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Generation mean analysis of earliness and fruit yield related traits in Cucumber

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ABSTRACT

Gene effects associated with earliness and yield-related traits offer an advantage in selecting appropriate breeding strategies to bring improvement of fruit yield in Cucumber (*Cucumis sativus* L.). Therefore, a generation mean analysis study was conducted to investigate the gene effects present in traits like plant height, days to the first female flower, number of female flower-bearing nodes, number of lateral branches, days took to first fruit harvest, fruit length of fruit and fruit width using three cross combinations viz., Pusa Barkha × Pusa Parthenocarpic Cucumber-6, Pusa Uday × Pusa Parthenocarpic Cucumber-6 and Punjab Naveen × Pusa Parthenocarpic Cucumber-6. All six generations P1, P2, F1, F2, BC1P1 and BC2P2 were developed. Scaling test results indicated that the simple additive-dominance model is inefficient in describing gene effects in all three crosses, and interallelic interactions are present for all traits under study. Additive gene effects were significant in at least one cross out of three for all traits under study except the number of lateral branches and fruit width. In cross Punjab Naveen × Pusa Parthenocarpic Cucumber-6, a significant negative dominant gene effect was recorded for days to the first female flower and days to the first fruit harvest, indicating earliness in this cross combination, for the number of female flower-bearing nodes, significant positive dominant effects were present in cross combinations of Pusa Barkha × Pusa Parthenocarpic Cucumber-6 and Pusa Uday × Pusa Parthenocarpic Cucumber-6. For fruit length, Punjab Naveen × Pusa Parthenocarpic Cucumber-6 combination possessed a significant additive gene effect which can be tapped through a simple selection procedure.

Keywords: *Cucumis sativus*, Dominance, Epistatic, Generation, Gene effect.

INTRODUCTION

Cucumber (*Cucumis sativus* L.) is one of the most versatile vegetable plants of the *Cucurbitaceae* family, with chromosome number 2n = 2x = 14. It is a monoecious, annual plant of trailing growth habit that has been under cultivation in various parts of the world for thousands of years. It is believed to have originated in India (Sebastian *et al*., 7; Yundaeng *et al*. 12) from its wild ancestor *Cucumis sativus* var. *hardwickii* R. Alef and is still distributed throughout the southern Himalayan belt. To its geographical location, it can be divided into four groups such as the Indian group, the Eurasian group, the East Asian group, and the Xishuangbanna group (Qi *et al*., 5). Globally, cucumber is considered to be the most revered vegetable crop in fourth place after tomatoes, cabbage, and onions (Tatlioglu, 11). Cucumber is grown mainly for its soft, crispy, shiny fruits, which are eaten either fresh or processed forms like salads or *raita*. Fruits are a rich source of vitamins A, C, and folic acid, and firm skin has various minerals such as calcium, potassium, and magnesium. India possesses a wide range of genetic diversity depending on plant growth habits, fruit size, fruit composition, skin colour, and fruit surface (Staub *et al*., 9), but this variability has never been fully utilized for crop improvement. Genetic evaluation of germplasm for yield attributes can prove fruitful in the initial selection of lines during the development of new varieties. With the view of the development of new cross combinations and their evaluation for gene effects this study was planned. Firstly, new combinations were developed and then evaluated for gene effects in action to get an idea about breeding methods that can result in considerable improvement.

MATERIALS AND METHODS

The present investigation was carried out at Research Farm, Division of Vegetable Science, Indian Agricultural Research Institute, New Delhi. Plant materials *viz*., Pusa Barkha, PPC-6, Pusa Uday and Punjab Naveen were used (Table 1). Hybrid combinations of Pusa Barkha × PPC-6, Pusa Uday × PPC-6 and Punjab Naveen × PPC-6 were selfed to raise F_2 generation. F_1 plants were backcrossed with either parent to raise BC_1P_1 (B_1) and BC_1P_2 (B_2) generations. The six generations (P_1, P_2, F_1, F_2,

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Table 1. Details of cucumber genotypes and their cross combinations included in study.

