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Heterosis and potence ratio studies for yield and its contributing traits in cucumber (*Cucumis sativus* L.)

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Abstract

The present experiment was conducted to estimate the heterosis and dominance effects in the inheritance of fruit yield and its contributing traits in cucumber by using nine parents (6 lines and 3 testers) crossed in Line × Tester design. ANOVA for Line × Tester analysis revealed the presence of sufficient genetic diversity for different traits in the experimental material. The mid parent heterosis among different genotypes was obtained in both positive and negative direction for different traits under study. Maximum average heterosis was observed for the yield per hectare followed by the seed vigour index II, number of marketable fruits per plant, severity of downy mildew, average fruit weight, harvest duration, severity of powdery mildew, node number bearing first female flower, fruit length, incidence of fruit fly, fruit breadth, seed vigour index I, total soluble solids, seed germination, days to marketable maturity and days to first female flower appearance. Partial to over dominance effects were involved in the inheritance of the studied traits. Hybrids estimated positive or negative potence ratio with >1 value is the indication of prevalence of over dominance in desirable direction and scope for exploitation *via* heterosis breeding in cucumber. Experimental results revealed that among 18 crosses, five crosses naming LC-1-1 × K-75, LC-1-1 × Poinsette, LC-2-2 × K-75, LC-2-2 × Poinsette and CGN-20515 × Poinsette were found superior on the basis of overall mean performance and heterotic response for most of the traits. These hybrid combinations could be exploited commercially for the development of hybrids/varieties for better yield, quality (TSS), insect-pest & disease resistance and seed traits in cucumber.

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Keywords: Mid parent heterosis, potence ratio, cucumber, degree of dominance, Line × Tester design.

Introduction

In India, a wide range of variability in vegetative and fruit characters is available for cucumber. Unfortunately, very little attention has been paid for its genetic improvement by using wild genotypes. A speedy improvement can be brought about by assessing the genetic variability and exploitation of heterosis. The exploitation of heterosis is much easier in cross pollinated crops and cucumber being monoecious, provides ample scope for the utilization of hybrid vigour on commercial scale (Singh et al. 2012). Cucumber (*Cucumis sativus* L., 2n=2x=14) belongs to the "gourd" family Cucurbitaceae. It is second most widely cultivated cucurbits after watermelon and important vegetable crop for both internal market and export purpose. It is grown for its tender green fruits during summer and rainy season throughout the country (Kumari et al. 2017). Cucumber is a low energy and high water content (95%) vegetable which makes it diuretic, possessing a deep cleansing action due to the presence of some natural chemical constituents such as glycolic, lactic, and salicylic acids. Currently, very few hybrids have been developed by public sector and the farmers are purchasing hybrid seeds from the private sector companies, who are charging exorbitantly. Stability of genotype is also important for its wider adaptation. To tide over the situation, there is a need to make concentrated efforts to develop F_1 hybrids and making their seed available to the farmers at a reasonable price. Development of F_1 hybrid cultivars offers opportunities for improvement in production, earliness, uniformity, quality and resistance to biotic and abiotic stresses. Maximum heterosis is observed in the F_1, but the superiority of the progeny over their parents is progressively lost in subsequent generations obtained through successive selfing (Meyer et al. 2004). Relative heterosis (mid parent heterosis/average heterosis) i.e. the superiority of a hybrid over its mid parent value, will help in understanding the genetic status of the yield and its component characters. In spite of presence of heterosis, its exploitation will take practical shape only when their F_1 hybrid seeds are produced at an affordable cost. Hence, knowledge of heterosis along with estimates of potence ratio which shed light about degree of dominance will yield more meaningful results to breeders for practical utility and exploitation of heterosis. So, the present investigations were conducted to exploit hybrid vigour for developing the best suitable combination which can replace the conventional varieties as well as hybrids from private sector and also to make F_1 hybrids seed production cost effective (Dogra and Kanwar 2011).

Materials and Methods

The experiment was conducted at the Experimental Research Farm, Department of Vegetable Science, Dr YS Parmar University of Horticulture and Forestry, Nauni, Solan, HP during rainy season of 2013 and 2014. The experimental material comprised of 6 lines (CGN-20256, CGN-20515, CGN-21585, LC-1-1, LC-2-2 and LC-12-4) and 3 broad based testers (Japanese Long Green, K-75 and Poinsette). Eighteen hybrids were developed by crossing 6 lines and 3 testers fashion during rainy season of 2013 as per Line × Tester design as suggested by Kempthorne (1957). Hybrid seeds were produced by conventional hand emasculation and hand pollination method. During *kharif* 2014, 18 F_1 hybrid crosses along with parents (9) were evaluated in randomized block design with three replications. Recommended agronomic practices and need based plant protection measures were taken. The harvestings were carried out manually. Ten plants of each entry in each replication were randomly selected for recording the observations on yield and its component characters. Data were recorded on days to first female flower appearance, node number bearing first female flower, days to marketable maturity, fruit length (cm), fruit breadth (cm), average fruit weight (g), number of marketable fruits per plant, harvest duration (days), marketable yield per hectare (q), total soluble solids (^{o}B), incidence of fruit fly (%), severity of powdery and downy mildew (%), seed germination (%) and seed vigour index-I and II. The data recorded were used to analyze genetic parameters like Line × Tester ANOVA, mid parent heterosis and potence ratio.

For the total soluble solids (TSS) randomly selected fruits were observed under room temperature with the help of 'ERMA Hand Refractometer' by putting 2-3 drops of juice on prism and the values expressed as TSS content of juice (AOAC, 1970). For the incidence fruit fly, total number of fruits per plant and fruits infested with fruit fly were counted from the randomly selected plants to work out its incidence as per the following formula:

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

The occurrence and severity of powdery mildew was recorded periodically under natural conditions. Fifteen leaves were randomly selected from different levels of height (from top to bottom) from ten vines of each parent/cross and disease severity for powdery mildew was recorded by adopting the 0-5 scale (Ransom *et al.* 1991). Similarly, the severity of downy mildew was recorded by adopting the 0-4 scale (Reuveni 1983).

