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Original scientific paper

HETEROSIS, COMBINING ABILITY AND GENE ACTION STUDIES IN CUCUMBER FOR DIFFERENT BIOTIC STRESSES TO DEVELOPE RESISTANT HYBRIDS

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Biotic stress is the major constrains for the realization of crop yield potential. As climate change progresses, the spread and intensity of biotic stress is expected to increase, with increased probability of crops being exposed to stress. Shielding crops from stress requires a better understanding of the plant's response and its genetic architecture. The dearth of research pertaining to the heterosis, combining ability and gene action studies for insect-pest (fruit fly) and disease incidences (powdery and downy mildew) in cucumber compels us to undertake this study. The experimental material comprised 15 F_1 crosses, developed by crossing 6 genotypes during the year 2015. Parents and the 15 hybrids, along with standard check (KH-1), were planted in a randomized complete block design during the year 2016 for screening against different insect-pest and diseases under natural field conditions. In the present studies, genotypes PI-618860, UHF-CUC-1, UHF-CUC-2 and Khira-75 and crosses Khira-75 x PI-618860, Khira-75 x UHF-CUC-1 and Khira-75 x UHF-CUC-2 were found superior in response to insect-pest and disease incidences. Further, gene action studies indicated predominant role of non-additive gene action governing all the traits under study.
Keywords: Biotic stress, cucumber, fruit fly incidence, powdery mildew and downy mildew.

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INTRODUCTION

Crops grown in open fields confront multiple unfavorable conditions for optimal plant growth and yield, of biotic origin. The ongoing climate change, accelerated by the increase in atmospheric CO_2 concentration (PETERS *et al.,* 2011), is resulting in an average rise in temperature and decrease in precipitation especially in regions with temperate climates (DAI, 2013), which further directly influence plant pathogens spread and geographic distribution. While studies show that on many occasions the effects on pathogenicity are pathosystem-specific (COAKLEY *et al.,* 1999), the consensus is that elevated temperatures will result in pathogen geographic expansion and enhanced fecundity, increasing the chances for host range expansion and rise of more virulent strains (GARRETT *et al.,* 2006; HARVELL *et al.,* 2002).

Cucumber (*Cucumis sativus* L.) is one of the most important cucurbitaceous vegetable crops, infected by number of insect-pests and diseases. Cucumber pests and diseases have major effect on its production. Due to greater susceptibility of cucumber crop to diseases and insect-pests, it becomes hard to achieve the maximum yield potential. Fruit fly (*Bacrocera cucurbitae* Coq.) is one of the most destructive pests often rendering cultivation of cucumber unprofitable (CHOUDHARY *et al.,* 2012), the fruit are damaged by the maggots of this fly as the female fly lays its eggs in the tissues of fruits. Due to fruit fly infestation, 73.83 per cent damage was reported from cucumber crop (KRISHNA *et al.,* 2006). Additionally, fungal pathogens can significantly limit productivity by colonizing the foliage or the fruits. Among the various diseases, powdery mildew caused by *Sphaerotheca fuliginea* is one of the most devastating diseases in cucurbits. Crop yield can decline as the disease severity increases. Severe infection by powdery mildew before the flowering stage can reduce the yield of cucumber fruit by 20-40% (LAMSAL *et al.,* 2011). Leaf infestation by this pathogen interferes with photosynthesis and respiration, leading to reduced fruit set, inadequate ripening, and poor flavour development (MCGRATH, 1996). On the other hand, downy mildew of cucumber (*Pseudoperonospora cubensis* Rostow.) also causes serious losses under favourable environmental conditions. In many regions of the world having high humidity, it is the main limiting factor for cucumber production (WEHNER and SHETTY, 1997). Downy mildew decreases flower set and fruit development by killing the foliage (HASHMI, 1994). From these reports, it is evident that the attack of these insect-pests and diseases is a key factor in reducing the yield and quality of cucumber. The use of cultivars that are resistant to these insect-pests and diseases can be effective in reducing damage and yield losses cucumber. But, there are very few hybrids/ varieties of cucumber available in India, which has resistance to insect-pests and diseases. Hence, there is immense need of developing resistant hybrids/ varieties of cucumber to minimize the severe yield losses caused by these biotic factors.