Sr. No.	Genotype/Variety	Source of Collection	Cross Combination
1	Pusa Barkha	IARI, New Delhi	Cross I - Pusa Barkha × PPC-6
2	Pusa Uday	IARI, New Delhi	Cross II - Pusa Uday × PPC-6
3	Punjab Naveen	PAU, Ludhiana	Cross III - Punjab Naveen × PPC-6
4	Pusa Parthenocarpic Cucumber-6 (PPC-6)	IARI, New Delhi	-

B_1 and B_2) of these crosses were evaluated under randomized block design with three replications during *kharif* season. Three to four seeds were sown on the side of the channel in a well prepared hill, with a spacing of 1.5 m between channels and 60cm between hills. All the recommended agronomic practices along with plant protection measures were followed to raise an ideal crop. Data were recorded on five plants each, of parents (P_1 and P_2) and F_1, 15 plants each of B_1 and B_2 and 40 plants each of F_2 from each replication on seven quantitative characters viz. plant height, number of lateral branches, days to first female flower, number of female flower bearing nodes, days taken to first fruit harvest, fruit length (cm) and fruit width (cm). The fruits were harvested at marketable stage. The data were subject to scaling tests (Hayman, 3) to identify the interacting and non-interacting crosses. The data from interacting crosses were analyzed through 6-parameters model (Hayman, 3; Jinks and Jones, 4). The estimates of mean and gene effects for interacting crosses, i.e. mean (*m*), additive (*d*), dominance (*h*), additive × additive (*i*), additive × dominance (*j*) and dominance × dominance (*l*) were obtained for yield related traits.

RESULTS AND DISCUSSION

Generation mean values (Table 2) were subjected to scaling test to separate interacting and non-interacting crosses by testing the adequacy of scale through scaling tests (Hayman 1958) for all the seven traits under study. Four test scales (A, B, C and D) have been used where significance of *A* and *B* scales indicate additive × dominance (*j*), *C* dominance × dominance (*l*) and *D* additive × additive (*i*) type of gene interactions respectively. When the scale is adequate, the values of *A*, *B*, *C* and *D* would be non-significant. The results of the scaling tests are presented in Table 3. Table 3 revealed that all crosses combinations were having more than one significant scales for all traits under study indicating the presence of epistatic or non-allelic interactions and inadequacy of additive-dominance model.

The gene effects for seven agronomic characters in all interacting crosses have been presented in Table 4. For plant height, all cross combinations had a significant positive additive gene effect which is undesirable and for non-allelic interactions, additive × additive type interactions were significantly negative for cross-I and cross-III gene effects were highly significant. Similar negative signs of '*h*' and '*l*' components reflected complementary form of epistasis for cross-I and cross-II and different signs represent duplicate epistasis in cross-III. Complementary epistasis in cross-I reflects that dominance at the loci is in negative direction i.e. towards reduced plant height and hence tend to increase heterosis in negative direction. Duplicate epistasis in rest two combinations indicates the presence of both additive and non-additive effects and lack of heterosis in positive direction. For number of lateral branches, cross I exhibited significant additive gene effects and additive × dominance type of gene interactions. Nature of epistasis was complementary. For Pusa Uday × Pusa Parthenocarpic Cucumber-6 cross dominance × dominance type of epistatic interactions were significant with duplicate nature. Due to predominance of additive gene effects in cross-I simple selection can be practiced in segregating generations for improvement of number of lateral branches in this cross combination. Bairagi *et al*. (1) and Rai *et al*. (6) also reported additive as well as dominance gene action in cucumber for vegetative characters.

Desirable results were reported in all three cross combinations in relation to days to first female flower trait which is directly related with earliness. For gene effects dominant effect was predominant in desired direction for cross III while in rest two combinations it was positive in undesirable direction. Among gene interactions dominant × dominant type were highly negative and significant for cross I and cross II and additive × additive in cross III. Different signs of dominance (*h*) and dominance × dominance (*l*) components reflected duplicate nature of epistasis in all combinations. Significance of dominant component indicates that heterosis breeding or recurrent selection would be a better strategy to improve this trait in crosses included in this study. Another parameter reflecting earliness i.e., days taken to first fruit harvest was recorded for all crosses in all six generations. Both additive and

Table 2. Estimates of generation mean ± SE_m of yield related traits.

