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Genetic Studies for Different Seed Traits in Cucumber (*Cucumis sativus* L)

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A B S T R A C T

The present investigation was carried out to study the mean performance, heterosis, combining ability and gene action for different seed traits *viz.*, seed germination, seed vigour index-I, seed vigour index-II and fruit yield in 15 F_1 crosses, developed by crossing 6 genotypes during the year 2015. The seeds of all parents and their crosses, along with standard check (KH-1) were assessed for different seed traits (under laboratory conditions) and fruit yield (under open field conditions) during the year 2016. Experimental results revealed that genotypes PI-618860, Khira-75, UHF-CUC-1 and UHF-CUC-2 were found superior on the basis of mean performance, heterosis and general combining ability studies. The cross combinations *viz.*, Khira-75 x PI-618860, Khira-75 x UHF-CUC-1, Khira-75 x UHF-CUC-2 and Khira-75 x PI-618860, UHF-CUC-1 x PI-618860, UHF-CUC-3 x Poinsette, UHF-CUC-3 x PI-618860 were found best on the basis of mean performance, heterosis and specific combining ability studies respectively. Further, Gene action studies indicated the predominant role of non-additive gene action for the control of all the traits under study; hence heterosis breeding can be utilized for the genetic improvement of seed vigour and yield traits in cucumber.

Keywords

Combining ability, Gene action, Heterosis, Seed germination, Seed vigour index-I and II.

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Introduction

Cucumber (*Cucumis sativus* L.) is an agriculturally and economically important vegetable crop, ranking fourth in vegetable production worldwide after tomato, cabbage, and onion (FAOSTAT 2016, http://faostat3.fao.org; Xu *et al.*, 2017). Nowadays, it is grown throughout the world in large commercial farms, glasshouses and small gardens. In India, cucumber is cultivated both in summer and rainy seasons, but it cannot withstand cold injury (Rastogi, 1998). It germinates only in an optimal temperature range of 24 to 28 °C. Today, with the emergence of new crop production technologies, demand for high quality vegetable seeds has increased among the farmers. Because, seed is most significant input factor, solely deciding the success or failure of any crop production programme (Bhardwaj and Kumar, 2012). Use of quality seed material is pre-requisite to realizing greater productivity in any crop (Munamava *et al.*, 2004). Further, crop yield also depends on the seed vigor and successful plant establishment under diverse environmental conditions. Moreover, seeds with poor vigor fail to germinate under adverse climatic conditions. So, there is an urgent need to develop new varieties/hybrids of cucumber having greater seed vigor and successful plant establishment under different environmental conditions (Finch-Savage and Bassel, 2016).

For developing superior varieties, it is necessary to improve the seed vigour and yield in cucumber. This can be achieved through effective utilization of germplasm resources and integration of genomic tools to impart efficiency and pace of breeding processes (Banga, 2012). Exploitation of heterosis in crop plants is one of the most attractive achievements in boosting up the production and productivity of cucumber. Heterosis breeding can be one of the most viable options for breaking the present yield barrier. Cucumber is monoecious in nature and it gives considerable number of seeds per fruit, which provides an opportunity for the exploitation of hybrid vigour in this crop (Bairagi *et al.,* 2002). Selection of suitable parental line is of utmost importance to exploit heterosis in any crop. Further, the knowledge of combining ability analysis is one of the powerful tools available which give the estimates of combining ability effects and side in selecting desirable parents and cross for further exploitation. Combining ability also specify the nature and magnitude of gene action involved in the expression of different quantitative traits (Machikowa, 2011). The importance of heterosis, combining ability and gene action studies for different yield traits in cucumber have been duly realized earlier by several workers like Mule *et al.,* (2012), Kumar *et al.,* (2013a), Golabadi *et al.,* (2015), Kumar *et al.,* (2016) and Kumar *et al.,* (2017). However, till date inadequate information is available in the literature pertaining to heterosis, combining ability and gene action studies for seed traits in cucumber. Therefore, keeping in view the above facts in mind, we have attempted to improve the seed traits and fruit yield per hectare through different estimates of heterosis, combining ability and gene action in cucumber.

