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Research Note

Combining ability studies exploiting gynoecy in cucumber (*Cucumis sativus* L.)

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Abstract
Twelve F_1 hybrids of cucumber derived from a top cross involving twelve monoecious parents and a stable gynoecious inbred (EC 709119) as female parent were evaluated in randomized block design (RBD) with three replications to assess general combining ability (GCA). Significant GCA effects were observed for all the characters except days to first male flower anthesis. The estimates of GCA effects revealed that none of the parents exhibited good GCA for all the characters together. Among 12 parents, CS123 was observed as the good general combiner for fruit yield per vine, length of main vine, branches per plant, number of harvests, duration of the crop, fruits per plant and number of seeds per fruit. The parents, CS128 and IC 538186 were general good combiners for earliness. The parent CS127 was found to be superior for fruit length, weight and girth.

Key words
Cucumber, combining ability, Gynoecy, F_1 hybrids

Cucumber (*Cucumis sativus* L.) is one of the most important and popular cucurbitaceous vegetable crops grown throughout the tropical and subtropical regions of the world. Among the cucurbits, cucumber is distinct with a unique sex mechanism and this feature can easily be manipulated for production of F_1 hybrid seeds. Gynoecy, condition where all the flowering nodes produce only pistillate flowers, can be exploited for improving yield and economizing F_1 hybrid production. In India, only few works utilizing gynoecious lines in heterosis breeding programme of cucumber have been reported (Wehner *et al*. (2000); More, 2002 and Sharma, 2010). The general combining ability analysis (GCA) helps to identify suitable monoecious parents which can be hybridized with gynoecious parent to exploit heterosis. The GCA analysis provides estimates of the average performance of a line in hybrid combination Sprague and Tautum (1942). They provide an indication of the genetic differences that exist among the lines being evaluated and the importance of genes with largely additive effects. The GCA analysis can be valuable for predicting hybrid performance in cucumber breeding (Lopez-Sese and Staub, 2002). Hence, the present study is undertaken to study the combining ability of gynoecious line with selected monoecious lines in cucumber.

Experimental materials consisted of twelve monoecious genotypes of cucumber (*Cucumis sativus* L.) collected from different parts of the country and a stable gynoecious inbred introduced from USA. During the first season (February-May 2012) twelve monoecious cucumber genotypes were crossed in a top cross fashion with gynoecious inbred (EC 709119) as female parent to produce twelve hybrids. The twelve monoecious parents were CS127, IC 527427, IC 410617, IC 410638, IC 538155, IC 527431, IC 538186, CS 128, CS 129, CS 25, CS 121 and CS 123. The gynoecious parent was maintained by spraying silver thiosulphate @ 200ppm at 3 true-leaf stage. In the second season, (November 2012-March 2013) the 12 hybrids along with their parents were evaluated in a randomized block design (RBD) with three replications. There were five plants/genotype/replication with an area of $15m^2$ per plot. Seedlings were raised in protrays and were transplanted in raised beds at a spacing of 2 x 1.5 m. Observations on important fruit and yield characters were recorded. Data recorded from the parents and hybrids were initially subjected to analysis of variance to detect the genotypic differences if any (Table 1). The mean data (Table 2) were subjected to combining ability analysis according to top cross method developed by Sprague and Tautum (1942). Breeding value (A) which represents the GCA effect of the individual test inbred in topcross analysis was calculated as per the normal deviate procedure (Sharma, 1988). The GCA effects of the parents and their percentage level of significance was estimated (Table 3). The significant deviation was estimated as the significant deviation from Z=0.

Evaluation of combining ability for 15 characters recorded significant GCA effects for all the characters except days to first male flower anthesis. The estimates of GCA effects revealed that none of the parents exhibited good GCA for all the characters together and the combining ability effects were not consistent for the yield components *viz*. number of fruits per vine, number of harvests and average fruit weight, possibly because of negative association among the characters (Mule *et al.*2012). This shows that genes for desirable characters would have to be combined from different sources as reported earlier (Nehe *et al.,* 2007). Among 12 parents, CS 123 was the good general combiner for fruit yield per vine. It also showed significant GCA effects for various characters like length of main vine, branches per plant, number of harvests, duration of the crop, fruits per plant and number of seeds per fruit.