As per the ISTA guidelines (Anonymous 1985), seed germination of each genotype was tested under laboratory conditions through blot paper method. Germination percentage of each replication was worked out by using following formula:

$$\text{Seed germination (\%)} = \frac{\text{Number of seeds germinated}}{\text{Total number of seeds placed for germination}} \times 100.$$

Seed vigour index was calculated as per the formulae given by Abdul-Baki and Anderson (1973):

Seed Vigor Index-I = Seed germination percentage × seedling length (cm)

Seed Vigor Index-II = Seed germination percentage × seedling dry weight (mg)

Data of all the previously mentioned characters were arranged and statistically analyzed to get ANOVA for Line × Tester analysis as per the model suggested by Kempthorne(1957) using statistical software package SPAR 2.0/ OP stat. Heterosis percentages, relative to the mid-parents, for the different studied characters were calculated using the procedure illustrated by Mather and Jinks (1971) as follows:

$$\text{Mid parent heterosis (\%)} = \frac{F_1 - \text{M.P.}}{\text{M.P.}} \times 100$$

Where; F_1 = mean value of the particular hybrid population and M.P. = mean value of the two parents for that hybrid $(P_1 + P_2)/2$.

Moreover, potence ratio was calculated as per Smith (1952) to determine the degree of dominance as follows:

$$P = \frac{F_1 - \text{M.P.}}{0.5\,(P_2 - P_1)}$$

Where, P: relative potence of gene set, F_1: first generation mean, P_1: the mean of lower parent, P2: the mean of higher parent, M.P.: mid-parents value = $(P_1 + P_2)/2$. Complete dominance was indicated when P = +1; while partial dominance is indicated when "P" is between (-1 and +1), except the value zero, which indicates absence of dominance. Over dominance was considered when potence ratio exceeds ±1. The positive and negative signs indicate the direction of dominance of either parent.

Results and Discussion

Performance of the evaluated genetic populations and hybrids: Results of the mean values of the parental/hybrid cultivar showed relatively significant wide range of genetic variability for most studied traits. The significant variations were observed for the traits determining the earliness of a variety/hybrid, namely, days to first female flower appearance (parents=52.05-57.99 and hybrids=49.07-61.50), node number bearing female flower (parents=4.20-8.97 and hybrids=3.15-10.28) and days to marketable maturity (parents =58.17-66.13 and hybrids=56.87-67.47). Ample variations with respect to earliness were also reported by Bairagi et al. (2005), Munshi et al. (2007), Hanchinamani et al. (2008), Yadav et al. (2009) and Kumar et al. (2013) in cucumber. All the parents and hybrids also revealed wide variations with respect to yield and yield contributing traits, namely fruit length (parents=12.20-24.17 and hybrids=15.07-22.10 cm) and breadth (parents=3.80-5.60 and hybrids=3.53-6.03 cm), average fruit weight (parents=184.44-312.43 and hybrids=214.33-369.60 g), number of marketable fruits per plant (parents=3.60-8.03 and hybrids=4.03-11.37), harvest duration (parents=15.76-28.17 and hybrids=15.93-36.46 days), marketable yield per hectare (parents=92.19-216.03 and hybrids=104.20-442.50 q, respectively). Similar results with respect to variation among yield and yield contributing traits in monoecious cultivars of cucumber have also been reported earlier by Munshi et al. (2007), Kumar et al. (2008), Hossain et al. (2010), Dogra and Kanwar (2011), Golabadi et al. (2012), Kumar et al. (2013) and Ranjan et al. (2015). The general approach of selecting parental lines based on mean performance does not necessarily give fruitful results (Allard 1960). The disease trait *viz*., incidence of fruit fly (parents=16.86-29.65 and hybrids=10.87-33.71 %), severity of powdery mildew (parents=10.30-20.17 and hybrids=9.47-25.13 %), severity of downy mildew (parents=12.90-35.53 and hybrids=11.30-30.93 %) and quality trait like total soluble solid (parents=2.90-4.03 and hybrids=2.88-4.07 ^{0}B) and seed traits viz., seed germination (parents=66.17-82.00 and hybrids=68-84 %), seed vigour index I (parents=2084.60-2787.77 and hybrids=1947.37-3216.90 %) and seed vigour index II (parents=663.20-1203.47 and hybrids=688.73-1996.00 %). Substantial variations for seed germination (Hamid et al. 2002, Kumar et al. 2013) and seed vigour (Nerson 2007, Kumar et al. 2013) 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. The results of the comparisons among mean performances, heterosis relatives to mid parent, and potence ratios of the tested population for the various studied characters of cucumber are presented in table 2-6. Therefore, before drawing any conclusion, we have determined heterotic potential and potence ratio for all the traits under study.

ANOVA for Line × Tester analysis: Mean squares (Table 1) due to genotypic differences found significant for all the traits studied. This indicated that the experimental material under study had sufficient genetic diversity for different traits. Further, partitioning of sum of squares due to genotypes indicated that the differences among parents and among hybrids were significant for most of the characters under study. While, mean squares due to parents vs. hybrids were significant for days to first female flower appearance (DTFFFA), node number bearing first female flower (NNBFFF), days to marketable maturity (DTMM), fruit length (FL), fruit breadth (FB), average fruit weight (AFW), number of marketable fruits per plant (NMFPP), harvest duration (HD), incidence of fruit fly (IFF), severity of powdery mildew (SPM), severity of downy mildew (SDM), total soluble solids TSS, seed germination (SG), seed vigour index-I (SVI-I) and II (SVI-II) indicating prevalence of heterosis for yield, earliness and its components.

Heterosis percentages (relative to the mid parent): 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 et al. 2014). Early flowering, fruit maturity and harvest may also be contributed to quick establishment of hybrid plants and their faster growth and development. Estimates of mid parent heterosis for 16 characters studied is presented in the table 2-6. In case of cucumber, for earliness traits like DTFFFA, NNBFFF and DTMM heterosis in negative direction is desirable to catch early market. Range of the mid parent heterosis was -7.21 to 7.35 for DTFFFA; -46.93 to 45.02 for NNBFFF; -5.92 to 8.41 for DTMM. The cross LC-2-2 × Poinsette (-7.21) showed significantly highest negative heterosis for DTFFFA, LC-1-1 × K-75 (-46.93) for NNBFFF and LC-2-2 × Poinsette (-5.91) for DTMM. Significant desirable negative heterosis over mid parent

Table 1: Analysis of variance for Line × Tester analysis including parents in cucumber (F_1)