Traits/cross	Generations					
	P_1	P_2	F_1	F_2	BC_1P_1	BC_2P_2
			Plant Height (cm)			
Cross I	375 ± 2.94	147.30±2.82	275.50±1.71	333.65±1.65	431.90 ±4.32	220.10 ± 3.43
Cross II	265.40±1.43	145.90±3.52	228.00±3.62	354.10±114.27	212.00±2.06	161.70 ±6.00
Cross III	415.50±2.07	148.00±3.66	217.50±5.94	325.55 ± 1.84	325.20± 1.84	163.30 ± 6.48
			Number of Lateral Branches			
Cross I	12.00 ± 1.06	7.20 ±0.32	14.30±0.36	20.20 ±0.43	20.30 ±0.42	13.50 ± 0.42
Cross II	12.40±0.33	7.00±0.33	9.50 ± 0.34	14.75 ± 0.48	9.70 ± 0.51	10.40 ± 0.74
Cross III	18.80 ± 0.57	12.70 ± 5.81	13.50 ±0.50	15.15±0.41	20.30±0.51	12.60±0.45
			Days to First Female Flower			
Cross I	71.50 ±0.54	56.70±0.49	66.60±0.71	63.50±0.85	73.20±0.99	64.40±1.19
Cross II	74.80±0.84	55.90±0.52	65.60±0.70	72.35±0.78	84.90±0.80	69.90±0.52
Cross III	80.80±0.64	55.70±0.86	71.90±0.73	80.45±0.44	71.00±0.98	66.80±0.64
			Number of Female Flower Bearing Nodes			
Cross I	12.30±0.47	23.40±0.76	25.10±0.82	11.25±0.31	13.00±0.57	23.70±0.74
Cross II	6.90±0.31	23.00±0.47	12.00±0.33	13.05±0.35	11.80±0.41	20.00±0.78
Cross III	6.50±0.34	22.80±0.61	12.40±0.54	11.90±0.27	11.60±0.56	14.60±0.56
			Days Taken to First Fruit Harvest			
Cross I	80.90±0.64	63.70±0.93	74.10±0.84	84.90±0.63	77.60±1.06	81.50±0.67
Cross II	84.80±0.67	64.50±0.68	77.00±1.35	87.05±0.60	101.50±0.71	84.80±0.80
Cross III	92.70±0.59	65.50±1.11	87.80±1.67	90.45±0.51	80.80±1.62	85.80±0.67
			Fruit Length (cm)			
Cross I	14.69±0.15	14.05±0.10	15.19±0.25	16.47±0.06	15.42±0.07	16.44±0.08
Cross II	14.09±0.08	14.07±0.09	16.85±0.32	13.63±0.67	13.21±0.09	14.52±0.18
Cross III	12.11±0.15	13.89±0.09	12.87±0.15	15.40±0.13	16.72±0.14	14.08±0.19
			Fruit Width (cm)			
Cross I	4.16±0.05	3.53±0.08	3.50±0.11	3.57±0.06	3.77±0.04	3.80±0.05
Cross II	4.37±0.04	3.45±0.06	4.32±0.09	4.05±0.04	4.07±0.05	3.91±0.06
Cross III	3.90±0.05	3.66±0.06	4.22±0.06	4.12±0.05	4.31±0.07	4.25±0.07

dominant gene effects were negatively significant in desired direction for cross-I, cross-III, and epistatic interactions of additive × additive, additive × dominance type were also, highly significant. For cross-I similar negative signs of dominance (*h*) and dominance × dominance (*l*) component reflected complementary nature of epistasis indicating the dominance at the loci in negative direction, i.e., towards earliness while in other two crosses it is duplicate in nature which shows negative direction of heterosis (Table 5). Due to preponderance of dominance gene effects in cross-I and cross-III heterosis breeding or recurrent selection would be the best strategy to improve this trait. The results of traits associated with earliness are in conformity with the findings of other authors (Shahi *et al.,* 8; Choudhary and Singh, 2; Tiwari *et al*., 10).

