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Heterotic potential, potence ratio, combining ability and genetic control of seed vigour traits for yield improvement in cucumber (*Cucumis sativus*)

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ABSTRACT

The paucity of research on seed quality enhancement for yield improvement in cucumber (*Cucumis sativus* L.) motivated us to undertake this study. Therefore, present investigation was carried out to estimate the combining ability, gene action, heterosis and potence ratio for seed vigour and yield traits in 48 F_1 crosses, developed by crossing 16 lines (8 gynoecious) and 3 testers during the year 2011. The seeds of all parents and their crosses, along with two standard checks (KH-1 and Pusa Sanyog), were assessed for different seed vigour (under laboratory conditions) and fruit yield (under open field conditions) traits during the year 2012. Experimental results revealed that parental lines LC-1-1, CGN-20953 and LC-3-3 were found superior on the basis of mean performance and general combining ability studies. Four cross combinations, viz., LC-1-1 × K-75, CGN-20953 × Poinsette, LC-3-3 × Poinsette and LC-3-3 × K-75 were found best on the basis of mean performance, specific combining ability and heterosis studies. Further, results of potence ratio reflected partial dominance for different seed vigour traits in all top five heterotic hybrids, while over dominance was exhibited by all the heterotic hybrids towards higher fruit yield per ha in cucumber. 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 fruit yield traits in cucumber.

Key words: Combining ability, Gene action, Heterosis, Potence ratio, Seed germination, Seed vigour index-I and -II

Seed quality is the sum of genetic, physical and physiological attributes that affect germination, vigor and longevity of seeds (Moterle *et al*. 2011). Seed viability and vigor helps in emergence and development of normal seedlings in wide environmental conditions (Goggi *et al.* 2008). Therefore, use of quality seed material is essential for ensuring higher productivity in any crop (Munamava *et al.* 2004). At present, owing to development of advanced crop production technologies, farmers are demanding for high quality vegetable seeds. Since, seed is the most important input factor in any crop production program on which success or failure of any crop totally depends (Bhardwaj and Kumar 2012). Moreover, crop yield potential also relies on the seed vigor and successful establishment of plants in different climatic conditions (Finch-Savage and Bassel 2016). Cucumber (*Cucumis sativus* L.) is the most extensively cultivated cucurbitaceous vegetable crop next to watermelon (Tatlioglu 1993). Nowadays, it is grown commercially throughout the world under protected as well as open field conditions. This crop is extensively cultivated both during summer and *kharif* seasons in India and it cannot tolerate cold injury (Rastogi 1998). The ideal temperature for its seed germination ranges between 24 to 28 °C. Besides this, seeds with poor vigor fail to germinate under unfavourable environmental conditions. Therefore, there is an immense need to develop new varieties and hybrids of cucumber with improved seed vigor and successful plant establishment under diverse climatic conditions.

Heterosis breeding provides a chance for achieving unique improvement in yield and its attributing traits in single generation that would be more difficult and time consuming with other conventional breeding approaches (Sherpa 2014). Cucumber being monoecious in nature have substantial seeds per fruit, which offers the chances for the exploitation of heterosis in this crop (Bairagi *et al*. 2002). Further, involvement of gynoecious lines for hybrid development increases the possibility of getting the hybrids with higher yields along with less cost of hybrid seed production as compared to monoecious hybrids (Rai and Rai 2006). Selection of appropriate parents is of greater importance to exploit hybrid vigour in any crop. The combining ability studies helps to recognize the parental lines with good general combining ability (GCA) and superior cross combinations based on their specific

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combining ability (SCA) effects (Legesse *et al.* 2009). Moreover, combining ability also determines the nature and magnitude of gene action involved in the expression of different quantitative traits (Machikowa 2011). Further, potence ratio is useful to determine the nature and direction of dominance. Earlier, several workers like Mule *et al.* (2012), Kumar *et al.* (2013a), Golabadi *et al.* (2015) and Kumar *et al.* (2016) have duly realized the importance of combining ability, gene action and heterosis studies for different yield and quality traits in cucumber. But, a very meager information is available in the literature on estimation of combining ability, gene action, heterosis and potence ratio for seed quality traits in cucumber. Therefore, taking all these factors into consideration, an attempt has been made to improve the seed quality traits and fruit yield per ha through different estimates of combining ability, gene action, heterosis and potence ratio in cucumber.