The highest GCA effect for vine length and number of branches per plant was shown by CS 123 (2.86; 2.30). As a general combiner it has the probability of increasing the vine length and the number of branches per plant by 49.74 per cent and 48.9 per cent respectively. Genotypic difference with respect to GCA for number of branches were reported by Rawat (2002), Singh *et al*. (2011) and Mule *et al.* (2012) in monoecious lines of cucumber. All other parents exhibited non-significant GCA effect for these characters.

The genotype CS 128 (-1.76) had the maximum GCA effect for days to first female flower followed by IC 538186 (-1.56) indicating that these are the good combiners for earliness. None of the parents exhibited significant GCA effect for days to first male flower anthesis. The maximum negative GCA effects for node at which first female flower emerged were shown by IC 538186 (-1.49). For the character, days to first harvest, which contributes to earliness the GCA was found highest for CS 128 (-2.76). Thus CS 128 and IC 538186 can be considered as good candidates for earliness and GCA effect on earliness is reported by Rawat (2002) in monoecious lines of cucumber. CS 123 (2.03) exhibited maximum GCA effect for number of harvests. The GCA effect for duration of the crop was highest in CS 121 (1.99) followed by CS 123 (1.52). So CS 123 as well as CS 121 can be considered as general good combiners for extended duration of the crop. This genotype had the highest GCA effect for number of fruits per plant (2.51) and yield per plant (2.55) indicating its potential in improving the yield. Similar results were recorded in monoecious lines of cucumber by Ananthan and Pappiah (1997), Hanchinamani and Patil (2009), Singh *et al.* (2011), Kushawa *et al.* (2011) and Mule *et al.* (2012).

The genotype CS 127 showed maximum GCA effect for average fruit weight (2.00), fruit length (2.17) and fruit girth (1.69) suggesting it as the best combiner for these characters. High GCA effect for fruit length, weight and girth in monoecious lines of cucumber was reported by Rawat (2002), Khushawa *et al*. (2011) and Mule *et al*. (2012).

The GCA effect for flesh thickness was maximum in IC 538155 (1.33) and CS 121 (1.33). The highest GCA effect for number of seeds per fruit was shown by CS 129 (1.52) and CS123 (1.52) indicating both the parents as general good combiners for the character. Significant GCA effect for flesh thickness and number of seeds in monoecious lines of cucumber was reported by Brar *et al*. (2011).

Inbred CS 123 was good general combiner for most of the characters including yield (Fig. 1). The parents, CS 128, IC 538186, CS 127 and IC 538155 were good combiner for important characters like earliness, fruit characters and flesh thickness (Fig. 2). However for recommending these parents for commercial exploitation further testing in different agro climatic conditions is needed. Inclusion of more monoecious lines in the crossing programme with gynoecious line will be effective in identifying best combiners for improving specific traits such as fruit length, average fruit weight and rind colour.

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Table 1. Topcross ANOVA for 15 characters in thirteen genotypes of cucumber and their 12 hybrids

Source of variation	df	Length of main vine (cm)	Branches/plant	Days to first male flower anthesis	Days to first female flower anthesis	Node at which first female flower emerged	Days to first harvest	Number of harvests
Replications	1	3232.08	0.61	0.96	6.13	0.41	0.4	0.005
Entries	24	10067.81	181.75	209.45	95.70	0.71	53.66	12.437
Parents	12	11836.89**	11.72**	403.91**	102.51**	0.78	49.98**	12.44*
Topcrosses	11	8440.89*	3.74	5.52	8.89	0.62	21.50	10.01
p *vs* c	1	6735.07	0	119.39*	968.85**	0.74	451.68**	6.76
Error	24	65626.67	3.16	21.25	22.78	0.81	11.81	103.96**

Source of variation	df	Duration of the crop	Fruits/plant	Yield/ plant (kg)	Average fruit weight (g)	Fruit length (cm)	Fruit girth (cm)	Flesh thickness	Number of seeds/fruit
Replication	1	7.605	7.22	1.014	112.5	0.09	0.54	0.01	153.83
Entries	24	32.79	375.52	31.36	7450.92	11.49	6.59	0.16	11105.11
Parents	12	46.046*	339.16**	29.87**	8800.80**	18.91**	8.04**	0.16**	15270.83**
Topcrosses	11	13.91	280.28*	23.89**	5667.05*	4.05**	3.26**	0.18**	7465.62**
p *vs* c	1	81.64	1787.53**	131.36**	10874.88*	4.46	25.74**	0.06*	1150.77
Error	24	20.08	109.62	7.54	1714.58	1.19	0.74	0.01	854.81