For number of female flower bearing nodes dominant gene effect was found significant in cross-I and cross-II and among epistatic interactions additive × additive type interactions were significantly positive in desirable direction. Duplicate nature of epistasis was evident from the different signs of dominance and dominance × dominance components in all combinations. Higher magnitude of dominant gene effects in cross I and cross II indicates feasibility of heterosis breeding or recurrent selection in bringing improvement in these two combinations

Table 3. Scaling test of three hybrid combinations for seven yield related traits.

Trait / Cross	Scales			
	A	B	C	D
		Plant Height (cm)		
Cross I	212.80**±9.31	17.40*±7.62	260.80**±8.51	15.30*±6.44
Cross II	-69.40**±5.66	-50.50**±13.01	549.10±457.19	334.50±228.64
Cross III	17.40*±7.30	-38.90*±14.74	303.70**±18.74	162.60**±9.67
		Number of Lateral Branches		
Cross I	14.30**±1.41	5.50**±0.99	33.00**±2.18	6.60**±1.05
Cross II	-2.50*±1.14	4.30*±1.57	20.60**±2.11	9.40**±1.33
Cross III	8.30**±1.28	-1.00±5.90	2.10±6.15	-2.60*±1.07
		Days to First Female Flower		
Cross I	8.30**±2.18	5.50*±2.54	-7.40±3.76	-10.60**±2.30
Cross II	29.40**±1.95	18.30**±1.37	27.50**±12.91	-10.10**±1.85
Cross III	-10.70**±2.20	6.00**±1.72	41.50**±2.55	23.10**±1.47
		Number of Female Flower Bearing Nodes		
Cross I	-11.40**±1.49	-1.10±1.86	-40.90**±2.25	-14.20**±1.13
Cross II	4.70**±0.95	5.00**±1.68	-1.70±1.65	-5.70**±1.13
Cross III	4.30**±1.29	-6.00**±1.72	-6.50**±1.68	-2.40**±0.96
		Days Taken to First Fruit Harvest		
Cross I	0.20±2.38	25.20**±1.84	46.80**±3.26	10.70**±1.79
Cross II	41.20**±2.09	28.10**±2.21	44.90**±3.75	-12.20**±1.61
Cross III	-18.90**±3.69	18.30**±2.43	28.00**±4.12	14.30**±2.03
		Fruit Length (cm)		
Cross I	0.96**±0.32	3.64**±0.32	6.78**±0.60	1.09**±0.18
Cross II	-4.52**±0.38	-1.88**±0.51	-7.34*±2.77	0.47±1.36
Cross III	8.46**±0.36	1.40*±0.42	9.86**±0.64	-
Fruit Width (cm)				
Cross I	-0.12±0.15	0.57**±0.18	-0.39±0.35	1.09**±0.18
Cross II	-0.55**±0.16	0.05±0.17	-0.26±0.26	0.12±0.13
Cross III	0.50**±0.17	0.62**±0.16	0.48±0.29	-0.32*±0.16

* P= 0.05, ** P= 0.01,

for number of female flower bearing nodes. For fruit length combination of Punjab Naveen × Pusa Parthenocarpic Cucumber-6 showed significant additive gene effect and additive × additive, dominance × dominance interactions while rest two combinations had significant negative interactions in undesirable direction. Epistasis operating in all three combinations was of complementary nature. For cross-II complementary epistasis of positive sign indicates the heterosis in desirable direction while in rest combinations negative signs of epistasis are in undesirable direction. Higher magnitude of additive component and its interaction of additive × additive type in cross-III indicates that simple selection procedures can prove efficient in improving this trait. For fruit width, cross-III had significant dominant gene effect and additive × additive type of epistatic interactions both in desirable direction. Cross-I had insignificant gene effects while additive × additive interactions were positively significant. Different signs of dominance (*h*) and dominance × dominance (*l*) components reflected duplicate nature of epistasis in these cross combinations (Table 5). Predominance of dominant effects indicates heterosis breeding or recurrent selection can be very useful in bringing improvement for this trait. Prevalence of additive

Table 4. Estimates of additive, dominance and epistatic interactions for quantitative traits in cucumber (six parameter model).

