The crosses $P_1 \times P_2$, $P_2 \times P_7$, $P_1 \times P_6$, $P_2 \times P_6$, $P_3 \times P_7$, $P_1 \times P_7$ with high SCA effects for most of the characters including yield/plant and may be utilized in exploitation of hybrid vigour. From the above cross combination it is clear that gynoecious as one of parent in cucumber hybrid development holds immense potentiality for exploitation of hybrid vigour with respect to earliness, yield and other yield related traits. These results were very much similar to the findings of Shushir *et al.* (2005), and Sreevani (2005). Fan *et al*. (2006) in cucumber found a positive correlation between gynoecy and number of fruits which suggested the association between total yield and sex expression in cucumber. The significance of GCA and SCA variances in the present study indicated the role of both additive (for selection) as well as non-additive gene action (for heterosis breeding) for the control of yield and earliness in cucumber by utilizing the gynoecious line as one of the parents.

Therefore Gynoecious × Gynoecious and Gynoecious × Monoecious hybrids were found to have maximum significant SCA effects for earliness and total yield and may

be exploited for commercial F_1 hybrid production because most of Indian cucumber cultivars are monoecious in nature and these are not suitable for growing under protected conditions as they require pollination for fruit set, whereas gynoecious varieties produce only pistillate flowers and has immense potential which facilitate easy and economic method of hybrid seed production also as compared to monoecious cultivars. Hence, these aforesaid gynoecious hybrids of cucumber have high potential for commercial cultivation with respect to yield, earliness and other important traits under north Indian plains.

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