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

Table 2. Mean values for different characters in parents and F_1 hybrids of cucumber

Hybrids/Parents	Length of main vine (cm)	Branches/ plant	Days to first male flower anthesis	Days to first female flower anthesis	Node at which first female flower emerged	Days to first harvest	No. of harvests	Duration of the crop
EC 709119 x CS 127	202.00	5.50	39.50	42.25	3.75	53.00	9.00	114.50
EC 709119 x IC 527427	240.00	4.50	43.50	40.75	3.50	52.50	7.50	114.50
EC 709119 x IC 410617	281.75	6.00	38.75	40.25	4.00	53.00	12.00	116.25
EC 709119 x IC 410638	280.00	4.75	41.25	41.50	5.25	52.50	11.00	116.25
EC 709119 x IC 538155	242.25	7.75	42.25	41.75	4.75	56.50	10.25	116.25
EC 709119 x IC 527431	273.75	6.50	39.50	44.25	4.25	53.00	10.25	114.50
EC 709119 x IC 538186	226.00	5.50	39.75	38.00	3.25	56.50	8.50	114.50
EC 709119 x CS 128	253.75	6.75	39.25	37.50	4.00	44.00	8.75	118.00
EC 709119 x CS 129	300.00	6.00	39.50	39.50	4.25	53.00	10.50	118.00
EC 709119 x CS 25	247.00	7.25	41.50	42.00	4.25	53.00	9.25	113.00
EC709119 x CS 121	287.25	6.25	41.25	43.25	3.50	56.50	12.25	121.75
EC 709119 x CS 123	460.25	9.50	43.50	43.50	4.25	53.00	14.00	120.50
CS-127	305.00	7.50	41.00	45.75	3.75	57.00	5.25	118.00
IC 527427	285.00	4.75	53.00	58.50	4.00	63.75	5.75	112.00
IC 410617	197.25	4.50	46.75	47.25	5.75	59.00	7.25	111.75
IC 410638	205.00	4.50	40.75	44.00	4.25	53.00	7.50	118.00
IC 538155	130.00	5.75	57.00	61.00	4.00	69.50	6.00	112.00
IC 527431	348.75	11.25	51.75	61.00	4.75	67.50	8.00	112.00
IC 538186	180.00	4.00	55.00	58.25	4.00	53.00	4.00	109.00
CS-128	276.25	8.75	48.00	47.50	3.75	58.25	9.50	113.75
CS-129	311.25	7.50	44.25	46.25	4.00	58.50	10.00	113.75
CS-25	280.00	6.75	45.75	48.00	4.75	56.50	7.00	109.25
CS-121	294.50	7.25	43.75	44.50	5.25	58.25	9.50	120.50
CS-123	337.50	8.00	43.00	49.00	4.25	57.50	11.25	123.75
EC 709119	116.00	2.00	0	39.25	3.75	56.00	4.00	107.50

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Table 2. Contd.,

Hybrids/Parents	Fruits/plant	Yield/ plant (kg)	Average fruit wt (g)	Fruit length (cm)	Fruit girth (cm)	Flesh thickness (cm)	Number of seeds per fruit
EC 709119 x CS 127	23.00	6.78	407.50	20.10	20.48	1.56	222.25
EC 709119 x IC 527427	25.00	6.83	302.50	16.30	18.90	1.98	159.40
EC 709119 x IC 410617	43.75	11.45	325.00	17.00	18.80	1.32	238.40
EC 709119 x IC 410638	38.50	12.03	267.50	15.30	17.70	2.00	247.80
EC 709119 x IC 538155	35.25	8.16	265.00	15.90	18.05	2.10	320.05
EC 709119 x IC 527431	38.25	9.25	275.00	16.60	17.75	1.65	225.00
EC 709119 x IC 538186	18.75	4.26	275.00	16.30	16.70	1.32	275.15
EC 709119 x CS 128	27.50	7.94	405.00	17.75	20.38	2.00	196.90
EC 709119 x CS 129	27.50	7.68	297.50	18.40	19.00	1.45	353.90
EC 709119 x CS 25	32.75	8.27	242.50	15.10	16.40	1.95	302.70
EC709119 x CS 121	35.00	9.05	275.00	15.70	18.35	2.10	238.90
EC 709119 x CS 123	63.75	17.96	277.00	16.30	17.35	1.75	353.75
CS-127	15.00	7.48	437.50	23.35	21.80	2.30	184.90
IC 527427	11.75	1.69	162.50	13.60	14.50	1.20	239.85
IC 410617	17.50	3.04	282.50	18.05	18.60	1.35	305.25
IC 410638	38.75	10.90	320.00	17.35	15.60	1.63	305.40
IC 538155	9.50	1.50	200.00	14.25	13.65	1.48	166.00
IC 527431	25.50	5.76	245.00	17.55	16.75	1.93	362.05
IC 538186	5.00	1.84	275.00	21.55	16.05	1.50	210.55
CS-128	39.25	10.48	282.50	15.60	17.05	1.55	411.20
CS-129	32.00	9.93	282.50	18.50	18.25	1.81	323.15
CS-25	20.25	5.11	307.50	20.05	17.45	1.88	290.00
CS-121	23.00	6.81	235.00	12.75	16.50	1.70	146.35
CS-123	43.75	11.10	277.50	16.90	16.95	1.81	187.25
EC 709119	6.25	0.98	225.00	15.75	16.35	1.90	138.60

