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Research Article

Line x tester analysis for yield and rust resistance in Cowpea (*Vigna unguiculata* L. Walp)

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Abstract :
The combining ability of the parents as well as the hybrids of cowpea (*Vigna unguiculata* L. Walp) involving three lines and sixteen testers was studied. The parents and their resultant 48 hybrids were evaluated in line x tester mating design and observations were recorded for nine quantitative and one qualitative trait. The GCA/SCA ratio indicated that all the traits studied were found to be predominantly controlled by non additive genes. Based on mean performance and GCA effects, line V 118 and testers IC 202784, IC 202782 and IC 202778 were found to be the best general combiner for seed yield/plant. The hybrids V 118 x IC 202782 and V 118 X IC 202784 were found to be superior for more than one trait based on *per se* performance and standard heterosis. Besides the heterotic potential, the hybrid V 118 x IC 202784 was found to be moderately resistant to rust.

Key words:
Cowpea, combining ability, heterosis, rust

Introduction

The average productivity of cowpea is low as compared to other pulse crops due to the lack of availability of high yielding genotypes and also susceptibility of the genotypes to major biotic stresses. Rust (*Uromyces vignae* Bercl.) inflicts considerable economic damage in *kharif* and early *rabi* season. Anil kumar *et al*. (1989) reported that rust alone could cause yield loss up to 50%. Hence, there is a paramount importance to improve the yield potential along with improving the resistance / tolerance to pest and diseases. The combining ability analysis is useful to find out the general combiners for yield and its components, nature and magnitude of gene action governing the expression of yields and its components which in turn helps in identification of proper breeding methodology. In this context, present investigation was carried out to estimate general and specific combining ability effects, to identify superior parents for breeding programme.

Material and methods

The experimental materials chosen for this study consisted of three cultivated varieties as lines viz., C152, V 118 and GC 3 and the 16 land races of India as testers viz., IC 97767, IC 202797, IC 243353, IC 259081, IC 259085, IC 97829, IC 202778, IC 202782, IC 214836, IC 219607, IC 68786, IC 202779, IC 202781, IC 202786, IC 202784 and Goa local. Each genotype was accommodated in a row of 4m length with a spacing of 45cm X15cm. Two staggered sowings were taken up at 10 days interval to have synchronization in flowering to facilitate the crossing work.

The resulting 48 F_1hybrids and their 19 parents were grown in a randomized block design with three replications at Agriculture college Botany garden, UAS, Dharwad during *kharif* 2005. Each treatment was represented by a row of 4m length. The crop was raised on rainfed conditions with all recommended package of practice and plant protection measures. Observations were recorded for nine traits viz., plant height, days to 50% flowering, days to physiological maturity, number clusters /plant, number of pods/plant, pod length, number of seeds/pod, test weight and seed yield/plant in randomly selected plants. Border plants were avoided for taking up observations. The analysis of variance was worked out as per procedure given by Sukatme and Amble (1985), whereas combining ability analysis was done as per Kempthorne (1957).

During the post rainy season 2005-06, 48 hybrids along with their parents were evaluated in a

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randomized block design with three replications separately for screening against rust disease in unprotected conditions in one row of 3 m length. Three rows of susceptible variety C-152 was raised all around the experimental plot two weeks before the test entries in order to facilitate easy spreading of the rust spores. The disease intensity (score) was recorded on 10 leaves of the middle and bottom portion from each plants/replication, selected at random during maximum disease incidence. Scoring for disease resistance was based on the use of standard scale given by Mayee and Datar (1986) (Table 1).

The percent disease index (PDI) was calculated by adopting the following formula

$$PDI = \frac{\text{Sum of individual grade recorded}}{\text{Total number of leaves assessed}} \times \frac{100}{\text{Maximum disease grade}}$$

Results and Discussion

The analysis of variance showed significant differences among the genotypes for all the traits indicating wider genetic variability among genotypes. The analysis of variance for combining ability revealed significant differences in the variance due to lines, testers and line x tester for all the traits and non additive variance component was higher than the additive variance. The higher estimate of dominance variance as compared to additive variances for all the traits was probably due to predominance of non additive gene action suggesting that these traits can be improved through heterosis breeding. Non additive genetic components for plant height, number of pods per plant , test weight and seed yield was reported by Bhushana (1996), Arun kumar (1989) and Marangappanavar (1984).

As the choice of the parents assumes greater importance in any breeding programme, the potentiality of a genotype might be judged by its *per se* performance and *gca* effects. So the parents should posses high order of expression, genetically it should have accumulated large additive gene action and complementation effect i.e., high *gca* effect.

Regarding the *per se* performance of parents (Table 2) the line V-118 and the testers IC 68786 and IC 202784 recorded desirable lower *per se* performance for days to maturity. The IC 219607, IC 97829 and IC 202797 showed high *per se* performance for number of pods per plant. IC 97767, IC 68786, IC 202779 and Goa local showed significant mean performance for seed yield per plant. The maximum test weight was recorded in IC 202781 and minimum in IC 202786.Testers IC 68786, IC 202779 and IC 202786 exhibited the highest *per se* but registered negative *gca* effects for seed yield.

The *gca* effects of parents suggested that V 118, Goa local, IC 202778, IC 202784 and IC 202782 were good combiners for different yield components (Table 3). The genotypes C-152, IC 97767, IC 202797, IC 97829, IC 202778, IC 219607 and IC 68786 recorded significant negative *gca* effects for four yield contributing characters.