Source / Character	Mean Sum of Squares								
	Replications	Treatments	Parents	P vs C	Crosses	Lines	Testers	Line × Testers	Error
Df	2	26	8	1	17	5	2	10	52
Days to first female flower appearance	0.411	23.032*	14.464*	0.400*	28.396*	9.022*	19.347*	31.907*	0.783
Node number bearing first female flower	0.091	12.750*	9.621*	9.221*	14.430*	9.249*	12.591*	5.543*	0.076
Days to marketable maturity	0.460	24.919*	26.861*	12.007*	24.765*	27.257*	30.745*	17.110*	0.533
Fruit length (cm)	2.445	18.285*	32.083*	81.633*	8.065*	10.092*	73.441*	59.325*	0.728
Fruit breadth (cm)	0.019	1.224*	0.773*	0.045*	1.506*	0.473*	1.688*	0.445*	0.027
Average fruit weight (g)	800.375	5,156.048*	3,248.331*	20,916.326*	5,126.722*	1,484.293*	6,960.699*	4,643.784*	176.887
No. of marketable fruits per plant	0.113	12.301*	6.369*	18.808*	14.710*	8.330*	4.338*	0.623*	0.112
Harvest duration (days)	1.561	91.191*	42.663*	95.156*	113.795*	58.051*	24.555*	1.942*	1.817
Marketable yield per hectare (q)	171.574	21,483.740*	4,180.226*	69,880.243*	26,779.716*	6,007.101*	1,431.802*	542.704*	197.115
Incidence of fruit fly (%)	0.196	115.958*	52.258*	2.977*	152.581*	51.213*	61.722*	38.557*	1.263
Severity of powdery mildew (%)	1.228	45.274*	27.680*	7.385*	55.782*	24.749*	31.848*	34.002*	2.414
Severity of downy mildew (%)	0.972	106.762*	169.549*	25.440*	81.999*	147.918*	39.548*	537.707*	1.387
Total soluble solids (°B)	0.005	0.282*	0.337*	0.009*	0.272*	0.525*	0.013*	0.047*	0.009
Seed germination (%)	2.420	50.391*	60.981*	8.451*	47.875*	77.433*	41.444*	17.796*	1.240
Seed vigour index-I	5,146.53	241,214.99*	145,186.80*	7,090.80*	300,176.74*	229,607.47*	1,211.16*	11,034.73*	10,472.30
Seed vigour index-II	7,682.73	284,177.78*	100,183.75*	1,393,857.28*	305,487.95*	153,078.57*	15,508.42*	5,060.32*	8,305.71

*Significant at 5% level of significance

Table 2:. Mean performance of parents for different traits in cucumber

Parents	DTF-FFA	NNB-FFF	DT-MM	FL	FB	AFW	NOM-FPP	HD	MYPH	IFF	SPM	SDM	TSS	SG	SVI-I	SVI-II
Lines																
CGN-20256	52.05	5.17	59.08	12.20	4.83	188.44	7.33	25.21	146.91	26.32	20.17	35.53	3.37	75.67	2084.60	683.09
CGN-20515	52.42	4.20	58.18	14.73	5.60	238.93	8.00	26.08	203.72	21.06	12.43	18.60	2.90	82.00	2420.23	809.20
CGN-21585	52.21	4.40	58.17	15.37	4.43	224.65	7.07	24.47	168.81	24.44	18.82	28.90	4.03	77.67	2170.67	663.20
LC-1-1	52.45	5.00	61.10	17.77	4.90	252.05	8.03	28.17	216.03	17.37	17.27	26.27	3.20	75.33	2581.70	1125.62
LC-2-2	52.86	5.97	61.32	15.70	5.10	231.42	7.43	26.49	183.40	16.86	14.47	16.83	3.10	77.67	2787.77	1203.47
LC-12-4	56.59	8.97	66.13	16.10	4.70	242.28	3.60	15.76	92.19	25.47	15.40	21.53	2.93	66.67	2170.93	865.67
Testers																
K-75	55.31	6.87	61.63	15.47	4.97	222.65	6.50	23.88	154.89	21.28	15.60	13.20	3.10	73.33	2435.01	973.44
JLG*	57.99	8.47	65.85	24.17	3.80	312.43	5.43	20.89	180.89	29.65	16.23	19.33	3.23	79.00	2397.10	838.84
Poinsette	52.91	4.40	59.57	15.73	5.20	237.27	7.83	26.61	198.29	22.43	10.30	12.90	3.17	80.33	2404.50	949.97
Range	52.05 to 57.99	4.20 to 8.97	58.17 to 66.13	12.20 to 24.17	3.80 to 5.60	188.44 to 312.43	5.43 to 8.03	15.76 to 28.17	92.19 to 216.03	16.86 to 29.65	10.30 to 20.17	12.90 to 35.53	2.90 to 4.03	66.67 to 82.00	2084.60 to 2787.77	663.20 to 1203.47
Mean	53.87	59.39	61.22	16.36	4.84	238.90	6.80	24.17	171.68	22.76	15.63	21.45	3.22	76.41	2383.61	901.39

*JLG = Japanese Long Green

Whereas: DTFFFA= Days to first female flower appearance, NNBFFF= Node number bearing first female flower, DTMM= Days to marketable maturity, FL= Fruit length, FB= Fruit Breadth, AFW=Average fruit weight, NMFPP= Number of marketable fruit per plant, HD= Harvest duration, YPH= Yield per hectare, IFF= Incidence of fruit fly, SDM= Severity of downy mildew, SPM= Severity of powdery mildew, TSS= Total soluble solids, SG= Seed germination(%), and SVI-I= Seed vigour index I and II

Table 3: Mean performance, mid parent value, heterosis percentage (relative to mid parent value) and potence ratio of 9 parents and their 18 F_1 hybrids for earliness and yield contributing traits in cucumber