MATERIALS AND METHODS

The present study was conducted at Experimental Research Farm and Laboratory of the Department of Vegetable Science, Dr Y S Parmar University of Horticulture and Forestry, Nauni, Solan (Himachal Pradesh), India. During the year 2011, crosses were made between 16 lines (females) and 3 testers (males) as per Line × Tester design (Kempthrone 1957) to develop 48 cross combinations (Table 1). Simultaneously, selfing of each parent was also done to have adequate seeds for sowing in the subsequent year. Afterwards during the year 2012, seeds of all the parents, 48 F_1 hybrids along with standard check cultivars (KH-1 and Pusa Sanyog) were evaluated for different seed quality traits viz. seed germination (%), seedling length (cm), seedling dry weight (mg), seed vigor index-I and -II under laboratory conditions. At the same time, seeds of all the genotypes were also sown in a randomized complete block design (RCBD) under open field conditions for determining fruit yield per ha (q). In order to ensure a healthy crop stand, standard cultural practices and plant protection measures as recommended in the 'Package of Practices for Vegetable Crops' published by Directorate of Extension Education, Dr Y S Parmar University of Horticulture and Forestry, Nauni, Solan (HP), India (Anonymous 2009) have been duly followed during both the years of study.

As per the ISTA guidelines (Anonymous 1985), seed germination of each genotype was tested under laboratory conditions through blot paper method. The seedling length and seedling dry weight of each genotype were recorded at the time of final germination count on 8th day from 20 randomly selected seedlings and mean value was worked out. Seed vigour index-I and -II were estimated by following

Table 1 List of cucumber genotypes used to assess the genetic potential of seed vigour traits for yield enhancement in cucumber

Genotype	Source	Pollination mechanism
Lines		
CGN-19533	Centre for Crop Genetic Resources, the Netherlands	Gynoecious
CGN-20256	Centre for Crop Genetic Resources, the Netherlands	Gynoecious
CGN-20515	Centre for Crop Genetic Resources, the Netherlands	Gynoecious
CGN-20953	Centre for Crop Genetic Resources, the Netherlands	Gynoecious
CGN-20969	Centre for Crop Genetic Resources, the Netherlands	Gynoecious
CGN-21585	Centre for Crop Genetic Resources, the Netherlands	Gynoecious
CGN-22930	Centre for Crop Genetic Resources, the Netherlands	Gynoecious
LC-1-1	Dhangota, Hamirpur, Himachal Pradesh, India	Monoecious
LC-2-2	Bhota, Hamirpur, Himachal Pradesh, India	Monoecious
LC-3-3	Awahdevi, Hamirpur, Himachal Pradesh, India	Monoecious
LC-12-4	Gagal, Kangra, Himachal Pradesh,India	Monoecious
LC-15-5	Sarkaghat, Mandi, Himachal Pradesh, India	Monoecious
LC-21-6	Dangar, Bilaspur, Himachal Pradesh, India	Monoecious
LC-25-7	Saru, Chamba, Himachal Pradesh, India	Monoecious
LC-28-8	Sambha, Jammu, Jammu and Kashmir, India	Monoecious
Gyne-5	ICAR-IARI Regional Station, Katrain, Kullu, HP, India	Gynoecious
Testers		
K-75	UHF, Nauni, Solan, Himachal Pradesh,India	Monoecious
Japanese Long Green	ICAR-IARI Regional Station, Katrain, Kullu, HP, India	Monoecious
Poinsette	National Seeds Corporation, New Delhi, India	Monoecious
Standard check cultivars		
KH-1	UHF, Nauni, Himachal Pradesh, Solan, India	Monoecious
Pusa Sanyog	ICAR-IARI Regional Station, Katrain, Kullu, HP, India	Gynoecious