Among the 48 cross combinations studied, only 14 crosses recorded high *per se* performance for more than one trait in favorable direction (Table 3). The hybrid V 118 x IC 202778 was earliest (74.00) to mature and C 152 x Goa local was found to be late (82.00). Hybrid V 118 x IC 202782 recorded the highest seed yield of 50.13 g/plant followed by GC 3 x Goa local, V 118 x IC 97767 and v118 x IC 202784 with seed yield of 41.33 and 39.20 g respectively. Among the 48 hybrids studied for rust disease, only two hybrids C 152 x IC 202778 and C 152 x IC 219607 registered significant lower mean value for this trait.

The hybrid GC 3 x IC 202797 recorded significant *sca* effect for eight traits followed by V 118 x IC 202784 for seven traits. Two hybrids C152 X 202778 and C152 219607 are showing desirable negative sca effects for rust disease resistance (Table 4). Most of the hybrids recorded desirable negative heterosis over standard check for days to 50 % flowering (Table 4). Hybrid C-152 x IC 97829 exhibited negative heterosis over standard check for days to maturity. A large number of crosses (22 out of 48) exhibited positively significant standard heterosis for seed yield. Except C-152 x IC 202784, all other hybrids recorded negative heterosis for rust intensity. Hyrbid V 118 x IC 202784 had high heterotic vigour for number of clusters/plant, number of pods per plant and pod length. Hybrid GC 3 x IC 202797 recorded high heterotic vigour for plant height.

The lack of relationship between parental *per se* performance and *gca* effects could be possibly due to predominance of non allelic interaction in governing these traits and the findings were in consonance with Jatasara (1980). The parents V-118, C 152, IC 202778, IC 219607 and IC 68786 might be utilized in breeding for earliness as they recorded low mean with negative *gca* effects, Four genotypes V 118,GC 3, IC 202778 and IC 219607 were emerged as good combiners as they showed negative and significant *gca* effects and low *per se* performance for rust disease, so the parents can be utilized as donors in the hybridization programme in order to infuse the

disease resistance against rust. No single parent was found to be good for all the traits. Similar findings was reported by Bhushana (1996) and Bhushana *et.al* (2000).The above results indicated that it would be desirable to have multiple crosses to isolate desirable segregants in advanced generations for yield and yield attributing traits as no parent was a good combiner for all the traits.

In general there was a good agreement between *per se* performance, *sca* effects and standard heterosis. Based on the *gca* status of parents, crosses were classified into HH (both the parents in the cross with high *gca* status) HL (one parent with high and another parent with low *gca* status) and LL (both parents with low *gca* status). The promising crosses resulted from the combinations of high x low *gca* parents could be possibly due to complimentary gene action of divergent genes in the hybrids and additive type of gene interaction (Table 5).

Heterotic hybrids found in case of high x high *gca* parental combinations and with significant *sca* effects were due to accumulation of additive genes in the hybrid from both the parents and additive x additive type of gene interaction. Low x low *gca* parental combinations showed higher *sca* effects and also evidenced high standard heterosis indicating the importance of dominance x dominance gene interactions. It was showed that the desirable *sca* effects of any cross combinations need not necessarily depend on the level of *gca* effects of parents involved (Lal *et al*.,1975 and Savithramma,1991). It indicated the role of additive and non additive gene action for the trait studied and also signify the importance of both the types of gene action for improvement in seed yield.

It was observed that the parents V 118, IC 202782, IC 202778, IC 219607 and IC 202784 were good general combiners for yield and rust disease resistance, and these parents can be advantageously used in the crossing programme of practical plant breeding like pedigree breeding etc., for the development of superior cowpea varieties. This is in concordance with the results obtained by Withanage Don Lesly and Uma (2007).The four hybrids V 118 x IC 202772, V 118 x IC 202778, V 118 x IC 97767 and GC 3 x Goa local were found to be the best hybrid combinations for yield and other contributing characters. These hybrids can be utilized to select desirable transgressive segregants in the subsequent generations.

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Table 1. Scoring for disease resistance was based on the use of standard scale given by Mayee and Datar (1986).

Score	Description	Category
0	No symptoms on the leaves	Immune
1	Small, round, powdery, brown uredospores covering one percent or less of the leaf area	Resistant
3	Typical uredospori covering 1- 10 percent of the leaf area	Moderately resistant
5	Typical uredospori, covering 11 to 25 percent of the leaf area	Moderately susceptible
7	Typical uredospori, covering 26 – 50 percent of the leaf area	Susceptible
9	Uredospori cover 51 percent or more of the leaf area, withering of leaf	Highly susceptible