Traits(s) / Cross(s)	Days to first female flower appearance				Node number bearing first female flower				Days to Marketable Maturity				Fruit Length (cm)			
	Mean	MP	MPH (%)	PR	Mean	MP	MPH (%)	PR	Mean	MP	MPH (%)	PR	Mean	MP	MPH (%)	PR
CGN-20256 ×K-75	55.80	53.68	3.95*	1.30	8.73	6.02	45.02*	3.19	65.43	60.36	8.41*	3.98	16.37	13.84	18.32*	1.55
CGN-20256×JLG	55.27	55.02	0.45	0.08	8.23	6.82	20.67*	0.85	63.68	62.47	1.95*	0.36	19.50	18.19	7.23	0.22
CGN-20256 × Poinsette	52.93	52.48	0.86	1.05	6.40	4.79	33.75*	4.19	61.80	59.33	4.17*	10.10	15.07	13.97	7.91	0.63
CGN-20515×K-75	52.53	53.87	-2.48	-0.92	6.38	5.54	15.27*	0.63	62.47	59.91	4.28*	1.49	17.60	15.10	16.56*	6.76
CGN-20515×JLG	54.10	55.21	-2.00	-0.40	6.68	6.34	5.45	0.16	61.03	62.02	-1.59	-0.26	18.23	19.45	-6.27	-0.26
CGN-20515×Poinsette	51.87	52.67	-1.51	-3.24	5.70	4.3	32.56*	14.00	60.01	58.88	1.93	1.63	16.70	15.23	9.65*	2.94
CGN-21585×K-75	53.57	53.76	-0.35	-0.12	7.22	5.64	28.13*	1.28	62.90	59.90	5.01*	1.73	18.87	15.42	22.37*	69.00
CGN-21585×JLG	59.10	55.10	7.26*	1.38	8.68	6.44	34.89*	1.10	64.81	62.01	4.52*	0.73	18.37	19.77	-7.08*	-0.32
CGN-21585×Poinsette	52.55	52.56	-0.02	-0.03	3.72	4.4	-15.45*	0.00	57.63	58.87	-2.11*	-1.77	16.67	15.55	7.20	6.22
LC-1-1×K-75	50.66	53.88	-5.98*	-2.25	3.15	5.94	-46.93*	-2.98	58.67	61.37	-4.39*	-10.17	22.10	16.62	32.97*	4.77
LC-1-1×JLG	53.20	55.22	-3.66*	-0.73	7.98	6.74	18.49*	0.72	62.25	63.48	-1.93*	-0.52	19.73	20.97	-5.91	-0.39
LC-1-1×Poinsette	53.03	52.68	0.66	1.52	5.38	4.7	14.47*	2.27	60.88	60.34	0.90	0.71	20.17	16.75	20.42*	3.35
LC-2-2×K-75	51.37	54.09	-5.02*	-2.22	5.02	6.42	-21.81*	-3.11	61.31	61.48	-0.27	-1.06	18.53	15.59	18.90*	25.61
LC-2-2×JLG	58.17	55.43	4.95*	1.07	10.08	7.22	39.61*	2.29	65.28	63.59	2.67*	0.75	19.73	19.94	-1.03	-0.05
LC-2-2×Poinsette	49.07	52.89	-7.21*	-152.6	3.17	5.19	-38.86*	-2.57	56.87	60.45	-5.91	-4.09	19.30	15.72	22.81*	239.0
LC-12-4× K-75	54.83	55.95	-2.00	-1.75	8.10	7.92	2.27	0.17	64.74	63.88	1.35	0.38	17.73	15.79	12.32*	6.17
LC-12-4×JLG	61.50	57.29	7.35*	6.01	10.28	8.72	17.89*	6.24	67.47	65.99	2.24*	10.57	19.27	20.14	-4.30	-0.21
LC-12-4× Poinsette	52.73	54.75	-3.69*	-1.10	4.83	6.69	-27.75*	-0.81	59.65	62.85	-5.09*	-0.98	18.87	15.92	18.57*	15.97
Range	51.37		-7.21	-152.6	3.15		-46.93	-3.11	56.87		-5.91	-10.17	15.07		-7.08	-0.39
	to		to	to	to		to	to	to		to	to	to		to	to
	61.50		7.35	6.01	10.28		45.02	14.00	67.47		8.41	10.57	22.10		32.97	239
SE(m)±	0.71				0.22				0.60				0.69			
$CD_{(0.05)}$	1.43				0.44				1.19				1.37			

JLG = Japanese Long Green; MP= Mid Parent; MPH= Mid Parent Heterosis; PR= Potence Ratio, *Significant at 5% level of significance

Table 4:. Mean performance, mid parent value, heterosis percentage (relative to mid parent value) and potence ratio of 9 parents and their 18 F_1 hybrids for yield and its contributing traits in cucumber