Considering growing awareness about residue free vegetables, reduced cost of production and export of fresh/canned vegetables, present day emphasis is on evolving hybrids/ varieties resistant to diseases and pests so that the usage of plant protection chemicals is kept at minimum. Moreover, the production of hybrids/varieties having resistance to diseases and pests would always have the greater benefit over the chemical control as the resistant varieties impede the epidemics and maintain the logical balance. Therefore, attempts are being made regularly to breed diseases and insect-pests resistant cultivars in cucumber. On the contrary the progress in the development of insect resistance is very limited. Host plant resistance is the economical method but such resistance against insect pest is never stable due to population pressure of insects on the host, as a result there is evolution of new biotypes and breakdown of resistance.

For identification of potential parents in cucumber on the basis of progeny performance requires large number of crosses, which is very laborious. Diallel analysis is a mating design whereby the selected parents are crossed in a certain order to predict combining ability of the parents and elucidate the nature of gene action involved in the inheritance of traits. The phenomenon of heterosis of F_1 hybrids can also reflect SCA and GCA of parental lines. Combining ability work as basic tool for improved production of crops in the form of F_1 hybrids. Heterotic studies can also provide the basis for exploitation of valuable hybrid combinations and their commercial utilization in future breeding programmes. Combining ability as defined by GRIFFING (1956) is one of such statistical procedures for analysis of diallel crosses in a generalized theoretical form. Combining ability and heterosis work as principal methods for screening of germplasm and to determine the ability of the genotypes to be included or not in a breeding programme on the basis of their GCA, SCA, reciprocal and heterotic effects. Therefore, both methods are very contributive in choosing potential parents with desired genetic variance, vigor and in some cases through maternal effects. Moreover, combining ability also indicates the nature and magnitude of gene action involved in the expression of quantitative traits (KHAN *et al.,* 2009). But, till date very meager information is available in the literature pertaining to the heterosis, combining ability and nature of gene and their interactions for insect-pest and disease resistance in cucumber. Hence, major objective of this study was to develop insect-pest and disease resistance cucumber hybrids through knowledge of the estimates of heterosis, combining ability and gene action.

MATERIALS AND METHODS

Experimental site and layout plan

The present studies were carried out at Experimental Research Farm of the Department of Vegetable Science, Dr YS Parmar University of Horticulture and Forestry, Nauni, Solan District of Himachal Pradesh (India) during *kharif* (June-September) 2015 and 2016. The experimental material for the present investigations was comprised of 6 genotypes *viz.,* Khira-75, UHF-CUC-1, UHF-CUC-2, UHF-CUC-3, Poinsette and PI-618860. The crosses were attempted during the year 2015 in diallel (excluding reciprocals) to obtain fifteen cross combinations. The F_1 population of 15 crosses along with parents was planted in randomized complete block design (RCBD) with 3 replications during the year 2016. The standard cultural practices for raising a healthy crop of cucumber as recommended in the “Package of Practices” for Vegetable Crops, published by the Directorate of Extension Education, Dr. YS Parmar University of Horticulture and Forestry, Nauni, Solan (ANONYMOUS, 2014) have been followed during both the years of study.

Table 1. List of the cucumber genotypes used in the hybridization along with standard check cultivars

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

Data recording and statistical analysis

The observations for fruit fly incidence (%) were recorded on five randomly selected plants in each entry (genotype/hybrid) over the replications. The total number of fruits per plant and fruits infested with fruit fly were counted from the randomly selected plants to work out the incidence of fruit fly as per the following formula:

$$\text{Fruit fly incidence (\%)} = \frac{\text{Number of fruit fly infested fruits}}{\text{Total number of fruits}} \times 100$$