Table 2. *Per se* performance of parents and hybrids

Genotypes	Plant height (cm)	Days to 50% flowering	Days to physiological maturity	No. clusters /Plant	No. pods /plant	Pod length (cm)	No. seeds/ pod	Test weight (g)	Seed yield /plant (g)	Rust intensity
C 152	37.67	52.00	74.33	13.93	19.67	13.80	11.77	12.87	20.20	9.00
V 118	35.67	48.33	66.33	9.87	17.53	13.08	11.75	13.30	17.83	3.00
GC 3	41.33	49.67	81.00	13.00	18.00	12.37	10.46	13.67	17.20	3.00
IC 97767	50.27	49.33	75.00	10.07	13.80	12.65	12.44	13.77	28.67	3.00
IC 202797	45.47	52.67	79.00	17.13	22.27	13.99	11.49	15.63	25.53	3.00
IC 243353	42.20	55.67	82.33	11.27	16.20	14.20	11.91	13.17	20.20	3.00
IC 259081	36.93	57.67	94.67	11.73	17.80	14.17	11.33	14.93	26.33	3.00
IC 259085	39.00	53.00	77.67	15.27	20.07	13.54	11.69	13.23	23.40	3.00
IC 97829	42.87	53.33	85.00	15.53	27.40	13.60	11.28	14.33	22.93	3.00
IC 202778	49.00	55.00	77.33	10.07	15.80	14.79	11.84	14.40	20.40	3.00
IC 202782	44.40	53.67	85.00	8.00	11.47	15.06	11.47	15.20	18.00	3.00
IC 214836	45.67	53.33	84.00	9.80	19.40	13.77	11.85	13.70	12.07	3.00
IC 219607	44.40	50.67	76.00	15.27	23.87	13.80	12.51	11.83	27.13	3.00
IC 68786	40.07	47.33	64.00	9.47	16.47	13.04	11.33	12.83	28.67	3.00
IC 202779	54.33	57.00	78.00	14.07	17.07	18.29	12.28	20.20	31.07	3.00
IC 202781	46.87	54.00	86.33	7.67	12.47	18.59	11.14	22.13	22.40	3.00
IC 202786	54.60	55.00	86.33	7.87	9.80	17.72	12.16	12.27	27.13	3.00
IC 202784	39.40	47.67	68.67	11.00	15.73	11.07	11.12	14.50	22.53	3.00
GOA LOCAL	47.53	51.00	82.33	10.27	14.60	19.04	12.43	17.73	28.53	7.00
C 152 X IC 97767	77.00	51.00	77.00	12.27	16.93	12.92	11.18	12.73	19.07	7.00
C 152 X IC 202797	77.00	55.00	77.00	8.13	12.6	11.77	9.89	16.10	16.80	7.67
C 152 X IC 243353	77.33	54.67	77.33	10.73	18.87	12.51	11.07	12.77	21.07	7.00
C 152 X IC 259081	77.67	52.33	77.67	14.13	24.4	13.59	11.76	12.77	20.93	7.00
C 152 X IC 259085	77.67	53.33	77.67	11.40	17.6	12.29	11.89	13.37	18.60	7.00
C 152 X IC 97829	74.00	50.67	74.00	10.73	17.93	13.76	11.80	17.20	20.13	7.67
C 152 X IC 202778	77.67	52.33	77.67	13.33	20.47	14.59	12.19	13.33	27.53	1.00
C 152 X I 202782	76.67	52.67	76.67	9.47	14.27	12.12	10.37	12.43	16.93	6.33
C 152 X IC 214836	77.33	51.33	77.33	10.67	14.27	12.55	10.77	11.83	17.20	7.67
C 152 X IC 219607	75.67	50.67	75.67	12.80	17.13	13.88	11.10	14.23	25.87	1.67
C 152 X IC 68786	74.67	48.33	74.67	10.40	14.27	13.25	11.00	12.10	11.93	8.33

Table 2. ***Contd.***.

Genotypes	Plant height (cm)	Days to 50% flowering	Days to physiological maturity	No. clusters /Plant	No. pods /plant	Pod length (cm)	No. seeds/ pod	Test weight (g)	Seed yield /plant (g)	Rust intensity
C 152 X IC 202779	76.33	49.00	76.33	14.27	20.13	13.85	12.12	12.90	21.20	7.67
C 152 X IC 202781	77.67	52.33	77.67	9.33	12.87	13.19	12.11	14.67	20.47	9.00
C 152 X IC 202786	79.00	52.67	79.00	12.40	15.80	13.39	9.93	12.50	15.30	7.00
C 152 X IC 202784	76.67	50.67	76.67	8.53	10.33	13.17	10.91	11.87	17.47	9.00
C 152 X GOA LOCAL	82.00	53.67	82.00	16.13	24.00	14.25	12.76	12.47	28.67	8.33
V 118 X IC 97767	77.00	47.00	77.00	19.40	30.53	13.64	10.88	17.70	39.20	3.00
V118X IC 202797	77.33	49.67	77.33	16.47	23.53	13.44	11.43	15.83	23.93	2.33
V118X IC 243353	77.67	51.33	77.67	15.47	20.2	12.66	11.83	13.67	14.53	3.00
V 118 X IC 259081	77.00	49.67	77.00	16.87	25.27	14.09	11.99	21.27	29.4	2.33
V 118 X IC 259085	78.33	50.00	78.33	14.07	18.67	13.87	11.59	22.57	17.67	3.00
V 118 X IC 97829	77.33	48.67	77.33	15.40	19.33	14.03	11.31	12.33	19.2	3.00
V 118 X IC 202778	74.67	49.67	74.67	20.93	29.13	13.99	12.07	12.50	36.87	2.33
V 118 X IC 202782	77.33	48.33	77.33	25.13	39.53	12.65	11.03	16.70	50.13	3.00
V 118 X IC 214836	78.33	50.33	78.33	14.27	23.87	13.28	11.25	14.50	23.93	2.33
V 118 X IC 219607	76.00	49.33	76.00	19.53	27.87	13.81	12.07	16.20	28.8	3.00
V 118 X IC 68786	78.33	50.00	78.33	15.13	22.07	13.72	11.13	14.20	27.4	2.33
V 118 X IC 202779	80.67	52.00	80.67	14.67	24.73	14.54	12.48	12.90	21.6	3.00
V 118 X IC 202781	79.00	53.33	79.00	16.33	29.33	14.47	11.93	17.37	26.57	3.00
V 118 X IC 202786	80.67	49.33	80.67	19.67	22.87	12.84	11.51	13.43	18.4	2.33
V 118 X IC 202784	79.00	51.33	79.00	25.67	42.6	15.16	12.37	16.43	39.2	3.00
V 118 X GOA LOCAL	78.67	51.33	78.67	13.53	18.47	13.53	12.03	10.30	25.8	3.00
GC 3 X IC 97767	76.33	49.00	76.33	13.93	22.2	14.64	12.05	11.47	22.27	3.00
GC 3 X IC 202797	75.33	50.33	75.33	18.20	25.93	13.96	11.93	12.37	27.47	2.33
GC 3 X IC 243353	76.67	50.67	76.67	12.93	17.67	13.44	11.84	11.90	17.6	2.33
GC 3 X IC 259081	77.33	48.67	77.33	13.07	18.47	13.81	11.77	15.63	27.13	3.00
GC 3 X IC 259085	77.33	50.33	77.33	12.87	22.87	12.43	11.40	12.23	20.13	2.33
GC 3 X IC 97829	76.00	48.33	76.00	12.33	18.07	13.55	11.72	13.80	20.27	2.33
GC 3 X IC 202778	77.00	50.33	77.00	14.00	17.13	12.73	11.55	12.63	29.6	2.33
GC 3 X IC 202782	77.00	49.33	77.00	13.00	17.73	13.23	11.69	12.17	21.87	3.00
GC 3 X IC 214836	78.00	50.33	78.00	16.33	22.13	14.31	12.53	11.93	25.8	2.33