the formulae suggested by Abdul-Baki and Anderson (1973). The fruits at marketable maturity were harvested regularly from 10 randomly selected plants and mean value was worked out to obtain average yield per plant. Thereafter, total number of plants accommodated in one-hectare area were multiplied with average yield per plant and expressed as total fruit yield per hectare. The data recorded on different seed and fruit yield traits were subjected to analysis of variance (ANOVA) manually in Microsoft Excel-2010 as per the formulae given by Panse and Sukhatme (1967). The Pearson's correlation coefficients were calculated by following Panse and Sukhatme (1967) through SPSS 16.0 software. Further, Line × tester analysis was done through OPSTAT software (Sheoran *et al.* 1998) as per the model suggested by Kempthorne (1957). The additive and dominance components of variance were calculated as per the formulae given by Singh and Chaudhary (1997) and Dabholkar (1992). The per cent contribution of lines, testers and their interactions were computed as per the formulae suggested by Singh and Chaudhary (1997). The heterosis over mid-parent (MPH), better parent (BPH), standard check-I (SCH-I) and standard check-II (SCH-II), was calculated manually in Microsoft Excel-2010 as per the formulae given by Singh (1973). Thereafter, statistical significance of MPH, BPH, SCH-I and SCH-II was determined by using t-test formulae adopted by Wynne *et al.* (1970). The nature and direction of dominance was determined by calculating the potence ratio (P) as per the formula given by Smith (1952).

RESULTS AND DISCUSSION

Mean performance and correlation studies

All the parents and hybrids exhibited substantial variations for different traits under study, viz. seed germination (parents=66.67-85.33 % and hybrids=68.00-86.00 %), seedling length (parents=26.47-37.00 cm and hybrids=25.50-39.33 cm), seedling dry weight (parents=10.73-19.70 mg and hybrids=8.83-24.80 mg), seed vigor index-I (parents=2011.07-2960.67 and hybrids=1947.93-3216.90), seed vigor index-II (parents=833.37-1576.73 and hybrids=687.93-1996.00) and fruit yield per ha (parents=101.30-244.36 q and hybrids=113.27-449.52 q) (Table 2). Substantial variations for seed germination (Hamid *et al.* 2002, Kumar *et al.*

Table 2 Top five parents and hybrids identified on the basis of mean performance for seed vigour and fruit yield traits in cucumber

Trait(s)		Seed germination (%)	Seedling length (cm)	Seedling dry weight (mg)	Seed vigour index-I	Seed vigour index-II	Fruit yield per ha (q)
Top five parents		CGN-20953 (85.33), CGN-20515 (82.00), CGN-19533 (81.33), CGN-22930 (81.00), Poinsette (80.33)	LC-3-3 (37.00), LC-2-2 (35.87), LC-1-1 (34.27), K-75 (33.20), LC-28-8 (32.93)	LC-3-3 (19.70), LC-2-2 (19.45), LC-1-1 (18.69), K-75 (16.52), LC-15-5 (16.42)	LC-3-3 (2960.67), LC-2-2 (2786.93), CGN-20953 (2688.27), LC-1-1 (2581.60), Gyne-5 (2580.27)	LC-3-3 (1576.73), LC-2-2 (1512.29), LC-1-1 (1408.43), LC-15-5 (1282.37), CGN-20953 (1250.43)	LC-1-1 (244.36), CGN-20953 (238.55), †JLG (224.33), Gyne-5 (217.51), LC-15-5 (213.54)
Top five cross combinations		CGN-20953 × Poinsette (86.00), LC-1-1 × K-75 (84.00), CGN-20515 × Poinsette (83.33), CGN-19533 × Poinsette (83.00), Gyne-5 × Poinsette (83.00)	LC-3-3 × K-75 (39.33), LC-1-1 × K-75 (38.30), LC-2-2 × Poinsette (37.30), CGN-20953 × K-75 (36.63), CGN-20953 × Poinsette (35.60)	LC-3-3 × K-75 (24.80), LC-1-1 × K-75 (23.77), LC-2-2 × Poinsette (22.47), LC-15-5 × Poinsette (20.20), Gyne-5 × K-75 (20.10)	LC-1-1 × K-75 (3216.90), CGN-20953 × Poinsette (3063.20), LC-3-3 × K-75 (3002.90), LC-2-2 × Poinsette (2995.00), Pusa Sanyog (2873.60)	LC-1-1 × K-75 (1996.00), LC-3-3 × K-75 (1893.07), LC-2-2 × Poinsette (1802.93), LC-15-5 × Poinsette (1649.13), Gyne-5 × K-75 (1589.13)	LC-1-1 × K-75 (449.52), CGN-19533 × K-75 (440.61), CGN-20953 × Poinsette (433.04), Gyne-5 × K-75 (421.47), LC-3-3 × Poinsette (356.23)
Mean performance of check cultivars		KH-1 (80.67) Pusa Sanyog (81.33)	KH-1 (34.30) Pusa Sanyog (35.33)	KH-1 (14.63) Pusa Sanyog (16.00)	KH-1 (2767.80) Pusa Sanyog (2873.60)	KH-1 (1181.63) Pusa Sanyog (1301.20)	KH-1 (283.44) Pusa Sanyog (305.44)
Range	Parents	66.67-85.33	26.47-37.00	10.73-19.70	2011.07-2960.67	833.37-1576.73	101.30-244.36
	Hybrids	68.00-86.00	25.50-39.33	8.83-24.80	1947.93-3216.90	687.93-1996.00	113.27-449.52
Mean ± SE (d)		77.54±1.49	31.38±1.13	14.85±1.10	2434.26±104.21	1153.58±91.84	235.45±11.45
CD $_{(P=0.05)}$		2.98	2.27	2.21	208.62	183.85	22.93