The occurrence and severity of powdery mildew (%) and downy mildew (%) was recorded periodically under natural conditions. Fifteen different leaves for each disease were randomly selected from different levels of height (from top to bottom) from five plants of each genotype/hybrid. Disease severity for powdery mildew was recorded by adopting the 0-5 scale given by RANSOM *et al.,* (1991), while disease severity for downy mildew was recorded by adopting the 0-4 scale given by REUVENI (1983). Disease severity index (%) in all the diseases was calculated by using the formula as given below:

$$\text{Disease severity index (\%)} = \frac{\sum (n \text{ x } v)}{Z \text{ x } N} \times 100$$

Where, n=number of leaves in each category; v=numerical value of each category; Z=numerical value of highest category; N= total number of leaves in sample

The data recorded on the 15 crosses, along with 6 parents and one standard check cultivar were subjected to analysis of variance manually in MS Excel-2007 worksheet as per the formulae given by PANSE and SUKHATME (1967). For diallel (excluding reciprocals) analysis, replication-wise mean values of parents and their F_1 hybrids for each trait were subjected to statistical analysis as explained by GOMEZ and GOMEZ (1983). The additive and dominance components of variance were computed by following SINGH and CHAUDHARY (1997) and DABHOLKAR (1992). The estimates of heterosis were calculated manually in MS Excel-2007 work sheet as the deviation of F_1 mean from the better parent (BP) and standard check-I (KH-1) by, respectively, using the following formulae:

$[(\overline{F}_1 - \overline{BP})/\overline{BP} \times 100]$ and $[(\overline{F}_1 - \overline{SC}_1)/\overline{SC}_1 \times 100]$ (SINGH, 1973).

Further, statistical significance of all the estimates of heterosis was assessed via the t-test (WYNNE *et al.,* 1970).

RESULTS AND DISCUSSION

Mean performance

All the parents and hybrids studied, responded differently to the attack of different insect-pest and diseases *viz.,* fruit fly incidence, severity of powdery mildew and downy mildew (Table 2). Substantial variation was observed among the parents and hybrids for fruit fly incidence (parents=5.90-8.79 and hybrids =4.32-19.58 %), severity of powdery mildew (parents=10.29-15.35 and hybrids=8.57-24.57 %) and downy mildew (parents=6.14-26.09 and hybrids=2.88-26.77 %). The lowest fruit fly incidence was recorded in the genotypes PI-618860 (5.90%), UHF-CUC-2 (6.09%), Khira-75 (6.71%) and UHF-CUC-1 (7.18%) and the cross combinations Khira-75 x PI-618860 (4.32), Khira-75 × UHF-CUC-2 (4.67%), Khira-75 × UHF-CUC-1 (4.67%), UHF-CUC-2 × PI-618860 (4.72%), UHF-CUC-1 × PI-618860 (4.75%) and UHF-CUC-1 × UHF-CUC-2 (5.47%). Minimum severity of powdery mildew was recorded in the genotype PI-618860 (10.29%), Khira-75 (10.71%) and UHF-CUC-2 (11.62%), while hybrid combinations Khira-75 × PI-618860 (8.57), Khira-75 × UHF-CUC-1 (9.23%), Khira-75 × UHF-CUC-2 (9.60%) and UHF-CUC-1 × UHF-CUC-2 (9.62%) recorded least severity of powdery mildew. The genotype, PI-618860 (6.14%) recorded minimum severity of downy mildew and the cross combinations, Khira-75 × PI-618860 (2.88%) and UHF-CUC-2 × PI-618860 (2.92%) recorded minimum severity of downy mildew.

Table 2. Best performing parents and hybrids identified on the basis of insect-pest and disease response in cucumber

Traits	Range		Mean ± S.E. (d)	Best parents	Best cross combinations along with mean performance of check cultivar
	Parents	Hybrids			
Fruit fly incidence (%)	5.90-8.79	4.32-19.58	9.79±0.69	PI-618860 (5.90), UHF-CUC-1 (7.18), UHF-CUC-2 (6.09), Khira-75 (6.71),	Khira-75 × UHF-CUC-1 (4.67), Khira-75 × UHF-CUC-2 (4.67), Khira-75 × PI-618860 (4.32), UHF-CUC-1 × PI-618860 (4.75), UHF-CUC-2 × PI-618860 (4.72) KH-1 (Check)-(10.48)
Severity of powdery mildew (%)	10.29-15.35	8.57-24.57	15.36±0.75	PI-618860 (10.29), Khira-75 (10.71), UHF-CUC-2(11.62),	Khira-75 x PI-618860 (8.57), Khira-75 x UHF-CUC-1 (9.23), Khira-75 x UHF-CUC-2 (9.60), UHF-CUC-1 x UHF-CUC-2 (9.62), KH-1 (Check)-(14.19)
Severity of downy mildew (%)	6.14-26.09	2.88-26.77	17.15±0.72	PI-618860 (6.14)	Khira-75 x PI-618860 (2.88), UHF-CUC-1 x PI-618860 (4.82), UHF-CUC-2 x PI-618860 (2.92), KH-1 (Check)-(19.08)