Table 2. ***Contd.***.

Genotypes	Plant height (cm)	Days to 50% flowering	Days to physiological maturity	No. clusters /Plant	No. pods /plant	Pod length (cm)	No. seeds/ pod	Test weight (g)	Seed yield /plant (g)	Rust intensity
GC 3 X IC 219607	78.00	50.00	78.00	13.87	18.53	12.63	11.25	11.53	19.33	2.33
GC 3 X IC 68786	77.00	49.33	77.00	12.73	18.87	13.69	12.01	10.67	20.07	2.33
GC 3 X IC 202779	78.33	49.33	78.33	15.20	24.73	12.33	10.87	15.33	25.67	2.33
GC 3 X IC 202781	81.33	49.33	81.33	19.87	26	14.63	12.64	12.57	29.67	3.00
GC 3 X IC 202786	79.00	48.33	79.00	9.40	12.67	13.05	11.64	14.60	16.8	3.00
GC 3 X IC 202784	78.33	51.00	78.33	13.87	20.07	13.20	11.67	12.30	25.53	2.33
GC 3 X GOA LOCAL	78.33	51.33	78.33	17.13	24.4	13.17	11.45	17.30	41.33	2.33
SEd ±	1.95	1.22	1.18	1.40	1.84	0.313	0.353	0.667	1.77	0.61

Table 3 : Combining ability effects of parents and hybrids for different economic traits

Genotypes	Plant height (cm)	Days to 50% flowering	Days to physiological maturity	No. clusters /Plant	No. pods /plant	Pod length (cm)	No. seeds/ pod	Test weight (g)	Seed yield /plant (g)	Rust intensity
Parents:										
C 152	-3.38**	1.33**	-0.42**	-2.94**	-4.20**	-0.26**	-0.28**	-0.62**	-4.06**	2.79 **
V 118	-0.19	-0.50*	0.40*	3.17**	4.93**	0.28**	0.10	1.54**	3.66**	-1.29 **
GC 3	3.57**	-0.83**	0.02	-0.23	-0.73*	-0.03	0.17**	-0.92**	0.40	-1.50 **
SEd ±	0.50	0.29	0.22	0.36	0.44	0.08	0.09	0.18	0.42	0.29
IC 97767	2.28**	-1.58**	-0.78*	0.71	2.03**	0.28*	-0.21	0.02	2.84**	0.29
IC 202797	0.90	1.08*	-1.01**	-0.22	-0.51	-0.39**	-0.49**	0.82**	-1.27	0.07
IC 243353	-0.12	1.64**-	-0.34	-1.44*	-2.28**	-0.58**	0.00	-1.17**	-6.27**	0.07
IC 259081	-0.39	-0.36	-0.23	0.20	1.52*	0.38**	0.26	2.61**	1.82**	0.07
IC 259085	-0.59	0.64	0.22	-1.71**	-1.48*	-0.59**	0.05	2.11**	-5.21**	0.07
IC 97829	-2.41**	-1.36**	-1.78**	-1.67**	-2.75**	0.33*	0.03	0.49	-4.14**	0.29
IC 202778	-2.10*	0.19	-1.12**	1.60**	1.05	0.32*	0.36*	-1.13**	7.33**	-2.15 **
IC 202782	-0.52	-0.47	-0.56	1.38*	2.65**	-0.78**	-0.55**	-0.18	5.64**	0.07
IC 214836	-0.06	0.08	0.33	-0.73	-1.11	-0.07	-0.06	-1.19**	-1.70*	0.07
IC 219607	-0.10	-0.58	-1.01**	0.91	-0.02	-0.01	-0.10	0.04	0.66	-1.71 **
IC 68786	-0.01	-1.36**	-0.90*	-1.73**	-2.79**	0.11	-0.20	-1.63**	-4.21**	0.29
IC 202779	-0.83	-0.47	0.88*	0.22	2.01**	0.12	0.24	-0.24	-1.18	0.29
IC 202781	-0.35	1.08*	1.77**	0.69	1.54*	0.65**	0.65**	0.92**	1.56*	0.96 **
IC 202786	-0.79	-0.47	1.99**	-0.67	-4.08**	-0.36**	-0.55**	-0.44	-7.17**	0.07
IC 202784	1.77*	0.42	0.44	1.33*	3.14**	0.39**	0.07	-0.42	3.39**	0.74 *
GOA LOCAL	-0.88	1.53**	2.10**	1.11	1.09	0.20	0.50**	-0.59*	7.93**	0.51
SEd ±	1.15	0.67	0.50	0.84	1.03	0.19	0.21	0.42	0.96	0.67
Hybrids:										
C 152 X IC 97767	-0.36	0.67	0.64	0.01	-2.09	-0.56 *	0.08	-0.61	-3.72 **	-0.13
C 152 X IC 202797	-2.78	2.00 *	0.86	-3.19 **	-3.89 **	-1.03 **	-0.92 **	1.95 **	-1.87	0.76
C 152 X IC 243353	0.11	1.11	0.53	0.63	4.16 **	-0.10	-0.24	0.61	7.39 **	0.10
C 152 X IC 259081	0.58	0.78	0.75	2.39 *	5.89 **	0.01	0.20	-3.17 **	-0.83	0.10
C 152 X IC 259085	-2.29	0.78	0.31	1.56	2.09	-0.31	0.54 *	-2.07 **	3.86 **	0.10
C 152 X IC 97829	2.93 *	0.11	-1.36 *	0.85	3.69 **	0.24	0.47	3.38 **	4.33 **	0.54