†Japanese Long Green

Table 3 Pearson's correlation coefficients among seed vigour and fruit yield traits in cucumber

Trait	Seed germination (%)	Seedling length (cm)	Seedling dry weight (mg)	Seed vigour index-I	Seed vigour index-II	Fruit yield/ha (q)
Seed germination (%)	1.00	0.06	0.13	0.50**	0.34**	0.33**
Seedling length (cm)		1.00	0.79**	0.89**	0.76**	0.45**
Seedling dry weight (mg)			1.00	0.74**	0.97**	0.36**
Seed vigour index-I				1.00	0.81**	0.54**
Seed vigour index-II					1.00	0.42**
Fruit yield/(q)						1.00

**Significant at P<0.01

2013b), seed vigour (Nerson 2007, Kumar *et al.* 2013b) and fruit yield (Dogra and Kanwar 2011, Golabadi *et al.* 2012, Kumar *et al.* 2013b) traits had also been reported earlier in different varieties of cucumber. But, none of them had studied the variations for seed vigour traits using hybrid varieties of cucumber. Among the top five parents and hybrids identified on the basis of mean performance; it was observed that LC-1-1, LC-3-3 and CGN-20953 (parents) and LC-1-1 × K-75, LC-3-3 × Poinsette and CGN-20953 × Poinsette (hybrids) excelled for most of the traits under study. These genotypes can be exploited for seed vigour and fruit yield improvement in cucumber. Further, estimates of Pearson's correlation coefficients revealed that fruit yield per ha was positively and significantly correlated with seed germination (0.33), seedling length (0.45), seedling dry weight (0.36), seed vigour index-I (0.54) and seed vigour index-II (0.42) (Table 3). Hence, it is evident that all the seed traits have significant positive contribution towards yield enhancement in cucumber. Bhardwaj and Kumar (2012) had reported significant positive correlation of fruit yield with all seed traits and highest correlation of seedling dry weight was observed with fruit yield in cucumber. In contrast to this, in present investigation greater influence of seed vigour index-I was recorded on fruit yield enhancement in cucumber.

Combining ability and gene action

The experimental results pertaining to significant combining ability effects for top five parents (GCA) and hybrids (SCA) have been presented in the Table 4, which revealed that combining ability was found variable as no single parent/cross combination has exhibited significant GCA/SCA effects for all the traits under study. However, the parental lines LC-1-1, LC-3-3 and CGN-20953 and hybrid combinations LC-1-1 × K-75, LC-3-3 × Poinsette and CGN-20953 × Poinsette based on their significant positive GCA and SCA effects, respectively were found superior for most of the traits under study. These cross combinations involved the parental lines either with good × good or good × average or good × poor GCA effects for different traits, viz. LC-1-1 × K-75 (good × poor) and CGN-20953 × Poinsette (good × good) for seed germination; LC-1-1 × K-75 (good × good) and CGN-20953 × Poinsette (good × average) for seed vigour index-I; LC-1-1 × K-75 (good × good) for seed vigour index-II; CGN-20953 × Poinsette (good × good) and LC-1-1 × K-75 (good × good) for fruit yield per ha and recorded significantly high positive SCA effects among different hybrids under study. This indicates the role of both additive and non-additive gene action for the control of different seed vigour and fruit yield 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, the hybrid combinations having 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. No information is available in the literature regarding the combining ability (GCA/SCA) of cucumber for seed vigour traits. However, for fruit yield; Dogra and Kanwar (2011), Kushwaha *et al.* (2011), Kumar *et al.* (2013a), Golabadi *et al.* (2015) and Kalidas *et al.* (2015) had also reported significant positive GCA and SCA effects using different genotypes of cucumber.