All the parents and hybrids studied, responded differently to the attack of different insect-pest and diseases and wide variations were recorded among the parents and hybrids for fruit fly incidence, severity of powdery mildew and downy mildew. Variation in response to fruit fly incidence was also reported earlier by THAKUR *et al.,* (1992) in bittergourd and SHARMA (2010), KUMAR (2013) and KUMARI (2015) in cucumber. Variations with respect to severity of different diseases were also recorded by MORISHITA *et al.,* (2003), BLOCK and REITSMA (2005), SAKATA *et al.,* (2008), KUMAR (2013) and KUMARI (2015) for severity of powdery mildew; CHAROENWATTANA (2009), BRAR *et al.,* (2011), CALL *et al.,* (2013), KUMAR (2013) and KUMARI (2015) for severity of downy mildew in cucumber.

On the basis of mean performance, genotype PI-618860 among parents was superior for different traits under study. Among the hybrids, Khira-75 × PI-618860, Khira-75 × UHF-CUC-1, Khira-75 × UHF-CUC-2 and UHF-CUC-1 × UHF-CUC-2 were found to be most promising for fruit fly and powdery mildew while Khira-75 × PI-618860 and UHF-CUC-2 × PI-618860 for downy mildew were found most promising.

Heterosis studies

The estimation of heterosis for different traits revealed significant differences among different cross combinations (Table 3). In the present study, number of the crosses revealed the significant negative heterosis for fruit fly incidence. But, the hybrid combinations Khira-75 × UHF-CUC-1 (-30.40), Khira-75 × UHF-CUC-2 (-23.32), Khira-75 × PI-618860 (-26.78), UHF-CUC-1 × UHF-CUC-2 (-10.18), UHF-CUC-1 × PI-618860 (-19.49) and UHF-CUC-2 × PI-618860 (-20.00) were rated as best heterotic crosses due to their significant negative values for all the estimates of heterosis under study whereas eight cross combinations showed significant negative increase over check KH-1. KUMAR (2006), SHARMA (2010), KUMAR (2013) and KUMARI (2015) in cucumber had also reported negative heterosis for fruit fly incidence in cucumber. Besides this, ample of the crosses recorded the significant negative heterosis for severity of different diseases under study. But, Khira-75 × UHF-CUC-1 (-13.81), Khira-75 × UHF-CUC-2 (-10.36), Khira-75 × PI-618860 (-16.72), UHF-CUC-1 × UHF-CUC-2 (-17.21) and UHF-CUC-1 × Poinsette (-6.78) for severity of powdery mildew, further seven cross combinations revealed significant negative heterosis over the check cultivar and Khira-75 x PI-618860 (-53.09), Khira-75 x UHF-CUC-1 (-15.90), Khira-75 x UHF-CUC-2 (-17.06), UHF-CUC-1 x UHF-CUC-2 (-18.62), UHF-CUC-1 x PI-618860 (-21.49) and UHF-CUC-2 x PI-618860 (-52.44) revealed significant negative values for all the estimates of heterosis for severity of downy mildew, in this case eight cross combinations showed significant negative increase over KH-1. Significant negative heterosis for severity of powdery mildew and downy mildew was also reported by SHARMA (2010), KUMAR (2013), KUMARI (2015) and BRAR *et al.,* (2011), KUMAR (2013), KUMARI (2015) respectively. On the basis of overall performance, heterosis studies revealed that hybrids Khira-75 × UHF-CUC-1, Khira-75 × UHF-CUC-2, Khira-75 × PI-618860 and UHF-CUC-1 × UHF-CUC-2 had significantly high heterotic values for different traits under study. Hence, hybrid vigor may be exploited commercially for the improvement of these traits in cucumber and these combinations after multilocation testing can be adopted for commercial cultivation.