Materials and Methods

The investigation was carried out at Experimental Research Farm and Laboratory of the Department of Vegetable Science, Dr YS Parmar University of Horticulture and Forestry, Nauni, Solan (HP), India. During the year 2015, crosses were made between 6 genotypes namely Khira-75, UHF-CUC-1, UHF-CUC-2, UHF-CUC-3, Poinsette and PI-618860 (Table 1). Simultaneously, each genotype was also selfed to get sufficient seeds for sowing in the next year. Thereafter during the year 2016, seeds of all the parents, 15 F_1 hybrids along with standard check cultivar (KH-1) were assessed for different seed traits viz., seed germination (%), seedling length (cm), seedling dry weight (mg), seed vigor index-I and II under laboratory conditions. Simultaneously, seeds of all the genotypes were also evaluated for fruit yield per hectare (q) in randomized complete block design under open field conditions. During both the years of study, standard cultural practices and plant protection measures for raising a healthy crop stand were adopted as per the recommendations given by Directorate of Extension Education, Dr YS Parmar UHF, Nauni, Solan, HP (Anonymous, 2014).

Seed germination of each genotype was tested under laboratory conditions through blot paper method as per the guidelines of ISTA (Anonymous 1985). The seedling length and seedling dry weight were recorded from 20 randomly selected seedlings of each genotype and averaged to get mean value. Seed vigour index-I and II were calculated as per the formulae given by Abdul-Baki and Anderson (1973). Pickings were made regularly from randomly selected 10 plants and were averaged to have total yield per plant. Then total yield per plant was multiplied with total number of plants accommodating in one hectare to obtain fruit yield per hectare. The data recorded for different traits were subjected to analysis of variance in MS Excel-2010 worksheet by using the formulae given by Panse and Sukhatme (1967). The additive and dominance components of variance were estimated by following Singh and Chaudhary (1997) and Dabholkar (1992).

The estimates of heterosis over better parent (BP), standard check (SC) were calculated manually in MS Excel-2010 worksheet by using the following formulae given by Singh (1973). Further, statistical significance of different estimates of heterosis was assessed through the t-test formulae adopted by Wynne *et al.,* (1970).

Results and Discussion

Mean performance and heterosis

The data recorded for seed germination, seed vigour index-I, seed vigour index-II and fruit yield per hectare showed significant differences among the parents and hybrids (Table 2).

The significant variations were observed among the parents and hybrids for seed germination (parents=80.06-85.53 and hybrids=80.54-87.79 %), seed vigor index-I (parents=2251.00-2799.73 and hybrids=2236.78-3014.82), seed vigor index-II (parents=1182.39-1338.34 and hybrids=1123.09-1451.41) and fruit yield per hectare (parents=151.91-290.84 and hybrids=119.40-338.25 q) (Table 2). Substantial variations for seed germination (Hamid *et al.,* 2002; Kumar *et al.,* 2013b; Kumari, 2015), seed vigour (Nerson, 2007; Kumar *et al.,* 2013b; Kumari, 2015) and yield per hectare (Munshi *et al.,* 2007; Kumar *et al.,* 2008; Hanchinamani *et al.,* 2008; Yadav *et al.,* 2009; Kumar *et al.,* 2010; Singh *et al.,* 2010; Hossain *et al.,* 2010; Dogra and Kanwar, 2011; Kumar *et al.,* 2011a; Golabadi *et al.,* 2012, Singh *et al.,* 2012, Airina *et al.,* 2013, Kumar *et al.,* 2013b, Jat *et al.,* 2015 and Kumar *et al.,* 2017) traits had also been reported earlier in different varieties of cucumber. Among the top five parents and hybrids identified on the basis of mean performance and heterosis studies; it was observed that PI-618860, Khira-75, UHF-CUC-1 and UHF-CUC-2 (parents) and Khira-75 x PI-618860, Khira-75 x UHF-CUC-1 and Khira-75 x UHF-CUC-2 (hybrids) excelled for most of the traits under study. These cross combinations also resulted in significantly higher positive heterosis over better parent (Table 3) and standard check cultivar (Table 4). These genotypes can be exploited for seed vigour and fruit yield improvement in cucumber.