Traits(s) / Crosses	Fruit Breadth				Average Fruit Weight				Number of Marketable Fruits per Plant				Harvest Duration			
	Mean	MP	MPH (%)	PR	Mean	MP	MPH (%)	PR	Mean	MP	MPH (%)	PR	Mean	MP	MPH (%)	PR
CGN-20256 ×K-75	4.97	4.90	1.43	1.00	235.62	205.55	14.63*	1.76	5.73	6.92	-17.14*	-2.86	20.73	24.55	-15.54*	-5.74
CGN-20256×JLG	3.53	4.32	-18.19*	-1.52	200.03	250.44	-20.13*	-0.81	6.43	6.38	0.78	0.05	22.27	23.05	-3.38	-0.36
CGN-20256×Poinsette	4.73	5.02	-5.68*	-1.54	228.18	212.86	7.20	0.63	8.17	7.58	7.78*	2.36	27.55	25.91	6.33	2.34
CGN-20515×K-75	4.77	5.29	-9.74*	-1.63	243.33	230.79	5.43	1.54	8.10	7.25	11.72*	1.13	27.31	24.98	9.33*	2.12
CGN-20515×JLG	6.03	4.70	28.30*	1.48	319.03	275.68	15.72*	1.18	7.83	6.72	16.60*	0.87	26.28	23.49	11.90*	1.08
CGN-20515×Poinsette	5.73	5.40	6.11*	1.65	277.65	238.1	16.61*	47.65	8.83	7.92	11.56*	10.76	29.03	26.35	10.19*	10.13
CGN-21585×K-75	4.50	4.70	-4.26	-0.74	271.75	223.65	21.51*	48.10	7.13	6.79	5.08	1.21	24.94	24.18	3.16	2.59
CGN-21585×JLG	4.27	4.12	3.77	0.49	235.18	268.54	-12.42*	-0.76	5.67	6.25	-9.28*	-0.71	20.55	22.68	-9.39	-1.19
CGN-21585×Poinsette	5.00	4.82	3.84	0.48	258.57	230.96	11.95*	4.38	10.70	7.45	43.62*	8.55	34.59	25.54	35.43*	8.46
LC-1-1×K-75	5.70	4.94	15.50*	21.86	365.20	237.35	53.87*	8.70	11.37	7.27	56.50*	5.37	36.46	26.03	40.10*	4.86
LC-1-1×JLG	4.00	4.35	-8.05*	-0.64	260.36	282.24	-7.75*	-0.72	6.40	6.73	-4.90	-0.25	22.55	24.53	-8.07	-0.54
LC-1-1×Poinsette	5.23	5.05	3.56	1.20	315.79	244.66	29.07*	9.63	9.40	7.93	18.54*	14.70	30.74	27.39	12.23*	4.29
LC-2-2×K-75	5.60	5.04	11.22*	8.69	311.21	227.04	37.08*	19.20	9.33	6.97	33.96*	5.09	30.48	25.19	21.02*	4.06
LC-2-2×JLG	4.13	4.45	-7.19*	-0.49	261.16	271.93	-3.96	-0.27	4.50	6.43	-30.02*	-1.93	17.23	23.69	-27.27*	-2.31
LC-2-2×Poinsette	5.10	5.15	-0.97	-1.00	315.07	234.35	34.45*	27.60	11.30	7.63	48.10*	18.35	36.27	26.55	36.61*	162.0
LC-12-4× K-75	5.27	4.84	9.00*	3.22	270.72	232.47	16.46*	3.90	6.30	5.05	24.75*	0.86	22.32	19.82	12.61*	0.62
LC-12-4×JLG	3.93	4.25	-7.53*	-0.71	242.57	277.36	-12.54*	-0.99	4.03	4.52	-10.74	-0.53	15.93	18.33	-13.07*	-0.93
LC-12-4× Poinsette	5.47	4.95	10.51*	2.08	302.45	239.78	26.14*	25.02	9.63	5.72	68.50*	1.85	31.28	21.19	47.65*	1.86
	3.53		-18.19	-1.63	200.03		-20.14	-0.99	4.03		-30.02	-2.86	15.93		-27.27	-5.74
Range	to		to	to	to		to	to	to		to	to	to		to	to
	6.03		28.30	21.86	365.20		53.87	48.10	11.37		68.50	18.35	36.46		47.65	162
SE(m)±	0.13				10.66				0.27				1.09			
$CD_{(0.05)}$	0.27				21.35				0.54				2.17			

JLG = Japanese Long Green; MP= Mid Parent; MPH= Mid Parent Heterosis; PR= Potence Ratio, *Significant at 5% level of significance was recorded in five each cross combination for DTFFFA, NNBFFF and DTMM traits respectively. The negative heterosis for these traits also revealed that that the hybrids are early maturing types than their parents. Earlier researchers, namely Kumbhar et al. (2005); Yadav et al. (2008); Kumar et al. (2010); Kushwaha et al. (2011) and Kumar et al. (2017) had also reported the importance of heterosis for earliness using monoecious cultivars of cucumber. For fruit parameters like FL, FB and AFW range of mid parent heterosis was -7.08 to 32.97, -18.19 to 28.30 and -20.13 to 53.87 respectively. Out of eighteen hybrids, significantly higher positive (desirable) heterosis was observed in 10 hybrids for FL, 6 for FB and 11 hybrids for AFW. While significantly highest positive (desirable) heterosis was observed in LC-1-1 × K-75 (32.97) hybrids for FL and same cross for AFW with value (53.87), CGN-20515 × JLG (28.30) for FB. The present findings are in conformity with Sudhakar et al. (2005), Kumar et al. (2010) and Singh et al. (2012) and Kumar et al. (2017). But, these results are in discrepancy with the earlier findings, that is, Kartalov (1966) reported that hybrids of cucumber were intermediate in fruit length; while Singh et al. (1970) observed that all the F_1 hybrids produced smaller fruits as compared to their respective mean of parents. The deviation could be on account of the variation in genotypes used in hybrid combinations and also in environments under which these were evaluated. The magnitude of heterosis over mid parent was highly significant in both the directions for above traits which are the indication of varied degree of dominance involved in the inheritance of above traits. Heterosis over mid parent in F_1 ranged -30.02 (LC-2-2 × Japanese Long Green) to 68.50 (LC-12-4 × Poinsette) for NOMFPP and -27.27 (LC-2-2 × Poinsette) to 47.65 (LC-12-4 × Poinsette) for harvest duration per cent respectively over mid parent. Significant desirable positive heterosis over mid parent was recorded in eleven and ten cross combinations for NMFPP and HD respectively. For yield per hectare heterosis over mid parent ranged from -31.18 to 138.70 percent. The highest estimate of hetersois over average or mid parent was shown by LC-1-1 × K-75 and 12 crosses showed significant estimates of heterosis over mid parent for YPH. 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 Kumar et al. (2017).

Cucumber is vulnerable to the attack of a number of insect-pest and diseases of which fruit fly, powdery mildew and downy mildew are the most destructive during rainy season in Himachal Pradesh. So keeping in view these points, mid parent heterosis for IFF, SPM and SDM varied between -43.75 to 31.97, -28.41 to 46.02 and -34.07 to 63.09 respectively. Out of 18 crosses 9 crosses for IFF, 2 crosses for SPM and 6 crosses for DM showed significant negative mid parent heterosis. The cross LC-1-1 × K-75 showed significant highest positive (desirable) heterosis over mid parent for TSS and ranged from -5.81 to 14.29. Out of eighteen hybrids, significantly higher positive (desirable) heterosis was observed in 4 hybrids for TSS. Seed viability and vigor helps in emergence and development of normal seedlings in wide environmental conditions. Therefore, use of quality seed material is essential for ensuring higher productivity in any crop. The range for seed germination was -3.36 to 13.01, for SVI-I it was -13.24 to 28.25 and -8.29 to 90.18 for SVI-II. Out of 18 crosses 6 crosses for SG, 3 crosses for SVI-I and 12 crosses for SVI-II exhibited significant positive mid parent heterosis. Hence, these hybrids can be exploited for the genetic improvement of seed vigour and yield traits in cucumber. These similar results were found by Kumar et al. 2018 depicted significantly positive values for all the estimates of heterosis. Hence, these hybrids can be exploited for the genetic improvement of cucumber.