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Table 3. Estimate of GCA effects of 12 cucumber genotypes for 15 characters

Characters	CS127	IC 527427	IC 410617	IC 410638	IC 538155	IC 527431	IC 538186	CS 128	CS 129	CS 25	CS 121	CS 123
Length of main vine (cm)	-1.12 (-36.43)	-0.53 (-19.15)	0.11 (3.98)	0.08 (3.98)	-0.50 (-19.15)	-0.01 (0)	-0.75 (-25.8)	-0.32 (-11.79)	0.39 (15.54)	-0.42 (-15.54)	0.20 (7.93)	2.86 (49.74*)
Branches per plant	-0.62 (-22.57)	-1.36 (-40.32)	-0.26 (-7.93)	-1.17 (-38.49)	1.02 (34.13)	0.11 (3.98)	-0.62 (-22.57)	0.29 (11.79)	-0.26 (-11.79)	0.66 (28.81)	-0.08 (-3.98)	2.30 (48.93*)
Days to first male flower anthesis	-0.78 (-25.80)	1.63 (44.52)	-1.23 (-38.49)	0.28 (11.79)	0.88 (31.59)	-0.78 (-28.81)	-0.63 (-22.57)	-0.93 (-31.57)	-0.78 (-25.8)	0.43 (15.54)	0.28 (11.79)	1.63 (44.52)
Days to first female flower anthesis	0.49 (19.15)	-0.22 (-7.93)	-0.45 (-15.54)	0.14 (3.98)	0.26 (11.79)	1.44 (41.92)	-1.52 (-43.32*)	-1.76 (-46.41*)	-0.81 (-28.81)	0.38 (15.54)	0.97 (34.13)	1.09 (36.43)
Node at which first female flower emerged	-0.60 (-22.57)	-1.05 (-34.13)	-0.15 (-15.54)	2.09 (48.21)	1.20 (38.49)	0.30 (11.79)	-1.49 (-43.32*)	-0.15 (-3.98)	0.30 (11.79)	0.30 (11.79)	-1.05 (-34.13)	0.30 (11.79)
Days to first harvest	-0.01 (0)	-0.17 (-7.93)	-0.01 (0)	-0.17 (-7.93)	1.05 (34.13)	-0.01 (0)	1.05 (36.43)	-2.76 (- 49.74*)	-0.01 (0)	-0.01 (0)	1.05 (36.43)	-0.01 (0)
Number of harvests	-0.69 (-25.80)	-1.51 (-43.32)	0.94 (31.59)	0.40 (15.54)	-0.01 (0)	-0.01 (0)	-0.96 (-31.59)	-0.83 (-28.81)	0.12 (3.98)	-0.56 (-22.57)	1.08 (36.43)	2.03 (47.72*)
Duration of the crop	-0.76 (-28.81)	-0.76 (-25.80)	-0.09 (-3.98)	-0.09 (-3.98)	-0.09 (-3.98)	-0.76 (-28.81)	-0.76 (-28.81)	0.57 (22.57)	0.57 (22.57)	-1.33 (-40.32)	1.99 (47.72)	1.52 (43.32*)
Fruits per plant	-0.94 (-31.59)	-0.77 (-25.80)	0.82 (28.81)	0.37 (15.54)	0.10 (3.98)	0.35 (15.54)	-1.30 (-38.49)	-0.56 (-19.15)	-0.56 (-19.15)	-0.11 (-3.98)	0.08 (0)	2.51 (49.38*)
Yield per plant (kg)	-0.68 (-25.80)	-0.67 (-25.80)	0.67 (25.8)	0.84 (28.80)	-0.28 (-7.93)	0.03 (0)	-1.41 (-41.90)	-0.35 (-11.79)	-0.42 (-15.54)	-0.25 (-7.93)	-0.02 (0)	2.55 (49.38*)
Average fruit weight (g)	2.00 (47.72*)	0.02 (0)	0.45 (15.54)	-0.63 (-22.57)	-0.68 (-25.8)	-0.49 (-19.15)	-0.49 (-19.15)	1.95 (47.13*)	-0.07 (0)	-1.10 (-36.43)	-0.49 (-19.15)	-0.45 (-15.54)
Fruit length (cm)	2.37 (49.18*)	-0.30 (-11.79)	0.19 (7.93)	-1.00 (-34.13)	-0.58 (-22.57)	-0.09 (-3.98)	-0.30 (-11.79)	0.72 (25.8)	1.17 (38.49)	-1.14 (-36.43)	-0.72 (-25.8)	-0.30 (-11.79)
Fruit girth (cm)	1.69 (44.52*)	0.45 (19.15)	0.38 (15.54)	-0.49 (-19.15)	-0.21 (-7.93)	-0.45 (-15.54)	-1.27 (-40.32)	1.61 (44.52*)	0.53 (19.15)	-1.51 (-43.32)	0.02 (0)	-0.76 (-28.81)
Flesh thickness (cm)	-0.44 (-15.54)	0.93 (31.59)	-1.22 (-38.49)	1.00 (31.59)	1.33 (40.32*)	-0.15 (-3.98)	-1.24 (-38.49)	1.00 (34.13)	-0.80 (-28.81)	0.83 (28.81)	1.33 (40.32*)	0.18 (7.93)
Number of seeds per fruit	-0.64 (-22.57)	-1.67 (-44.52)	-0.37 37.29)	-0.22 (-7.93)	0.96 (31.59)	-0.59 (-22.57)	0.23 (7.93)	-1.05 (-34.13)	1.52 (43.32)	0.68 (25.8)	-0.36 (-15.54)	1.52 (43.32*)