Combining ability and gene action

For effective improvement in polygenic traits, information about the combining ability of parents and their crosses, the estimates of genetic components of variance and the type of gene action involved are of prime importance to the breeders.

It guides the breeders to select appropriate parents for heterosis and recombination breeding, hence are important in crop improvement studies. The combining ability studies evaluate the parental lines on the basis of their general combining ability (GCA) effects and the performance of these parents in specific cross combinations (SCA) (Kumar *et al.,* 2016).

Among the parents for GCA effects genotypes, UHF-CUC-1, UHF-CUC-2 and PI-618860 were found good general combiners for seed germination, seed vigour index-I, seed vigour index-II and fruit yield per hectare and exhibited significant positive effects (Table 5).

Table.1 Sources of cucumber genotypes used as parent and check

Lines/Parents	Source
Khira-75	Department of Vegetable Science, UHF, Solan, HP
UHF-CUC-1	Department of Vegetable Science, UHF, Solan, HP
UHF-CUC-2	Department of Vegetable Science, UHF, Solan, HP
UHF-CUC-3	Department of Vegetable Science, UHF, Solan, HP
Poinsette	IARI, Regional Research Station, Katrain, Kullu Valley, HP
PI-618860	North Central Regional Plant Introduction Station, USA
KH-1 (Check)	Department of Vegetable Science, UHF, Solan, HP

Table.2 Mean performance of parents, crosses and standard check cultivar for seed traits and fruit yield in cucumber

Traits → Parents & Crosses ↓	Seed Germination	Seed Vigour Index-I	Seed Vigour Index-II	Yield Per Plot (kg)	Yield Per Hectare (q)
Khira-75	83.40 (9.13) **	2766.70	1326.42	39.73	264.87
UHF-CUC-1	84.49 (9.19)	2641.21	1338.34	35.90	239.31
UHF-CUC-2	83.82 (9.16)	2507.08	1337.52	35.98	239.88
UHF-CUC-3	80.85 (8.99)	2360.86	1207.34	28.59	190.60
Poinsette	80.06 (8.95)	2251.00	1182.39	22.79	151.91
PI-618860	85.53 (9.25)	2799.73	1334.74	43.63	290.84
Khira-75 x UHF-CUC-1	86.46 (9.30)	2828.35	1368.32	48.87	325.81
Khira-75 x UHF-CUC-2	86.41 (9.30)	2869.57	1408.86	49.06	327.04
Khira-75 x UHF-CUC-3	81.83 (9.05)	2387.14	1225.02	22.52	150.13
Khira-75 x Poinsette	80.54 (8.97)	2236.78	1123.09	17.91	119.40
Khira-75 x PI-618860	87.79 (9.37)	3014.82	1451.41	50.74	338.25
UHF-CUC-1 x UHF-CUC-2	85.42 (9.24)	2631.98	1372.41	43.84	292.25
UHF-CUC-1 x UHF-CUC-3	80.56 (8.98)	2239.81	1183.51	26.01	173.38
UHF-CUC-1 x Poinsette	81.66 (9.04)	2644.09	1205.92	29.28	195.17
UHF-CUC-1 x PI-618860	85.48 (9.25)	2858.31	1378.77	46.65	311.01
UHF-CUC-2 x UHF-CUC-3	81.40 (9.02)	2323.89	1133.79	19.98	133.19
UHF-CUC-2 x Poinsette	82.39 (9.08)	2640.47	1244.32	32.21	214.72
UHF-CUC-2 x PI-618860	85.58 (9.25)	2867.60	1439.31	46.60	310.68
UHF-CUC-3 x Poinsette	81.37 (9.02)	2341.54	1163.12	20.99	139.96
UHF-CUC-3 x PI-618860	81.45 (9.03)	2242.18	1181.10	21.77	145.10
Poinsette x PI-618860	80.67 (8.98)	2334.51	1211.23	22.59	150.58
KH-1 (check)	**82.59 (9.09)**	**2596.32**	**1305.07**	**30.62**	**204.14**
Range	**80.54-87.79**	**2236.78-3014.82**	**1123.09-1451.41**	**17.91-50.74**	**119.40-338.25**
Population mean	**83.17**	**2562.91**	**1278.27**	**33.47**	**223.10**
SE(m)±	**0.84**	**85.49**	**52.91**	**3.64**	**24.24**
$CD_{(0.05)}$	**1.68**	**171.15**	**105.92**	**7.28**	**48.53**