Table 3. Estimates of heterosis for economically important insect-pest and diseases in cucumber hybrid combinations

	Fruit fly incidence (%)		Severity of powdery mildew (%)		Severity of downy mildew (%)	
	Percent increase/decrease over		Percent increase/decrease over		Percent increase/decrease over	
Cross combination(s)	Better parent	Standard Check	Better parent	Standard Check	Better parent	Standard Check
Khira-75 x UHF-CUC-1	-30.40*	-55.44*	-13.81*	-34.95*	-15.90*	-38.47*
Khira-75 x UHF-CUC-2	-23.32*	-55.44*	-10.36*	-32.35*	-17.06*	-23.32*
Khira-75 x UHF-CUC-3	84.20*	17.94*	118.67*	65.05*	1.95	31.81*
Khira-75 x Poinsette	185.25*	82.63*	81.14*	36.72*	16.17*	32.91*
Khira-75 x PI-618860	-26.78*	-58.78*	-16.72*	-39.61*	-53.09*	-84.91*
UHF-CUC-1 x UHF-CUC-2	-10.18*	-47.81*	-17.21*	-32.21*	-18.62*	-40.46*
UHF-CUC-1 x UHF-CUC-3	84.96*	26.72*	51.05*	36.58*	78.30*	30.45*
UHF-CUC-1 x Poinsette	33.01*	-8.87*	-6.78*	-15.72*	67.05*	22.22*
UHF-CUC-1 x PI-618860	-19.49*	-54.68*	98.44*	43.90*	-21.49*	-74.74*
UHF-CUC-2 x UHF-CUC-3	147.95*	44.08*	75.04*	43.34*	46.54*	35.48*
UHF-CUC-2 x Poinsette	62.56*	-5.53*	11.96*	-8.32*	51.76*	40.30*
UHF-CUC-2 x PI-618860	-20.00*	-54.96*	0.194	-27.34*	-52.44*	-84.70*
UHF-CUC-3 x Poinsette	131.00*	79.87*	61.75*	73.15*	6.05*	21.33*
UHF-CUC-3 x PI-618860	167.96*	50.86*	130.80*	67.37*	105.86*	-33.75*
Poinsette x PI-618860	231.86*	86.83*	135.96*	71.11*	101.14*	-35.27*

*Significant at 5% level of significance

Combining ability

The common approach of selecting parents on the basis of *per se* performance does not necessarily lead to fruitful results (ALLARD, 1960). Therefore, before drawing any conclusions, we determined combining ability for the traits under study. For studying combining ability the most commonly utilized experimental approach is the diallel design (SPRAGUE and TATUM, 1942). General combining ability (GCA) is a measure of additive genetic action; and specific combining ability (SCA) is deviation from additivity (KEMPTHORNE, 1969; MAYO, 1980). General combining ability is a main effect and SCA is an interaction (OLFATI *et al.*, 2012). The aim is to determine the breeding value of the cross (GRIFFING, 1956). Complete diallel cross designs involve equal numbers of occurrences of each distinct cross among inbred lines. When the population is large, or reciprocal crosses are similar to direct crosses, it becomes impractical to carry out an experiment using a complete diallel cross design. With cucumber partial diallel crosses are a subset of crosses used (OLFATI *et al.*, 2012). Combining ability studies guide the breeders to select appropriate parents for heterosis and recombination breeding, hence are important in crop improvement studies. The analysis of variance for combining ability revealed significant differences among the parents and hybrids for all the traits under study (Table 7). The genotype, UHF-CUC-2 (-2.38, -1.97), Khira-75 (-2.35, -2.66) and UHF-CUC-1 (-1.41, -1.96) (for fruit fly incidence and severity of powdery mildew respectively) and PI-618860 (-8.16), UHF-CUC-1 (-1.74) and UHF-CUC-2 (-1.42) (for severity of downy mildew) were found good general combiners as reflected from their consistent performance for desirable negative GCA effects (Table 4). Significant negative general combining ability (GCA) effects of different parental material for biotic stresses were also reported by earlier workers *viz.*, KUMAR (2006), SHARMA (2010), KUMAR (2013) and KUMARI (2015) for fruit fly incidence, SHARMA (2010), KUMAR (2013) and KUMARI (2015) for severity of powdery mildew and BRAR *et al.*, (2011), KUMAR (2013) and KUMARI (2015) for severity of downy mildew in cucumber. On the basis of present investigations for GCA effects, it may be concluded that the four genotypes, *viz.*, PI-618860, Khira-75, UHF-CUC-1 and UHF-CUC-2 were found to be good general combiners for different traits under study. These genotypes may be utilized in hybridization programs for obtaining superior resistant hybrids or transgressive segregants.