Potence Ratio: The potence ratio exhibited in 18 F_1 crosses are presented in table 2-6. In F_1 hybrids for days to first female flower appearance the potence ratio ranged from -152.6 (LC-2-2 × Poinsette) to 6.01 (LC-12-4 × JLG) with twelve crosses indicating over dominance (>±1) and six combination exhibiting partial dominance, for node number bearing first female flower the potence ratios ranged from -3.11 (LC-2-2 × K-75) to 14.00 (CGN-20515 × Poinsette), with eleven crosses indicated over dominance (>±1) and six indicated partial dominance (-1 to +1) where as in one cross there was absence of dominance (0) in F_1 generation and for days to marketable maturity, in F_1 the potence ratios ranged from -10.17 (LC-1-1 × K-75) to 10.57 (LC-12-4 × JLG) with ten crosses indicated over dominance (>±1) and eight indicated partial dominance (-1 to +1) in the inheritance of days to marketable maturity. These results were similar to the results of El-Tahawey *et al.* (2015) who reported negative estimates of potence ratio for number of nodes to the first female flower and number of days to the first female flower in number of crosses of pumpkin. Kumar et al. (2017) illustrated that all the hybrid combinations have positive nature for all the traits related to earliness. These results reflected over dominance in nine crosses towards lower number of days to first female flower appearance, node number bearing first female flower and days to marketable maturity. On the other hand, absence of dominance was found only in one cross combination, for all the traits related to earliness.

Table 5: Mean performance, mid parent value, heterosis percentage (relative to mid parent value) and potence ratio of 9 parents and their 18 F_1 hybrids for yield and insect pest and diseases traits in cucumber

Trait(s) / Cross(s)	Yield per Hectare (q)				Incidence of Fruit Fly (%)				Severity of Powdery Mildew (%)				Severity of Downy mildew (%)			
	Mean	MP	MPH (%)	PR	Mean	MP	MPH (%)	PR	Mean	MP	MPH (%)	PR	Mean	MP	MPH (%)	PR
CGN-20256 ×K-75	144.13	150.90	-4.49	-1.70	25.13	23.80	5.59*	0.53	25.07	17.89	40.17*	3.14	17.27	24.37	-29.12*	-0.64
CGN-20256×JLG	137.10	163.90	-16.35*	-1.58	30.79	27.99	10.02*	1.68	13.03	18.20	-28.41*	-2.62	24.60	27.43	-10.32*	-0.35
CGN-20256 × Poinsette	198.82	172.60	15.19*	1.02	16.72	24.38	-31.41*	-3.94	14.30	15.24	-6.14	-0.19	22.80	24.22	-5.84	-0.13
CGN-20515×K-75	210.14	179.31	17.20*	1.26	18.07	21.17	-14.64*	-28.18	13.73	14.02	-2.03	-0.18	18.20	15.90	14.47*	0.85
CGN-20515×JLG	266.59	192.31	38.63*	6.51	29.20	25.36	15.16*	0.90	17.13	14.33	19.54*	1.47	30.93	18.97	63.09*	32.78
CGN-20515 × Poinsette	261.64	201.01	30.17*	22.33	19.84	21.75	-8.76*	-2.78	9.47	11.37	-16.67	-1.78	16.17	15.75	2.67	0.15
CGN-21585×K-75	206.87	161.85	27.82*	6.47	23.05	22.86	0.83	0.12	25.13	17.21	46.02*	4.92	24.77	21.05	17.67*	0.47
CGN-21585×JLG	142.34	174.85	-18.59*	-5.38	33.71	27.05	24.64*	2.56	20.70	17.53	18.12*	2.45	15.90	24.12	-34.07*	-1.72
CGN-21585×Poinsette	295.21	183.55	60.83*	7.58	16.63	23.44	-29.04*	-6.77	16.57	14.56	13.80	0.47	22.50	20.90	7.66	0.20
LC-1-1×K-75	442.70	185.46	138.7*	8.41	10.87	19.33	-43.75*	-4.32	12.93	16.44	-21.33*	-4.20	15.07	19.74	-23.64*	-0.71
LC-1-1×JLG	177.69	198.46	-10.47	-1.18	29.91	23.51	27.22*	1.04	17.33	16.75	3.46	1.12	26.60	22.80	16.67*	1.10
LC-1-1×Poinsette	316.61	207.16	52.83*	12.34	15.44	19.90	-22.41*	-1.76	13.67	13.79	-0.83	-0.03	18.83	19.59	-3.85	-0.11
LC-2-2×K-75	309.68	169.15	83.09*	9.86	12.80	19.07	-32.88*	-2.84	15.52	15.04	3.23	0.86	17.20	15.02	14.55*	1.20
LC-2-2×JLG	125.35	182.15	-31.18*	-45.25	30.69	23.26	31.97	1.16	16.63	15.35	8.34	1.45	24.03	18.08	32.91*	4.76
LC-2-2×Poinsette	379.81	190.85	99.01*	25.38	16.96	19.65	-13.67*	-0.96	12.27	12.39	-0.93	-0.06	11.30	14.87	-23.98*	-1.81
LC-12-4× K-75	182.03	123.54	47.34*	1.87	18.68	23.38	-20.09*	-2.24	21.73	15.50	40.19*	62.30	17.97	17.37	3.48	0.15
LC-12-4×JLG	104.29	136.54	-23.62*	-0.73	31.29	27.56	13.53*	1.78	16.43	15.82	3.89	1.48	26.37	20.43	29.07*	5.40
LC-12-4× Poinsette	310.80	145.24	113.99*	3.12	22.65	23.95	-5.43	-0.86	12.58	12.85	-2.10	-0.11	14.30	17.22	-16.93*	-0.68
Range	104.29 to 442.7		-31.18 to 138.70	-45.25 to 25.38	10.87 to 33.71		-43.75 to 31.97	-28.18 to 2.56	9.47 to 25.13		-28.41 to 46.02	-4.20 to 62.30	11.30 to 30.93		-34.07 to 63.09	-1.81 to 32.78
SE(m)±	11.33				0.91				1.23				0.97			
$CD_{(0.05)}$	22.69				1.82				2.45				1.94			

JLG = Japanese Long Green; MP= Mid Parent; MPH= Mid Parent Heterosis; PR= Potence Ratio, *Significant at 5% level of significance