Table 3 : Contd..

Genotypes	Plant height (cm)	Days to 50% flowering	Days to physiological maturity	No. clusters /Plant	No. pods /plant	Pod length (cm)	No. seeds/ pod	Test weight (g)	Seed yield /plant (g)	Rust intensity
C 152 X IC 202778	3.56 *	0.22	1.64 **	0.19	2.42	1.08 **	0.53 *	1.13 *	0.26	-3.68**
C 152 X IC 202782	2.31	1.22	0.08	-3.46 **	-5.38 **	-0.29	-0.39	-0.71	-8.65 **	-0.57
C 152 X IC 214836	0.98	-0.67	-0.14	-0.15	-1.62	-0.57 *	-0.47	-0.30	-1.05	0.76
C 152 X IC 219607	0.62	-0.67	-0.47	0.34	0.16	0.70 **	-0.10	0.87	5.26 **	-3.46**
C 152 X IC 68786	2.31	-2.22	-1.58 *	0.59	0.07	-0.04	-0.11	0.40	-3.81 **	1.21 *
C 152 X IC 202779	-2.11	-2.44	-1.69 **	2.50 *	1.14	0.54 *	0.57 *	-0.19	2.44 *	0.54
C 152 X IC 202781	-3.33 *	-0.67	-1.25 *	-2.90 **	-5.66 **	-0.65 **	0.16	0.42	-1.04	1.21 *
C 152 X IC 202786	0.24	1.22	-0.14	1.52	2.89 *	0.55 *	-0.82 **	-0.39	2.53 *	0.10
C 152 X IC 202784	-2.44	-1.67 *	-0.92	-4.35 **	-9.80 **	-0.41	-0.47	-1.05 *	-5.87 **	1.43**
C 152 X GOA LOCAL	-0.33	0.22	2.75 **	3.48 **	5.91 **	0.86 **	0.96 **	-0.27	0.79	0.99
V 118 X IC 97767	0.93	-1.50	-0.17	1.03	2.38	-0.38	-0.59 *	2.19 **	8.70 **	-0.04
V118X IC 202797	-1.89	-1.50	0.38	-0.97	-2.09	0.10	0.24	-0.48	-2.46 *	-0.49
V118X IC243353	-1.81	-0.39	0.05	-0.75	-3.64 **	-0.49 *	0.15	-0.65	-6.86 **	0.18
V 118 X IC 259081	-0.41	-0.06	-0.73	-0.99	-2.38	-0.02	0.04	3.17 **	-0.08	-0.49
V 118 X IC 259085	-0.41	-0.72	0.16	-1.88	-5.97 **	0.72 **	-0.14	4.97 **	-4.79 **	0.18
V 118 X IC 97829	-1.98	-0.06	1.16	-0.59	-4.04 **	-0.03	-0.40	-3.65 **	-4.32 **	-0.04
V 118 X IC 202778	-1.03	-0.61	-2.17 **	1.67	1.96	-0.06	0.03	-1.87 **	1.88	1.74 **
V 118 X IC 202782	0.66	-1.28	-0.06	6.10 **	10.76**	-0.30	-0.10	1.39 **	16.83 **	0.18
V 118 X IC 214836	-1.14	0.17	0.05	-2.66 *	-1.15	-0.38	-0.37	0.20	-2.04	-0.49
V 118 X IC 219607	-0.23	-0.17	-0.95	0.96	1.76	0.09	0.49	0.67	0.48	1.96 **
V 118 X IC 68786	-3.07 *	1.28	1.27 *	-0.79	-1.26	-0.12	-0.35	0.33	3.94 **	-0.71
V 118 X IC 202779	-0.83	2.39 **	1.83 **	-3.22 **	-3.40 **	0.68 **	0.56 *	-2.35 **	-4.88 **	-0.04
V 118 X IC 202781	1.88	2.17 **	-0.73	-2.02	1.67	0.10	-0.40	0.96	-2.66 *	-0.71
V 118 X IC 202786	6.06 **	-0.28	0.72	2.67 *	0.82	-0.54 *	0.38	-1.62 **	-2.09	-0.49
V 118 X IC 202784	4.71 **	0.83	0.60	6.67 **	13.34 **	1.03 **	0.62 *	1.36 **	8.14 **	-0.49
V 118 X GOA LOCAL	-1.45	-0.28	-1.40 *	-5.24 **	-8.75 **	-0.40	-0.16	-4.60 **	-9.79 **	-0.26
GC 3 X IC 97767	-0.57	0.83	-0.47	-1.04	-0.29	0.93 **	0.51	-1.58 **	-4.98 **	0.17
GC 3 X IC 202797	4.67 **	-0.50	-1.24 *	4.16 **	5.97 **	0.93 **	0.68 *	-1.48 **	4.33 **	-0.28
GC 3 X IC 243353	1.69	-0.72	-0.58	0.12	-0.52	0.60 *	0.09	0.05	-0.53	-0.28