A perusal of the data presented in Table 5 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, variance ratio/predictability ratio ($2\sigma^2g/(2\sigma^2g+\sigma^2s)$) was found less than one for all the traits, viz. seed germination (0.79), seedling length (0.63), seedling dry weight (0.64), seed vigour index-I (0.26), seed vigour index-II (0.47), and fruit yield per ha (0.71). 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 fruit yield traits in cucumber. Dogra and Kanwar (2011), Kumar *et al.* (2013a) and Golabadi *et al.* (2015) had also reported pre-dominance of non-additive gene action for fruit yield in cucumber. However, pre-dominant role of additive gene action for the control of non-marketable yield has also been reported by Olfati *et al.* (2012). This might be attributed to the different type of parental material used in their study. The proportional contribution of lines, testers and their interactions revealed that contribution of lines for different traits ranged from 32.30 (fruit yield per ha) to 50.06 (Seed vigour index-II) per cent. The contribution of lines was found higher than the individual contribution of testers and lines × testers interactions for seed germination (43.51 %), seedling dry weight (46.50 %), seed vigour

Table 4 Estimates of general (GCA) and specific combining ability (SCA) effects for seed vigour and fruit yield traits in cucumber

Trait	*Top five significant desirable parents	*Top five significant desirable cross combinations
Seed germination (%)	CGN-20953 (3.44), LC-1-1 (2.77), CGN-20515 (2.33), (Poinsette (2.19) and Gyne-5 (2.10)	LC-1-1 × K-75 (5.67), LC-3-3 × Japanese Long Green (3.74), CGN-20515 × K-75 (3.44), CGN-19533 × Poinsette (3.26), and CGN-20953 × Poinsette (2.81)
Seedling length (cm)	LC-2-2 (2.86), LC-3-3 (2.65), K-75 (2.08), LC-15-5 (2.01) and CGN-20953 (1.95)	LC-2-2 × Poinsette (4.34), CGN-20953 × Poinsette (3.55), LC-3-3 × K-75 (3.25), LC-15-5 × Poinsette (2.96) and LC-1-1 × K-75 (2.94)
Seedling dry weight (mg)	LC-3-3 (3.81), LC-2-2 (3.48), LC-1-1 (2.92), LC-15-5 (2.31) and Gyne-5 (1.91)	LC-2-2 × Poinsette (4.32), LC-3-3 × K-75 (4.14), LC-1-1 × K-75 (4.00), LC-15-5 × Poinsette (3.22) and CGN-20953 × Japanese Long Green (2.68)
Seed vigour index-I	LC-3-3 (263.12), CGN-20953 (261.83), LC-1-1 (250.31), LC-2-2 (250.14) and LC-15-5 (196.14)	LC-1-1 × K-75 (435.15), CGN-20953 × Poinsette (396.67), LC-2-2 × Poinsette (340.15), LC-15-5 × Poinsette (261.42) and LC-3-3 × K-75 (208.34)
Seed vigour index-II	LC-3-3 (321.31), LC-1-1 (285.35), LC-2-2 (284.45), LC-15-5 (198.69) and Gyne-5 (176.97)	LC-1-1 × K-75 (429.71), LC-2-2 × Poinsette (347.33), LC-3-3 × K-75 (290.82), LC-15-5 × Poinsette (279.19) and CGN-20953 × Japanese Long Green (224.66)
Fruit yield per ha (q)	LC-1-1 (74.67), CGN-20953 (59.48), CGN-19533 (57.61), Gyne-5 (52.67) and K-75 (31.37)	CGN-19533 × K-75 (99.72), LC-25-7 × Japanese Long Green (94.03), CGN-20953 × Poinsette (92.11), LC-1-1 × K-75 (91.59) and Gyne-5 × K-75 (85.52).