Traits	m	d	h	i	j	l
			Plant Height (cm)			
Cross I	333.65**±1.66	211.80**±5.52	-16.50±13.16	-30.60*±12.89	97.70*±5.89	-199.60**±23.68
Cross II	354.10**±114.28	50.30**±6.34	-646.65±457.31	-669±457.30	-9.45±6.62	788.90 ± 457.90
Cross III	325.55** ± 3.47	161.90**±6.75	-389.45**±20.35	-325.20**±19.34	28.15**±7.07	346.70**± 32.85
			Number of Lateral Branches			
Cross I	20.20**±0.43	6.80**±0.60	-8.50**±2.21	-13.20**±2.11	4.40**±0.82	-6.60 ± 3.25
Cross II	14.75**±0.49	-0.70±0.91	-19.00**±2.70	-18.80**±2.66	-3.40**±0.94	17.00* ± 4.21
Cross III	15.15**±0.41	7.70±0.69	2.95±3.66	5.2*±2.15	4.65±3.00	-12.50 ± 6.74
			Days to First Female Flower			
Cross I	63.50**±0.85	8.80**±1.56	23.70**±4.68	21.20**±4.61	1.4±1.6	-35.00** ± 7.28
Cross II	72.35**±0.79	15.00**±0.97	20.45**±3.80	20.20**±3.70	5.55**±1.09	-67.90** ± 5.27
Cross III	80.45**±0.44	4.20**±1.18	-42.55**±3.09	-46.20**±2.96	-8.35±1.30	50.90** ± 5.37
			Number of Female Flower bearing Nodes			
Cross I	11.25**±0.32	-10.70**±0.94	35.65**±2.46	28.40**±2.27	-5.15**±1.05	-15.90**±4.40
Cross II	13.05**±0.35	-8.20**±0.89	8.45**±2.31	11.40**±2.27	-0.15 ±0.94	-21.10**±3.93
Cross III	11.90**±0.27	-3.00**±0.79	2.55±2.03	4.80*±1.92	5.15**±0.87	-3.10 ± 3.60
			Days Taken to First Fruit Harvest			
Cross I	84.90**±0.64	-3.90**±1.26	-19.60**±3.72	-21.40**±3.58	-12.50**±1.38	-4.00 ± 6.00
Cross II	87.05**±0.60	16.70**±1.08	26.75**±3.53	24.40**±3.22	6.55** ± 1.18	-93.70** ± 5.71
Cross III	90.45**±0.51	-5.00**±1.76	-19.90**±4.44	-28.60**±4.06	-18.60**±1.87	29.20** ± 8.14
			Fruit Length (cm)			
Cross I	16.48**±0.07	-1.02**±0.12	-1.36**±0.45	-2.18**±0.36	-1.34**± 0.15	-2.42** ± 0.76
Cross II	13.63**±0.67	-1.31**±0.21	3.71±2.74	0.94±2.72	-1.32**± 0.22	5.46 ± 2.90
Cross III	15.40**±0.13	2.64**±0.24	-0.13±0.74	3.53**±0.26	-0.22±0.00	-9.86** ± 1.16
			Fruit Width (cm)			
Cross I	3.58**±0.06	-0.03±0.08	0.50±0.32	0.84**±0.29	-0.35**± 0.09	-1.29** ± 0.47
Cross II	4.05**±0.05	0.16±0.09	0.17±0.27	-0.24±0.25	-0.30**± 0.10	0.74 ± 0.44
Cross III	4.12**±0.06	0.06±0.10	1.08**±0.32	0.64*±0.31	-0.06 ± 0.11	-1.76** ± 0.50

*P=0.05, ** P=0.01

effects for these yield attributing traits is in line with the findings of Tiwari *et al*. (10) and Rai *et al*. (6).