Table 3 : Contd..

Genotypes	Plant height (cm)	Days to 50% flowering	Days to physiological maturity	No. clusters /Plant	No. pods /plant	Pod length (cm)	No. seeds/ pod	Test weight (g)	Seed yield /plant (g)	Rust intensity
GC 3 X IC 259081	-0.17	-0.72	-0.02	-1.39	-3.52 **	0.01	-0.24	0.00	0.91	0.39
GC 3 X IC 259085	2.69	-0.06	-0.47	0.32	3.88 **	-0.41	-0.40	-2.90 **	0.93	-0.28
GC 3 X IC 97829	-0.95	-0.06	0.20	-0.26	0.35	-0.21	-0.06	0.28	-0.00	-0.50
GC 3 X IC 202778	-2.53	0.39	0.53	-1.86	-4.38 **	-1.01 **	-0.56 *	0.73	-2.13	1.94 **
GC 3 X IC 202782	-2.97 *	0.06	-0.02	-2.64 *	-5.38 **	0.59 *	0.49	-0.68	-8.18 **	0.39
GC 3 X IC 214836	0.16	0.50	0.09	0.38	2.81 **	2.77 *	0.95 **	0.10	3.09 **	-0.28
GC 3 X IC 219607	-0.39	0.83	1.42 *	-0.42	-1.30	-1.92	-0.79 **	-1.53**	-5.73 **	1.50 **
GC 3 X IC 68786	0.76	0.94	0.31	-0.33	0.21	1.19	0.16	-0.73	-0.13	-0.50
GC 3 X IC 202779	2.94 *	0.06	-0.13	0.47 *	0.72	2.26	-1.22 **	2.55 **	2.44 *	-0.50
GC 3 X IC 202781	1.45	-1.50	1.98 **	0.14	4.92 **	3.99 **	0.56 *	-1.38**	3.70 **	-0.50
GC 3 X IC 202786	-6.31 **	-0.94	-0.58	0.16	-4.19**	-3.72 **	-0.01	2.01 **	-0.43	0.39
GC 3 X IC 202784	-2.26	0.83	0.31	-0.24	-2.33 *	-3.54 **	-0.62 **	-0.31	-2.27	-0.94
GC 3 X GOA LOCAL	1.78	0.06	-1.35 *	0.14	1.76	2.84 *	-0.45 *	4.87 **	9.00 **	-0.72
SEd ±	1.99	1.16	0.87	0.30	1.45	1.77	0.32	0.72	1.66	1.15