*Significant at P<0.05

Table 5 Estimates of genetic components of variance for different traits and proportional contribution of lines, testers and their interactions to sum of squares of the hybrids in cucumber

Trait	σ2 GCA† (Lines)	σ2 GCA (Testers)	σ2 GCA (Average)	σ2 SCA††	σ2g	σ2s	Predictability ratio 2σ2g/ (2σ2g+σ2s)	% contribution of		
								Lines	Testers	Lines × Testers
Seed germination (%)	3.70	3.96	3.92	6.06	15.68	24.24	0.79	43.51	22.42	34.07
Seedling length (cm)	1.15	2.88	2.60	5.58	10.43	22.33	0.63	33.24	23.73	43.02
Seedling dry weight (mg)	3.22	2.42	2.55	5.40	10.20	21.63	0.64	46.50	17.68	35.82
Seed vigour index-I	21459.66	4346.86	7047.21	47023.50	28188.84	188094.00	0.26	48.98	6.82	44.20
Seed vigour index-II	24561.21	10259.58	12517.43	41010.21	50069.72	164040.84	0.47	50.06	11.74	38.20
Fruit yield/ha (q)	881.62	2524.06	2264.43	4092.58	9057.72	16370.32	0.71	32.30	28.25	39.45

†GCA: General combining ability; ††SCA: specific combining ability

index-I (48.98 %) and seed vigour index-II (50.06 %). The range of the proportional contribution of testers varied from 6.82 (seed vigour index-I) to 28.25 (fruit yield per ha) per cent. The proportional contribution of lines × tester interactions ranged from 34.07 (seed germination) to 44.20 (seed vigour index-I) per cent. The contribution of lines × testers interactions was found higher than the individual contribution of lines and testers for seedling length (43.02 %) and fruit per ha (39.45 %), signifying that interaction contributed prominently to the expression of seedling length and fruit yield per hectare in cucumber.

Estimates of heterosis and potence ratio

The different estimates of heterosis (average heterosis, heterobeltiosis and standard heterosis) and potence ratio of top five cross combinations for seed vigour and yield traits in cucumber have been presented in the Table 6. The experimental results revealed that the cross combination CGN-20953 × Poinsette for seed germination; LC-3-3 × K-75 and LC-1-1 × K-75 for seedling length; LC-3-3 × K-75, LC-1-1 × K-75, LC-2-2 × Poinsette, LC-15-5 × Poinsette and Gyne-5 × K-75 for seedling dry weight; LC-1-1 × K-75 for seed vigour index-I; LC-1-1 × K-75, LC-3-3 × K-75, LC-2-2 × Poinsette, LC-15-5 × Poinsette and Gyne-5 × K-75 for seed vigour index-II and LC-1-1 × K-75, CGN-19533 × K-75, CGN-20953 × Poinsette, Gyne-5 × K-75 and LC-3-3 × Poinsette for fruit yield per ha, depicted significantly positive values for all the estimates of heterosis. In over all, cross combination LC-1-1 × K-75, CGN-20953 × Poinsette and LC-3-3 × K-75 were found

Table 6 Estimates of heterosis and potence ratio of top five cross combinations for seed vigour and fruit yield traits in cucumber