In F_1 for yield traits like fruit length the potence ratios ranged from -0.39 (LC-1-1 × JLG) to 239 (LC-2-2 ×Poinsette) with eleven crosses indicated over dominance (>±1), seven indicated partial dominance (-1 to +1), for fruit breadth the potence ratios ranged from -1.63(CGN-20515 × K-75) to 21.86 (LC-1-1 × K-75) with ten crosses indicated over dominance (>±1), six indicated partial dominance (-1 to +1) and two crosses indicating complete dominance (1) and for average fruit weight it ranged from -0.99 (LC-12-4 × JLG) to 48.1 (CGN-21585 x K-75) with over dominance (>±1) was recorded by the twelve crosses and partial dominance (-1 to +1) with six crosses in F_1. For number of marketable fruits per plant, potence ratios ranged from -2.86 (CGN-20256 × K-75) to 18.35 (LC-2-2 × Poinsette) in F_1 with twelve crosses indicate over dominance (>±1), six crosses partial dominance (-1 to +1). For the trait harvest duration potence ratios in F_1 ranged from -5.74 (CGN-20256 × K-75) to 162 (LC-2-2 × Poinsette) with fourteen crosses indicate over dominance (>±1), four crosses partial dominance (-1 to +1). Yield per hectare recorded potence ratios ranged from -45.25 (LC-2-2 × JLG) to 25.38 (LC-2-2 × Poinsette) and with seventeen crosses indicating over dominance (>±1) and only one cross (LC-12-4 × JLG) with partial dominance in F_1. Similar results were also found by Kumar *et al.* (2017) revealed positive nature; which reflected over dominance towards longer fruit length, higher fruit breadth and average fruit weight. Abd-Rabou and Zaid (2013) reported over dominance for number of fruits per plant, harvest duration and marketable yield/plant in cucumber and reported that potence ratio of seven cucumber hybrids was higher than one, indicating over dominance of this trait towards the heavy parent. On the contrary, two hybrids showed over dominance and one revealed partial dominance towards the lighter parent. In pumpkin, El-Tahawey et al. (2015) had reported positive estimates of potence ratio in most of the hybrids for average fruit weight.

For incidence of fruit fly, potence ratios ranged from -28.18 (CGN-20515 × K-75) to 2.56 (CGN-21585 × JLG) with thirteen crosses indicating over dominance (>±1), five crosses partial dominance (-1 to +1) , and for severity of powdery mildew in F_1 the potence ratios

Table 6:. Mean performance, mid parent value, heterosis percentage (relative to mid parent value) and potence ratio of 9 parents and their 18 F_1 hybrids for quality and seed traits in cucumber

Traits / Crosses	TSS (%)				Seed germination (%)				Seed Vigour Index -I				Seed vigour Index-II			
	Mean	MP	MPH (%)	PR	Mean	MP	MPH (%)	PR	Mean	MP	MPH (%)	PR	Mean	MP	MPH (%)	PR
CGN-20256 ×K-75	3.13	3.24	-3.25	-0.78	72.00	74.50	-3.36*	-2.14	2261.80	2259.81	0.09	0.01	1128.77	828.27	36.28*	2.07
CGN-20256×JLG	3.47	3.30	5.15*	2.43	77.67	77.34	0.43	0.20	2291.20	2240.85	2.25	0.32	960.50	760.97	26.22*	2.56
CGN-20256×Poinsette	3.08	3.27	-5.81*	-1.90	76.33	78.00	-2.14	-0.72	1947.37	2244.55	-13.24*	-1.86	1203.63	816.53	47.41*	2.90
CGN-20515×K-75	3.10	3.00	3.33	1.00	81.33	77.67	4.72*	0.85	2691.80	2427.62	10.88*	35.75	1358.27	891.32	52.39*	5.69
CGN-20515×JLG	3.03	3.07	-1.14	-0.21	75.00	80.50	-6.83*	-3.67	2432.30	2408.67	0.98	2.04	959.70	824.02	16.47	9.16
CGN-20515×Poinsette	2.88	3.04	-5.11	-1.15	83.33	81.17	2.67*	2.59	2381.17	2412.37	-1.29	-3.97	1249.50	879.59	42.06*	5.26
CGN-21585×K-75	3.45	3.57	-3.23	-0.25	73.67	75.50	-2.42*	-0.84	2203.90	2302.84	-4.30	-0.75	949.50	818.32	16.03	0.85
CGN-21585×JLG	4.07	3.63	12.12*	1.10	78.00	78.34	-0.43	-0.50	2090.20	2283.89	-8.48*	-1.71	688.73	751.02	-8.29	-0.71
CGN-21585 × Poinsette	3.53	3.60	-1.94	-0.16	77.00	79.00	-2.53*	-1.50	2194.80	2287.59	-4.06	-0.79	849.97	806.59	5.38	0.30
LC-1-1×K-75	3.60	3.15	14.29*	9.00	84.00	74.33	13.01*	9.67	3216.90	2508.36	28.25*	9.66	1996.00	1049.53	90.18*	12.44
LC-1-1×JLG	3.12	3.22	-2.95	-6.33	76.33	77.17	-1.08	-0.46	2371.87	2489.40	-4.72	-1.27	1099.80	982.23	11.97	0.82
LC-1-1×Poinsette	3.50	3.19	9.89*	21.00	80.67	77.83	3.65*	1.14	2460.13	2493.10	-1.32	-0.37	1264.20	1037.80	21.82*	2.58
LC-2-2×K-75	2.98	3.10	-3.87	0.00	78.00	75.50	3.31*	1.15	2604.73	2611.39	-0.26	-0.04	1359.20	1088.46	24.87*	2.35
LC-2-2×JLG	3.30	3.17	4.27	2.08	76.67	78.34	-2.13	-2.50	2450.40	2592.44	-5.48	-0.73	1195.50	1021.16	17.07*	0.96
LC-2-2×Poinsette	3.02	3.14	-3.67	-3.29	80.33	79.00	1.68	1.00	2996.27	2596.14	15.41*	2.09	1804.60	1076.72	67.60*	5.74
LC-12-4× K-75	2.97	3.02	-1.49	-0.53	68.00	70.00	-2.86*	-0.60	2077.17	2302.97	-9.80*	-1.71	930.50	919.56	1.19	0.20
LC-12-4×JLG	3.22	3.08	4.55	0.93	73.33	72.84	0.68	0.08	2248.90	2284.02	-1.54	-0.31	1019.37	852.26	19.61*	12.46
LC-12-4× Poinsette	3.03	3.05	-0.66	-0.17	76.00	73.50	3.40*	0.37	2340.43	2287.72	2.30	0.45	1216.03	907.82	33.95*	7.31
Range	2.88 to 4.07		-5.81 to 14.29	-6.33 to 21.00	68.00 to 84.00		-6.83 to 13.01	-3.67 to 9.67	1947.37 to 3216.90		-13.24 to 28.25	-3.97 to 35.75	688.73 to 1996.0		-8.29 to 90.18	-0.71 to 12.46
SE(m)±	0.08				0.90				82.45				73.78			
$CD_{(0.05)}$	0.15				1.79				165.07				147.71			