*Significant at 5% level of significance

** Figures present in Parenthesis are square root transformed

Table.3 Crosses showing heterobeltiosis for seed traits and fruit yield in cucumber

Traits → Crosses ↓	Seed Germination	Seed Vigour Index-I	Seed Vigour Index-II	Yield Per Plot (kg)	Yield Per Hectare (q)
Khira-75 x UHF-CUC-1	2.33*	2.23*	2.24*	23.01*	23.01*
Khira-75 x UHF-CUC-2	3.09*	3.72*	5.33*	23.48*	23.47*
Khira-75 x UHF-CUC-3	-1.88	-13.72*	-7.64*	-43.32*	-43.32*
Khira-75 x Poinsette	-3.43*	-19.15*	-15.33*	-54.92*	-54.92*
Khira-75 x PI-618860	2.64*	7.68*	8.74*	16.30*	16.30*
UHF-CUC-1 x UHF-CUC-2	1.10	-0.35	2.55*	21.85*	21.83*
UHF-CUC-1 x UHF-CUC-3	-4.65*	-15.20*	-11.57*	-27.55*	-27.55*
UHF-CUC-1 x Poinsette	-3.35*	0.11	-9.89*	-18.44*	-18.44*
UHF-CUC-1 x PI-618860	-0.06	2.09*	3.02*	6.92*	6.94*
UHF-CUC-2 x UHF-CUC-3	-2.89*	-7.31*	-15.23*	-44.47*	-44.48*
UHF-CUC-2 x Poinsette	-1.71	5.32*	-6.97*	-10.48*	-10.49*
UHF-CUC-2 x PI-618860	-1.50	2.42*	7.61*	6.81*	6.82*
UHF-CUC-3 x Poinsette	0.64	-0.82	-3.66*	-26.58*	-26.57*
UHF-CUC-3 x PI-618860	-4.77*	-19.91*	-11.51*	-50.10*	-50.11*
Poinsette x PI-618860	-5.68*	-16.62*	-9.25*	-48.22*	-48.23*
Range	**-5.68-3.09**	**-19.91-7.68**	**-15.33-8.74**	**-54.92-23.48**	**-54.92-23.47**

Table.4 Crosses showing standard heterosis for seed traits and fruit yield in cucumber

Traits → Crosses ↓	Seed Germination	Seed Vigour Index-I	Seed Vigour Index-II	Yield Per Plot (kg)	Yield Per Hectare (q)
Khira-75 x UHF-CUC-1	4.69*	8.94*	4.85*	59.60*	59.60*
Khira-75 x UHF-CUC-2	4.63*	10.52*	7.95*	60.22*	60.20*
Khira-75 x UHF-CUC-3	-0.92	-8.06*	-6.13*	-26.45*	-26.46*
Khira-75 x Poinsette	-2.48*	-13.85*	-13.94*	-41.51*	-41.51*
Khira-75 x PI-618860	6.30*	16.12*	11.21*	65.71*	65.70*
UHF-CUC-1 x UHF-CUC-2	3.43*	1.37	5.16*	43.17*	43.16*
UHF-CUC-1 x UHF-CUC-3	-2.46*	-13.73*	-9.31*	-15.06*	-15.07*
UHF-CUC-1 x Poinsette	-1.13	1.84	-7.60*	-4.38*	-4.39*
UHF-CUC-1 x PI-618860	3.50*	10.09*	5.65*	52.35*	52.35*
UHF-CUC-2 x UHF-CUC-3	-1.44	-10.49*	-13.12*	-34.75*	-34.76*
UHF-CUC-2 x Poinsette	-0.24	1.70	-4.65*	5.19*	5.18*
UHF-CUC-2 x PI-618860	2.01	10.45*	10.29*	52.19*	52.19*
UHF-CUC-3 x Poinsette	-1.48	-9.81*	-10.88*	-31.45*	-31.44*
UHF-CUC-3 x PI-618860	-1.38	-13.64*	-9.50*	-28.90*	-28.92*
Poinsette x PI-618860	-2.32*	-10.08*	-7.19*	-26.22*	-26.24*
Range	**-2.48-6.30**	**-13.85-16.12**	**-13.94-11.21**	**-41.51-65.71**	**-41.51-65.70**