Value in parantheses represents per cent significance of GCA (*Significant at 5% level

Fig 1. GCA effects of CS 123

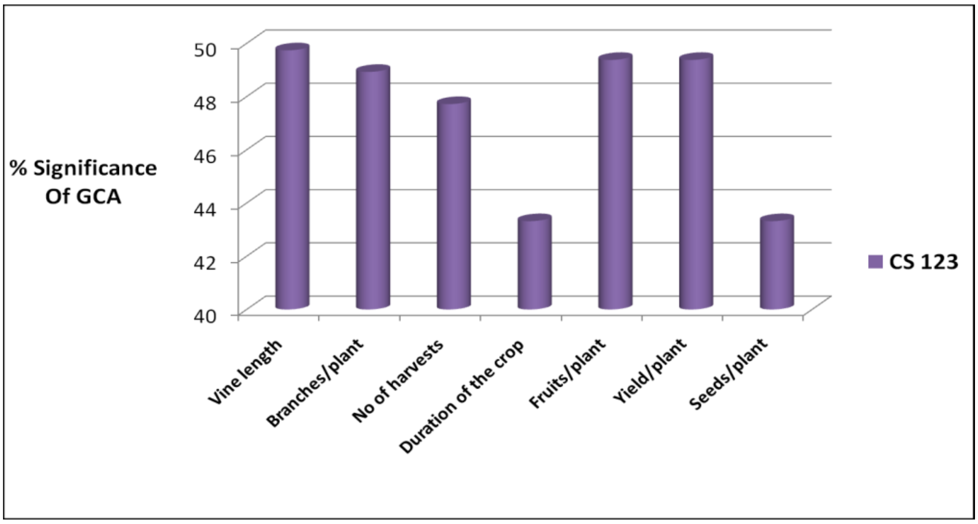

Fig 2. GCA effects of other characters