Table 4. Estimates of general combining ability (GCA) effects of parents for economically important insect-pest and diseases in cucumber

Parents/Traits	Fruit fly incidence (%)	Severity of powdery mildew (%)	Severity of downy mildew (%)
Khira-75	-2.35*	-2.66*	2.13*
UHF-CUC-1	-1.41*	-1.96*	-1.74*
UHF-CUC-2	-2.38*	-1.97*	-1.42*
UHF-CUC-3	1.36*	1.78*	4.59*
Poinsette	3.99*	3.06*	4.60*
PI-618860	0.79*	1.74*	-8.16*
SE (g_i)	0.161	0.175	0.168
SE (g_i- g_j)	0.25	0.271	0.26
CD (g_i)	0.33	0.36	0.35
CD (g_i- g_j)	0.52	0.56	0.54

*Significant at 5% level of significance

Specific combining ability effect helps in identifying the best cross combinations for various traits. These effects arise due to non-additive gene interactions. Among all the hybrids, six best crosses *viz.,* UHF-CUC-1 × PI-618860 (-4.81) (good × poor), UHF-CUC-2 × PI-618860 (-3.42) (good × poor), Khira -75 × Poinsette (-3.24) (good × poor), Khira -75 × PI-618860 (-2.31) (good × poor), UHF-CUC-3× PI-618860 (-7.20) (poor × poor) and UHF-CUC-3 × Poinsette (-5.21) (poor × poor) for incidence of fruit fly; the crosses, UHF-CUC-1 × UHF-CUC-2 (-1.89) (good× good), Khira-75 × PI-618860 (-4.22) (good × poor), UHF-CUC-2 × Poinsette (-4.56) (good × poor), UHF-CUC-1 × PI-618860 (-6.64) (good × poor), UHF-CUC-3 × Poinsette (-7.25) (poor × poor) and UHF-CUC-3 × PI-618860 (-8.63) (poor × poor) for severity of powdery mildew and UHF-CUC-1 × PI-618860 (-4.27) (good × good), UHF-CUC-2 × PI-618860 (-2.66) (good × good), UHF-CUC-3 × PI-618860 (-10.57) (poor × good), Khira-75 × PI-618860 (-4.88) (poor × good), Khira-75 × UHF-CUC-1 (-3.49) (poor × good), and Khira-75 × Poinsette (-1.96) (poor × poor) for severity of downy mildew revealed significant negative SCA effects (Table 5).

Most of these crosses had the parents involved with good x poor GCA effects, which indicated the involvement of both additive and non-additive gene action. Such types of cross combinations are most desirable for genetic improvement of any crop through heterosis breeding. The other crosses had the involvement of either good x good or average x good or poor x poor combiners, which indicated the presence of additive x additive or additive x dominance or additive x additive type of gene interactions. Significant negative estimates of heterosis with the involvement of parents with different GCA effect have also been reported earlier by BRAR *et al.*, (2011) for severity of downy mildew, KUMAR (2006) for incidence of fruit fly and KUMAR (2013) and KUMARI (2015) for incidence of fruit fly, severity of powdery and downy mildew in cucumber.