For traits associated with earliness (days to first female flower and days to first fruit harvest), cross combination of Punjab Naveen × Pusa Parthenocarpic Cucumber-6 exhibited dominant gene effect and for fruit length and fruit width additive and dominant effects were prominent in this combination. For other fruit yield parameters like number of lateral branches, number of female flower bearing nodes cross combination of Pusa Barkha × Pusa Parthenocarpic Cucumber-6 showed additive and dominant gene effects in desired direction. The cross combinations where the gene effects were either entirely additive or dominant can be relied upon to practice individual plant selection in segregating plant material or heterosis breeding and recurrent selection respectively to bring the improvement in respect to yield or earliness traits. The study's overall results showed that the traits exhibited complex genetic behaviour. Simple selection in early segregating generations may not be effective for the improvement of these traits. Complex genetic behaviour, particularly additive and dominance components, could be exploited in later generations. Selection for improvement of all the traits should be delayed to later segregating population generations in cucumber. Heterosis breeding is feasible due to

Table 5. Estimates of heterotic effects and epistasis in three hybrid combination.

Traits/Cross	Heterotic Effect (h+l)-(d-i)	Sign of h, l	Type of Epistasis
	Plant Height (cm)		
Cross I - Pusa Barkha × PPC-6	-458.50	-h,-l	Complementary
Cross II - Pusa Uday × PPC-6	-577.05	-h, +l	Duplicate
Cross III - Punjab Naveen × PPC-6	-529.85	-h, +l	Duplicate
	Number of Lateral Branches		
Cross I - Pusa Barkha × PPC-6	-34.80	-h, -l	Complementary
Cross II - Pusa Uday × PPC-6	-20.10	-h, +l	Duplicate
Cross III - Punjab Naveen × PPC-6	-12.05	+h, -l	Duplicate
	Days to First Female Flower		
Cross I - Pusa Barkha × PPC-6	1.1	+h, -l	Duplicate
Cross II - Pusa Uday × PPC-6	-42.25	+h, -l	Duplicate
Cross III - Punjab Naveen × PPC-6	-42.05	-h, +l	Duplicate
	Number of Female Flower Bearing Nodes		
Cross I - Pusa Barkha × PPC-6	58.85	+h, -l	Duplicate
Cross II - Pusa Uday × PPC-6	6.95	+h, -l	Duplicate
Cross III - Punjab Naveen × PPC-6	7.25	+h, -l	Duplicate
Days Taken to First Fruit Harvest			
Cross I - Pusa Barkha × PPC-6	-41.10	-h, -l	Complementary
Cross II - Pusa Uday × PPC-6	-59.25	+h, -l	Duplicate
Cross III - Punjab Naveen × PPC-6	-14.30	-h, +l	Duplicate
	Fruit Length (cm)		
Cross I - Pusa Barkha × PPC-6	-6.28	-h, -l	Complementary
Cross II - Pusa Uday × PPC-6	11.42	+h, +l	Complementary
Cross III - Punjab Naveen × PPC-6	-12.63	-h, -l	Complementary
	Fruit Width (cm)		
Cross I - Pusa Barkha × PPC-6	0.08	+h, -l	Duplicate
Cross II - Pusa Uday × PPC-6	0.51	+h, +l	Complementary
Cross III - Punjab Naveen × PPC-6	-0.1	+h, -l	Duplicate

the presence of dominance and complementary epistatic gene action for fruit characters in some cross combinations.

AUTHORS' CONTRIBUTION

Conceptulization of research (ADM, TKB, SSD), Designing of the experiment (ADM, TKB, SSD, AB, KG); Execution of field experiment and data collection (SSD, TKB, ADM). Analysis of data and interpretation (SSD, AB, CB, KG); Preparation of the manuscript (SSD, SD, AN).

DECLARATION

The authors declare no conflict of interest.

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