Table.5 Estimates of general combining ability effects of parents for different seed traits and fruit yield in cucumber

Traits → Parents ↓	Seed germination (%)	Seed vigour Index I	Seed vigour Index II	Marketable yield per plot (kg)	Marketable yield per hectare (q)
Khira-75	-0.11	20.51	14.27	1.39	9.28
UHF-CUC-1	1.45*	109.63*	43.05*	4.83*	32.22*
UHF-CUC-2	0.80*	56.70*	40.05*	4.93*	32.87*
UHF-CUC-3	-1.05*	-98.19*	-46.49*	-4.92*	-32.77*
Poinsette	-1.69*	-153.95*	-84.49*	-8.66*	-57.73*
PI-618860	0.60*	65.31*	33.60*	2.42*	16.13*
SE(gi)	0.191	19.689	11.984	0.84	5.597
SE (gi-gj)	0.295	30.502	18.566	1.301	8.671
CD (gi)	**0.40**	**40.95**	**24.93**	**1.75**	**11.64**
CD (gi-gj)	0.61	63.44	38.62	2.71	18.04

*Significant at 5% level of significance

Table.6 Estimates of specific combining effects of parents for different seed traits and fruit yield in cucumber

Traits → Parents ↓	Seed germination (%)	Seed vigour Index-I	Seed vigour Index-II	Yield per plot (Kg)	Yield per hectare (q)
Khira-75 x UHF-CUC-1	-0.05	-50.24	4.02	-3.93	-26.19
Khira-75 x UHF-CUC-2	-0.07	-131.45*	6.20	-3.94	-26.28
Khira-75 x UHF-CUC-3	-1.19*	-122.77*	-37.44	-1.49	-9.92
Khira-75 x Poinsette	-1.34*	-176.88*	-24.39	-3.55	-23.65
Khira-75 x PI-618860	1.84*	152.60*	9.87	6.21*	41.43*
UHF-CUC-1 x UHF-CUC-2	0.97	141.93*	48.76	5.69*	37.96*
UHF-CUC-1 x UHF-CUC-3	-1.77*	-185.61*	-48.54	-11.00*	-73.33*
UHF-CUC-1 x Poinsette	-2.42*	-280.22*	-112.47*	-11.86	-79.09*
UHF-CUC-1 x PI-618860	2.55*	278.57*	97.77*	9.88*	-65.90*
UHF-CUC-2 x UHF-CUC-3	-2.39*	-280.02*	-87.05*	-7.61*	-50.73*
UHF-CUC-2 x Poinsette	-0.65	180.03*	-26.64	-0.60	-3.98*
UHF-CUC-2 x PI-618860	0.89	174.98*	28.12	5.70*	38.01*
UHF-CUC-3 x Poinsette	1.93*	331.30*	98.30*	12.18*	81.21*
UHF-CUC-3 x PI-618860	2.83*	339.17*	175.20*	15.50*	103.32*
Poinsette x PI-618860	-0.65	-230.50*	-45.01	-5.60*	-37.30*
SE(sij)	0.524	54.075	32.913	2.306	15.373
SE(sij-sik)	0.10	0.10	0.10	0.10	0.10
SE(sij-skl)	0.724	74.715	45.476	3.186	21.24
CD(sij)	**1.09**	**112.48**	**68.46**	**4.80**	**31.98**
CD(sij-sik)	0.21	0.21	0.21	0.21	0.21
CD(sij-skl)	1.51	155.41	94.59	6.63	44.18

Table.7 Estimates of genetic components of variance for different seed traits and fruit yield in cucumber