Table 5. Estimates of specific combining ability (SCA) effects of crosses for economically important insect-pest and diseases in cucumber

Crosses/Traits	Fruit fly incidence (%)	Severity of powdery mildew (%)	Severity of downy mildew (%)
Khira-75 x UHF-CUC-1	1.18	2.02*	-3.49*
Khira-75 x UHF-CUC-2	1.06	0.82	-0.12
Khira-75 x UHF-CUC-3	0.01	0.81	0.89
Khira-75 x Poinsette	-3.24*	-0.64	-1.96*
Khira-75 x PI-618860	-2.31*	-4.22*	-4.88*
UHF-CUC-1 x UHF-CUC-2	-1.29*	-1.89*	0.74
UHF-CUC-1 x UHF-CUC-3	2.65*	8.18*	5.25*
UHF-CUC-1 x Poinsette	6.80*	2.87*	5.44*
UHF-CUC-1 x PI-618860	-4.81*	-6.64*	-4.27*
UHF-CUC-2 x UHF-CUC-3	4.53*	4.15*	4.67*
UHF-CUC-2 x Poinsette	-1.83*	-4.56*	3.08*
UHF-CUC-2 x PI-618860	-3.42*	5.22*	-2.66*
UHF-CUC-3 x Poinsette	-5.21*	-7.25*	0.52
UHF-CUC-3 x PI-618860	-7.20*	-8.63*	-10.57*
Poinsette x PI-618860	1.27*	3.53*	-0.86
SE (S_{ij})	0.443	0.481	0.461
SE (S_{ij}-S_{ik})	0.10	0.10	0.10
SE (S_{ij}-S_{kl})	0.611	0.664	0.637
CD (S_{ij})	0.92	1.00	0.96
CD (S_{ij}-S_{kl})	1.27	1.38	1.32

*Significant at 5% level of significance

Table 6. Estimates of genetic components of variance for different traits in cucumber

Trait	gca	sca	σ^2g	σ^2s	Variance ratio (σ^2g/σ^2s)	Predictability ratio ($2\sigma^2g/2\sigma^2g + \sigma^2s$)
Fruit fly incidence (%)	50.560	19.769	6.23	19.02	0.33	0.39
Severity of powdery mildew (%)	48.521	26.672	5.95	25.79	0.23	0.32
Severity of downy mildew (%)	189.519	29.782	23.59	28.97	0.81	0.62

†gca = general combining ability, ‡ sca= specific combining ability

Table 7. Analysis of variance for various traits and combining ability in cucumber

Source Trait	Mean Sum of Squares							
	Replications	Genotypes	Error	Total	gca	sca	Errors	Total
Df	2.00	20	40	62	5	15	40	60
Fruit fly incidence (%)	0.96	82.39*	0.74	84.09	50.560*	19.769*	0.748	71.07
Severity of downy mildew (%)	1.43	96.40*	0.88	98.71	48.521*	26.672*	0.883	76.07
Severity of powdery mildew (%)	7.18	209.15*	0.81	217.14	189.519*	29.782*	0.811	220.11

*Significant at 5% level of significance

Gene action

To effect the 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. After identification of appropriate parents and potential crosses through combining ability analysis, the next important step is to adopt suitable breeding methodology to achieve the desired result which depends upon the type of gene action governing the traits (COCKERHAM, 1961; SPRAGUE, 1966). In this regards, diallel analysis approach is considered most appropriate which not only evaluates parents and crosses for combining ability but also provides realistic information on the nature of gene action controlling the traits in a crop. In the present studies, mean sum of squares due to general combining ability (GCA) and specific combining ability (SCA) were used to estimate the variances for general combining ability (GCA) and specific combining ability (SCA), respectively, based on which nature of gene action has been worked out. The mean sum of squares due to general combining ability (GCA) and specific combining ability (SCA) were highly significant for all the traits under study. However, perusal of the data presented in Table 3 indicated that dominance component of variance (σ^2s) were higher than the additive components (σ^2g) for most of the traits under study, indicating the role of non-additive gene action. Similarly, predictability ratio was also found less than one for all the traits under study *viz.*, incidence of fruit fly (0.39), severity of powdery mildew (0.32) and severity of downy mildew (0.62). It further confirmed the predominant role of non-additive gene action in the expression of almost all the traits under this study. After having an insight into the GCA and SCA variances as well as additive (σ^2A) and dominant (σ^2D) components of variance, it may be worthwhile to effect improvement in cucumber by developing superior open-pollinated varieties through selection in segregating population for fruit fly incidence (KUMAR, 2006; KUMAR, 2013 and KUMARI, 2015). Alternatively exploitation of hybrid vigour or reciprocal recurrent selection, which capitalizes on both additive and non-additive variances, might be more effective for severity of powdery mildew and downy mildew, which had either high or equal dominant (σ^2D) components of variance to that of additive (σ^2A) components (GHADERI and LOWER, 1979; LOWER *et al.*, 1982; MUSMADE and KALE, 1986; KUMAR, 2013; KUMARI, 2015).