Table 4 : Standard heterosis of hybrids for different economic traits

Genotypes	Plant height (cm)	Days to 50% flowering	Days to physiological maturity	No. clusters /Plant	No. pods /plant	Pod length (cm)	No. seeds/ pod	Test weight (g)	Seed weight /plant (g)	Rust intensity
C 152 X IC 97767	3.36	-1.92	3.59*	-11.96	-13.90	-6.38**	-5.04	-1.04	-5.61	-22.22 **
C 152 X IC 202797	-6.73	5.77*	3.59*	-41.63**	-35.93 **	-14.69**	-15.97**	25.13 **	-16.83	-14.81 *
C 152 X IC 243353	-1.77	5.13*	4.04*	-22.97*	-4.07	-9.37**	-6.00*	-0.78	4.29	-22.22 **
C 152 X IC 259081	-1.24	0.64	4.48**	1.44	24.07 *	-1.55	-0.11	-0.78	3.63	-22.22 **
C 152 X IC 259085	-9.38	2.56	4.48**	-18.18	-10.51	-10.92**	1.02	3.89	-7.92	-22.22 **
C 152 X IC 97829	-0.35	-2.56	-0.45	-22.97*	-8.81	-0.29	0.23	33.68 **	-0.33	-14.81 *
C 152 X IC 202778	13.27 *	0.64	4.48**	-4.31	4.07	5.70*	3.51	3.63	36.30 **	-88.89 **
C 152 X IC 202782	3.01	1.28	3.14*	-32.06**	-27.46 **	-12.17**	-11.95**	-3.37	-16.17	-29.63 **
C 152 X IC 214836	0.71	-1.28	4.04*	-22.44*	-27.46 **	-9.08**	-8.49	-8.03	-14.85	-14.81 *
C 152 X IC 219607	-0.35	-2.56	1.79	-8.13	-12.88	0.58	-5.72	10.62 *	28.05 **	-81.48 **
C 152 X IC 68786	4.42	-7.05**	0.45	-25.36*	-27.46 **	-3.96	-6.57*	-5.96	-40.92 **	-7.41
C 152 X IC 202779	-9.56	-5.77*	2.69	2.39	2.37	0.39	2.94	0.26	4.95	-14.81 *
C 152 X IC 202781	-11.50 *	0.64	4.48**	-33.01**	-34.58 **	-4.44*	2.89	13.99 **	1.32	0.00
C 152 X IC 202786	-3.19	1.28	6.28**	-11.00	-19.66 *	-3.00	-15.69**	-2.85	-24.26 **	-22.22 **
C 152 X IC 202784	-3.54	-2.56	3.14*	-38.76**	-47.46 **	-4.54*	-7.36*	-7.77	-13.53	0.00
C 152 X GOA LOCAL	-4.96	3.21	10.31**	15.79	22.03 *	3.29	8.38**	-3.11	41.91 **	-7.41
V 118 X IC 97767	15.22 **	-9.62**	3.59**	39.23**	55.25 **	-1.16	-7.59*	37.56 **	94.06 **	-66.67 **
V118X IC 202797	4.07	-4.49	4.04*	18.18	19.66 *	-2.61	2.94	23.06 **	18.48 *	-74.07 **
V118X IC 243353	1.59	-1.28	4.48**	11.00	2.71	-8.26**	0.45	6.22	-28.05 **	-66.67 **
V 118 X IC 259081	4.60	-4.49	3.59*	21.05*	28.47 **	2.13	1.81	65.28 **	45.54 **	-74.07 **
V 118 X IC 259085	4.07	-3.85	5.38**	0.96	-5.08	0.48	-1.59	75.39 **	-12.54	-66.67 **
V 118 X IC 97829	-4.96	-6.41**	4.04*	10.53	-1.69	1.64	-3.96	-4.15	-4.95	-66.67 **
V 118 X IC 202778	9.56	-4.49	0.45	50.24**	48.14 **	1.35	2.49	-2.85	82.51 **	-74.07 **
V 118 X I 202782	7.08	-7.05**	4.04*	80.38**	101.02 **	-8.31**	-6.34*	29.79 **	148.18 **	-66.67 **
V 118 X IC 214836	3.54	-3.21	5.38**	2.39	21.36 *	-3.77	-4.42	12.69 *	18.48 *	-74.07 **
V 118 X IC 219607	5.84	-5.13*	2.24	40.19	41.69 **	0.10	2.49	25.91 **	42.57 **	-66.67 **
V 118 X IC 68786	-1.42	-3.85	5.38**	8.61	12.20	-0.58	-5.44	10.36 *	35.64 **	-74.07 **
V 118 X IC 202779	2.30	0.00	8.52**	5.26	25.76 **	5.33*	6.00*	0.26	6.93	-66.67 **

Table 4 : Contd..

Genotypes	Plant height (cm)	Days to 50% flowering	Days to physiological maturity	No. clusters /Plant	No. pods /plant	Pod length (cm)	No. seeds/ pod	Test weight (g)	Seed weight /plant (g)	Rust intensity
V 118 X IC 202781	10.80 *	2.56	6.28**	17.22	49.15 **	4.88*	1.36	34.97 **	31.52 **	-66.67 **
V 118 X IC 202786	20.71 **	-5.13*	8.52**	41.15**	16.27	-6.96**	-2.27	4.40	-8.91	-74.07 **
V 118 X IC 202784	23.89 **	1.28	6.28**	84.21**	116.61 **	9.86**	5.10	27.72 **	94.06 **	-66.67 **
V 118 X GOA LOCAL	0.53	-1.28	5.83**	-2.87	-6.10	-1.93	2.15	-19.95 **	27.72 **	-66.67 **
GC 3 X IC 97767	21.24 **	-5.77*	2.69	0.00	12.88	6.09**	2.38	-10.88 *	10.23	-66.67 **
GC 3 X IC 202797	31.50 **	-3.21	1.35	30.62**	31.86 **	1.16	1.36	-3.89	35.97 **	-74.07 **
GC 3 X IC 243353	20.88 **	-2.56	3.14*	-7.18	-10.17	-2.61	0.57	-7.51	-12.87	-74.07 **
GC 3 X IC 259081	15.22 **	-6.41**	4.04*	-6.22	-6.10	0.10	0.00	21.50 **	34.32 **	-66.67 **
GC 3 X IC 259085	22.30 **	-3.21	4.04*	-7.66	16.27	-9.95	-3.17	-4.92	-0.33	-74.07 **
GC 3 X IC 97829	7.79	-7.05**	2.24	-11.48	-8.14	-1.84	-0.45	7.25	0.33	-74.07 **
GC 3 X IC 202778	15.58 **	-3.21	3.59*	0.48	-12.88	-7.73	-1.93	-1.81	46.53 **	-74.07 **
GC 3 X IC 202782	7.43	-5.13*	3.59*	-6.70	-9.83	-4.15	-0.68	-5.44	8.25	-66.67 **
GC 3 X IC 214836	16.99 **	-3.21	4.93**	17.22	12.54	3.67	6.46*	-7.25	27.72 **	-74.07 **
GC 3 X IC 219607	15.40 **	-3.85	4.43*	-0.48	-5.76	-8.50**	-4.42	-10.36 *	-4.29	-74.07 **
GC 3 X IC 68786	18.76 **	-5.13*	3.59*	-8.61	-4.07	-0.77	2.04	-17.10 **	-0.66	-74.07 **
GC 3 X IC 202779	22.30 **	-5.13*	5.38**	9.09	25.76 **	-10.63**	-7.70*	19.17 **	27.06 **	-74.07 **
GC 3 X IC 202781	19.65 **	-5.13*	9.42**	42.58**	32.20 **	5.99**	7.36*	-2.33	46.86 **	-66.67 **
GC 3 X IC 202786	-2.12	-7.05**	6.28**	-32.54**	-35.59 **	-5.41*	-1.13	13.47 **	-16.83	-66.67 **
GC 3 X IC 202784	15.40 **	-1.92	5.38**	-4.78	2.03	-4.35	-0.31	-4.40	26.40 **	-74.07 **
GC 3 X GOA LOCAL	19.12**	-1.28	5.38**	22.97**	24.07 *	-4.54*	-2.72	34.46 **	104.62 **	-74.07 **
SEd ±	1.95	1.22	1.18	1.40	1.84	0.313	0.353	0.667	1.77	0.61