JLG = Japanese Long Green; MP= Mid Parent; MPH= Mid Parent Heterosis; PR= Potence Ratio, *Significant at 5% level of significance

ranged from -4.20 (LC-1-1 × K-75) to 62.30 (LC-12-4 × K-75) with eleven crosses indicated over dominance (>±1), seven indicated partial dominance (-1 to +1). And for severity of downy mildew the potence ratios ranged from -1.81 (LC-2-2 × Poinsette) to 32.78 (CGN-20515 × JLG), with seven crosses indicated over dominance (>±1), eleven indicated partial dominance (-1 to +1).

The quality traits estimated for the potence ratios to know their inheritance pattern. In F_1 for the total soluble solid the potence ratios ranged from -6.33 (LC-1-1 × JLG) to 21.00 (LC-1-1 × Poinsette) with nine crosses indicated over dominance (>±1), seven indicated partial dominance (-1 to +1) and one each of hybrid shown complete dominance (=1) and absence of dominance (=0) in the inheritance of fruit TSS. For seed germination the potence ratios ranged from -3.67 (CGN-20515 × JLG) to 9.67 (LC-1-1 × K-75) with eight crosses indicate over dominance (>±1), nine crosses partial dominance (-1 to +1) and one cross combination with complete dominance (=1), for seed vigour index I potence ratios for this trait ranged from -3.97 (CGN-20515 × Poinsette) to 35.75 (CGN-20515 × K-75) in F_1 and with nine each of crosses indicate over dominance (>±1) and partial dominance (-1 to +1). For seed vigour index II it ranged from -0.71 (CGN-21585 × JLG) to 12.46 (LC-12-4 × JLG) and twelve crosses indicate over dominance (>±1), six crosses partial dominance (-1 to +1). No information is available in the literature pertaining to potence ratio estimation for seed vigour traits; however, Kumar et al. (2017) had also reported partial dominance in all top five heterotic hybrids for different seed vigour traits, in cucumber.

Conclusion

The present study illustrated that heterosis breeding is the best possible breeding strategy for improving yield and its contributing traits in cucumber, all of which are governed by non additive gene effects. In the present investigation broader range of mid parent heterosis and potence ratio in both positive and negative direction were observed. We also found that partial to over-dominance effects are involved in the inheritance of fruit yield and other economically important traits. Three parental lines (CGN-20515, CGN-20256, LC-1-1 and K-75) were found to be most promising because they produced the maximum frequency of high-yielding hybrids with desirable traits and appreciable disease tolerance when crossed either among them or with other parents. We were also able to identify some promising hybrids for particular traits based on their *per se* performance, the level of heterobeltiosis manifested in them, their quality and disease reaction. Two hybrids (LC-1-1 × K-75, LC-2-2 × Poinsette) could compete with the existing commercial hybrids that are available in the tropics, and so may be recommended for commercial.

सारांश

वर्तमान अध्ययन खीरे में 9 पित्रों (6 लाइन एवं 3 टेस्टर्स) को समाहित का वंशक्रम x परीक्षण (लाइन ग टेस्टर) अभिकल्प से फल उपज एवं उपज में सहायक घटकों के ओज वंशागतित्व के प्रभावी प्रभाव को ज्ञात करने के लिये आंकलन किया गया। वंशक्रम ग परीक्षण (लाइन ग टेस्टर) के एनोवा से स्पष्ट हुआ कि अध्ययन सामग्री में गुणों की विविधता ज्यादा है। विभिन्न प्रभेदों में मध्य पितृ ओज सकारात्मक व नकारात्मक दोनों दिशा में पाया गया। अधिकतम औसत ओज कुछ गुणों उपज/हे. के लिए पाया गया तथा इसके बाद बीज ओज सूचकांक–II, प्रति पौध बाजार (योग्य फलों की संख्या, मृदुरोमिल आसिता की उग्रता, औसत फल भार, तुड़ाई अवधि, चूर्णिल आसिता की उग्रता, प्रथम मादा पुष्प विकसित होने वाले पार्श्व गाँठ, फल की लम्बाई, फल मक्खी का प्रकोप, फल की चौड़ाई, बीज ओज सूचकांक–I, कुल विलेय ठोस, बीज जमाव, बाजार योग्य पकाव के दिन तथा प्रथम मादा पुष्प विकास का समय के लिये पाया गया। आंशिक से अति प्रभाविता वंशागतित्व के लिये जिम्मेदार घटक है। सकारात्मक या नकारात्मक संकर आंकलन में क्षमता अनुपात >1 मूल्य यह संकेत देता है कि अति प्रभाविता वांछित दिशा में हैं तथा खीरा में संकर प्रजनन कर ओज को प्राप्त किया जा सकता है। कुल प्रायोगिक 18 संकरणों में 5 संकरण एल सी–1–1 x के–75, एल सी–1–1 x प्वाइनसेट, एल सी–2–2 x के–75, एल सी–2–2 x प्वाइनसेट तथा सी जीएन– 20515 x प्वाइनसेट औसत क्षमता माध्य के अनुसार उत्तम पाये गये और इनमें ओजोस्विता परिणाम ज्यादा था। इन संकर संयोजों को संकर/प्रजाति विकास में व व्यवसायिक रूप से अधिक उपज, गुणवत्ता (कुल विलेय ठोस), कीट व रोग प्रतिरोधिता एवं बीज गुण के लिये अपनाया जा सकता है।

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