CONCLUSION

On the basis of mean performance and general combining ability studies, we concluded that among the parents, genotypes PI-618860, Khira-75, UHF-CUC-1 and UHF-CUC-2 were found superior in response to insect-pest and disease incidence. The cross combinations Khira-75 x PI-618860, Khira-75 x UHF-CUC-1, Khira-75 x UHF-CUC-2, UHF-CUC-2 x PI-618860 and UHF-CUC-1 x UHF-CUC-2 were found best on the bases of mean performance, heterosis and specific combining ability for different traits under study. Further, gene action studies concluded that all the traits were inherited by dominance components of variance. Hence, heterosis breeding could be exploited commercially in cucumber for the development of insect-pests and disease resistance hybrids/transgressive segregants. Therefore, depending upon the trait of interest due attention should be given on the genotypes used as a parents for the development of insect-pests and disease resistance hybrids/transgressive segregants in cucumber. Development of resistant or tolerant cultivars is one of the best options to minimize the losses due to disease/insect occurrence. Although there are effective chemical control measures of a number of insect pests and diseases, the cost of such chemicals is very high and many chemicals exhibit residual effects. Further, there is a need to undertake intensive research programme to make best use of available germplasm in the country and above all to utilize wild relatives and exotic collections for development of pre bred lines so that as and when resistance source require these lines can be utilize successfully against certain biotic stresses.

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PROUČAVANJE HETEROZISA, KOMBINACIONE SPOSOBNOSTI I GENSKE AKCIJE KOD KRASTAVCA U USLOVIMA RAZLIČITIH BIOTIČKIH STRESOVA ZA POTREBE OPLEMENJIVANJA

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Izvod

Biotički stres je glavna prepreka za ostvarivanje potencijala za prinos useva. Kako klimatske promene napreduju, očekuje se da će se širenje i intenzitet biotičkog stresa povećati, uz povećanu verovatnoću da će usevi biti izloženi stresu. Zaštita useva od stresa zahteva bolje razumevanje odgovora biljke i njene genetske arhitekture. Nedostatak istraživanja u vezi sa heterozisom, kombinacionim sposobnostima i delovanjem gena za insekte-štetočine (voćna mušica) i oboljenja od bolesti (pepelnice i plamenjače) kod krastavca je uticala na sprovođenje ovog istraživanja. Eksperimentalni materijal se sastojao od 15 F1 ukrštanja, razvijenih ukrštanjima 6 genotipova tokom 2015. godine. Roditelji i 15 hibrida, zajedno sa standardnom kontrolom (KH-1), posađeni su u randomiziranom kompletnom blok dizajnu tokom 2016. godine za skrining na različite štetočine i bolesti u prirodnim poljskim uslovima. U ovim istraživanjima, genotipovi PI-618860, UHF-CUC-1, UHF-CUC-2 i Khira-75 i ukrštanja Khira-75 x PI-618860, Khira-75 x UHF-CUC-1 i Khira-75 x UHF-CUC-2 bili su superiorni kao odgovor na pojavu insekata i štetočina. Dalje, ispitivanje delovanja gena ukazuju na dominantnu ulogu neaditivnog delovanja gena koji regulišu sve ispitivane osobine.

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