Table 5. Best cross combinations exhibiting high *per se* performance, standard heterosis and their GCA status

Character	Desirable crosses	F_1 Mean performance	Standard Heterosis	SCA effects	GCA status
Plant Height	GC 3 x IC 202797	49.53	31.50	4.67**	H x H
	V 118 x IC 202784	46.67	23.89	4.71**	L x L
	GC 3 x IC 202779	46.07	22.30	2.94*	H x H
	GC 3 x IC 259085	46.07	22.30	2.67	H x L
	V 118 x IC 202786	45.47	20.71	6.06**	L x H
Days to 50% flowering	V 118 x IC 97767	47.00	-9.62	-1.50	L x H
	C 152 x IC 68786	48.33	-7.05	-2.22	H x L
	V 118 x IC 202782	48.33	-7.05	-1.28	L x H
	GC 3 x IC 97829	48.33	-7.05	-0.06	L x H
	GC 3 x IC 202786	48.33	-7.05	-0.94	L x H
Days to physiological maturity	C 152 x IC 97829	74.00	-0.45	-1.36*	H x H
	C 152 x IC 68786	74.67	0.45	-1.58*	H x L
	V 118 x IC 202778	74.67	0.45	-2.17*	L x H
	GC 3 x IC 202797	75.33	1.35	-1.24*	H x H
	C 152 x IC 219607	75.67	1.79	-0.47	H x H
Number of clusters per plant	V 118 x IC 202784	25.67	84.21	6.67**	L x H
	V 118 x IC 202782	25.13	80.38	6.10**	L x L
	V 118 x IC 202778	20.93	50.24	1.67	L x H
	GC 3 x IC 202781	19.87	42.58	0.41	H x L
	V 118 x IC 202786	19.67	41.15	2.67*	L x L
Number of pods per plant	V 118 x IC 202784	39.53	101.02	13.34**	L x L
	V 118 x IC 202782	30.53	55.25	10.76**	L x L
	V 118 x IC 97767	29.33	49.15	2.38	L x L
	V 118 x IC 212781	29.13	48.14	1.67	L x L
	V 118 x IC 202778	27.87	41.69	1.96	L x L

Table 5. Contd..

Character	Desirable crosses	F_1 Mean performance	Standard Heterosis	SCA effects	GCA status
	V 118 x IC 202784	15.16	9.86	1.03**	H x L
Pod length	GC 3 x IC 97767	14.64	6.09	0.93**	L x L
	GC 3 x IC 202781	14.63	5.99	3.99**	L x H
	V 118 x IC 202779	14.54	5.33	0.68**	H x H
Number of seeds per pod	C 152 x Goa Local	12.76	8.38	0.96**	H x H
	GC 3 x IC 202781	12.64	7.36	0.56*	L x H
	GC 3 x IC 214836	12.53	6.46	0.10	L x H
	V 118 x IC 202779	12.48	6.00	0.56*	H x H
	V 118 x IC 202784	12.37	5.10	0.62*	H x H
Test weight	V 118 x IC 259085	22.57	75.39	4.97**	H x H
	V 118 x IC 259081	21.27	65.28	3.17**	H x H
	V 118 x IC 97767	17.70	37.56	2.19**	H x H
	V 118 x IC 202781	17.37	34.97	0.96	H x H
	C 152 x IC 97829	12.20	33.68	3.38**	L x H
Seed yield per plant	V 118 x IC 202782	50.13	148.18	16.83**	L x H
	GC 3 x Goa Local	41.33	104.62	9.00**	L x H
	V 118 x IC 202784	39.20	94.06	8.14**	L x H
	V 118 x IC 97767	39.20	94.06	8.70**	L x H
	V 118 x IC 202778	36.87	82.51	1.74**	L x H
Rust intensity	C 152 x IC 202778	1.00	-88.89	-3.68**	H x L
	C 152 x IC 219607	1.67	-81.48	-3.46**	H x L