Cross combination	Per cent increase/decrease over				Potence ratio (%)	Cross combination	Per cent increase/decrease over				Potence ratio (%)
	Mid parent	Better parent	Standard Check-I	Standard Check-II			Mid parent	Better parent	Standard Check-I	Standard Check-II	
Seed germination (%)						*Seedling length (cm)*					
CGN-20953 × Poinsette	3.83*	0.79*	6.61*	5.74*	0.07	LC-3-3 × K-75	12.05*	6.30*	14.66*	11.32*	0.23
LC-1-1 × K-75	13.01*	11.51*	4.13*	3.28	0.26	LC-1-1 × K-75	13.53*	11.76*	11.66*	8.41*	0.27
LC-3-3 × JLG†	4.40*	3.75*	2.89	2.05	0.09	LC-2-2 × Poinsette	13.37*	3.99	8.75*	5.58	0.25
Gyne-5 × Poinsette	4.40*	3.32	2.89	2.05	0.09	CGN-20953 × K-75	13.23*	10.33*	6.79*	3.68	0.26
CGN-19533 × Poinsette	2.68	2.05	2.89	2.05	0.05	CGN-20953 × Poinsette	15.90*	13.02*	3.79	0.76	0.31
Seedling dry weight (mg)						*Seed vigour index-I*					
LC-3-3 × K-75	36.94*	25.89*	69.51*	55.00*	0.68	LC-1-1 × K-75	28.27*	24.61*	16.23*	11.95*	0.55
LC-1-1 × K-75	35.02*	27.18*	62.47*	48.56*	0.66	CGN-20953 × Poinsette	20.31*	13.95*	10.67*	6.60	0.38
LC-2-2 × Poinsette	30.72*	15.53*	53.59*	40.44*	0.54	LC-3-3 × K-75	11.32*	1.43	8.49*	4.50	0.21
LC-15-5 × Poinsette	28.87*	23.02*	38.07*	26.25*	0.55	LC-2-2 × Poinsette	15.39*	7.47*	8.21*	4.22	0.29
Gyne-5 × K-75	27.22*	21.67*	37.39*	25.63*	0.52	LC-15-5 × Poinsette	16.42*	13.90*	3.41	-0.39	0.32
Seed vigour index-II						*Fruit yield per ha (q)*					
LC-1-1 × K-75	52.39*	41.72*	68.92*	53.40*	0.97	LC-1-1 × K-75	115.52*	83.96*	58.59*	47.17*	6.73
LC-3-3 × K-75	35.81*	20.06*	60.21*	45.49*	0.63	CGN-19533 × K-75	148.21*	141.76*	55.45*	44.25*	55.56
LC-2-2 × Poinsette	33.02*	19.22*	52.58*	38.56*	0.59	CGN-20953 × Poinsette	92.08*	81.53*	52.78*	41.78*	15.85
LC-15-5 × Poinsette	32.95*	28.60*	39.56*	26.74*	0.64	Gyne-5 × K-75	115.98*	93.77*	48.70*	37.99*	10.12
Gyne-5 × K-75	32.57*	31.21*	34.49*	22.13*	0.64	LC-3-3 × Poinsette	75.43*	67.76*	25.68*	16.63*	16.50

* Significant at P<0.05. †Japanese Long Green

most heterotic for different traits under study. Hence, these hybrids can be exploited for the genetic improvement of seed vigour and yield traits in cucumber. Till date, no report of heterosis studies is available in the literature for seed vigour traits in cucumber. However, significant heterosis for fruit yield in cucumber had also been reported earlier by Dogra and Kanwar (2011), Kushwaha *et al.* (2011), Singh *et al.* (2012), Airina *et al.* (2013) and Sharma *et al.* (2016). Further, different estimates of potence ratio for top five heterotic hybrids (Table 6) illustrated that all the hybrid combinations had positive nature for all the seed vigour and yield traits under study. These results reflected partial dominance in all top five heterotic hybrids for different seed vigour traits, while over dominance was exhibited by all the heterotic hybrids towards higher fruit yield per hectare in cucumber. No information is available in the literature pertaining to potence ratio estimation for seed vigour traits; however, Kumar *et al*. (2017) had also reported over dominance for number of fruits per plant, harvest duration and marketable yield/plant in cucumber, while Abd-Rabou and Zaid (2013) had observed that estimates of potence ratio for 10 hybrids of cucumber exhibited over dominance in five hybrids for marketable yield/plant in cucumber.

Conclusion

From the present study, it is concluded that parental lines LC-1-1, CGN-20953 and LC-3-3 were found superior on the basis of mean performance and general combining ability studies. While four cross combination, viz. LC-1-1 × K-75, CGN-20953 × Poinsette, LC-3-3 × Poinsette and LC-3-3 × K-75 were found best based on mean performance, specific combining ability and heterosis studies. These, hybrids can be released for commercial cultivation in different parts of the country after stability testing in multilocation yield trials. While identified novel parental lines, viz. LC-1-1, CGN-20953 and LC-3-3 can be utilized worldwide for the exploitation of heterosis for seed vigour and yield traits in cucumber.

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