Character	gca	sca	σ^2g	σ^2s	Variance ratio (σ^2g/σ^2s)	Predictability ratio ($2\sigma^2g/2\sigma^2g + \sigma^2s$)
Seed germination (%)	11.307	3.946	1.28	2.90	0.44	0.46
Seed vigour Index-I	85212.818	59190.534	9256.02	48025.86	0.19	0.27
Seed vigour Index-II	22542.765	6966.154	2300.82	2829.97	0.81	0.62
Marketable yield per plot (kg)	247.309	87.835	28.38	67.53	0.42	0.45
Marketable yield per hectare (kg)	10992.199	3903.782	1261.24	3001.48	0.42	0.45

Similar findings have been reported by Kumar, 2013 and Kumari, 2015 for seed germination, seed vigour index-I and seed vigour index-II and Kumbhar *et al.*, (2005), Munshi *et al.*, (2006), Singh and Sharma (2006), Yadav *et al.*, (2007), Hanchinamani and Patil (2009), Dogra and Kanwar (2011), Khuswaha *et al.*, (2011), Kumar *et al.*, (2011b), Olfati *et al.*, (2012), Bairagi *et al.*, (2013), Kumar *et al.*, (2013), Golabadi *et al.*, (2015) and Kumar *et al.*, (2017) for fruit yield in cucumber.

For various seed traits *viz.*, seed germination, seed vigour index-I, seed vigour index-II and fruit yield, crosses Khira-75 x PI-618860, UHF-CUC-1 x PI-618860, UHF-CUC-3 x Poinsette and UHF-CUC-3 x PI-618860 recorded significantly high positive specific combining ability (SCA) effects among all the hybrids under study (Table 6). Similar findings for seed traits have been reported by Kumar, 2013 and Kumari, 2015. These crosses indicated the role of both additive and non-additive gene action for improvement of these seed traits. The crosses having the parents with good × good GCA effects can be utilized to get transgressive segregants in early generations i.e., F_2. While, hybrid combination having the parents with good × average GCA effects may give desirable transgressive segregants in the later segregating generations and cross combinations having the parents with good × poor GCA effects may be utilized for exploitation of heterosis in F_1 generation. However, for fruit yield Dogra and Kanwar (2011), Kushwaha *et al.*, (2011), Kumar *et al.*, (2013a), Golabadi *et al.*, (2015), Kalidas *et al.*, (2015) and Kumar *et al.*, (2017) had also reported significant positive GCA and SCA effects.

A perusal of the data presented in table 7 indicated that the estimates of σ^2 SCA were higher in magnitude as compared to σ^2 GCA (average) for all the traits under study, thereby indicating the predominant role of non-additive gene action governing all the traits. Further, predictability ratio ($2\sigma^2g/(2\sigma^2g+\sigma^2s)$) was found less than one for all the traits *viz.*, seed germination (0.46), seed vigour index-I (0.27), seed vigour index-II (0.62) and fruit yield per hectare (0.45). Again it confirmed the role of non-additive gene action controlling all the traits under study; hence heterosis breeding can be utilized for the improvement of seed vigour and yield traits in cucumber. Dogra and Kanwar (2011), Kumar *et al.*, (2013a), Golabadi *et al.*, (2015) and Kumar *et al.*, (2017) had also reported pre-dominance of non-additive gene action for fruit yield in cucumber.

From the present studies it is concluded that genotypes Khira-75, UHF-CUC-1, UHF-CUC-2 and PI-618860 were found superior on the basis of mean performance and general combining ability studies. While cross combination *viz.*, Khira-75× PI-618860, Khira-75× UHF-CUC-1, Khira-75× UHF-

CUC-2 and Khira-75 x PI-618860, UHF-CUC-1 x PI-618860, UHF-CUC-3 x Poinsette, UHF-CUC-3 x PI-618860 were found best on the basis of mean performance, heterosis and specific combining ability studies respectively. These, hybrids can be released for commercial cultivation in different parts of the country after multilocation testing. While identified novel genotypes viz., Khira-75, UHF-CUC-1, UHF-CUC-2 and PI-618860 can be utilized worldwide for the exploitation of heterosis for seed vigour and yield improvement in cucumber.

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