Genetics of traits associated with pod borer resistance and seed yield in chickpea (*Cicer arietinum* L.)

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Received: 18 Jul 2014; Accepted: 2 Apr 2016.

Abstract
The combining ability analysis using Line × Tester model was conducted in chickpea to know the general and specific combining ability of the distingushing parents and their crosses, respectively and to select best material for further breeding programme and generation advanceme-nt. Two genetically diverse testers *viz*., JAKI-9218 and ICCV-2 as females and 8 males *viz*., HC-5, ICC-506, PKV Harita, Chandrapur Chanoli, JG-62, Gulak-1, AKG-10-1 and Bushy mutant and their 16 crosses along with two checks were evaluated in a Randomized Complete Block Design for seed yield per plant under unprotected condition and pod borer resistance under field conditions. The resistant genotypes had lower percentage of pod borer damage along with higher levels of malic acid contents. The malic acid content had significant and negative association with larval count at vegetative, flowering and pod formation stage in addition to the percentage of pod damage. The parent Gulak-1 was the best general combiner for seed yield per plant; ICC-506 for most of the traits associated with pod borer resistance and ICCV-2 for percent malic acid content. Therefore, these genotypes were considered as the good parental material for utilizing as one of the parents in further breeding programs as donors for the concerned traits. Two crosses *viz*.,ICCV-2 × Chandrapur Chanoli, JAKI-9218 × ICC-506 evinced significant sca effects in desirable direction at least for one of the traits associated with pod borer resistance along with one of the parents with a high gca effect and a high mean performance for the traits concerned, indicating opportunity for obtaining desirable segregation in further generations. A high heritability in broad sense was observed for all the traits except for larval count at the flowering stage. The non-additive variance was found predominant in inheritance of seed yield and additive variance for most of the traits associated with pod borer resistance. Hence, superior transgressive segregation may be obtained from this material either through biparental mating or diallel selective mating.

Key words: Chickpea, Combining ability, Gene action, Line x tester analysis, Pod borer resistance, Malic acid content.

INTRODUCTION

Pulses constitute an important ingredient of vegetarian diet. They are the important source of protein which nutritionally balances the proteins of cereal grains for millions of people, hence truly called as poor man's meat. They also serve as mini-nitrogen factory with profound ameliorative effects on the physiological, chemical and biological properties of soil. Among the pulses, chickpea is an important crop in India being grown on the largest area i.e. 9.21 million ha with a total production of 8.25 million tones and the production of 895 kg/ha (Anonymous, 2013). Although India is the largest producer of chickpea in the World, its average chickpea productivity is very low as compared to other countries like Italy, Iran and Turkey.

Besides being considered as a protein source, chickpea plays an important role in human nutrition as a source of supplying energy, fiber, vitamins and minerals for large population sectors in the developing world and is considered a healthy food in many developed countries. However, chickpea yields remained almost static over the past two decades largely because of many factors including insect pests and diseases. Noctuid pod borer, *Helicoverpa armigera* (Hubner) (Lepidoptera: Noctuidae) is the most importa-nt key pest Worldwide (Sarwar *et al*., 2011). In severe cases it causes about 75 to 90 percent losses in seed yield (Sarwar, 2013[a]), despite the application of costly insecticides. It has also developed high levels of resistance to several insecticides. In addition to the huge direct economic losses, deleterious effects of pesticides remain in the environment. Therefore, development of a cost effective and an environmentally friendly approach like improvement of cultivars resistant to *H. armigera* is necessary. The resistant cultivars reduce yield losses due to insect pests (Sarwar, 2013[b]), particularly under subsistence farming conditions in the developing countries (Sharma *et al*., 1999).

A large number of high yielding chickpea varieties have been released, which have accelerated the chickpea production in the country since inception of All India Coordinated Pulses Improvement Project (AICPIP) in 1966. However, to meet the future requirements, it is utmost necessary to breed resistant varieties having agronomically superior traits suiting to the need of farmers and its end users as well. Breeding of such a variety essentially needs selection of the parents on the basis of distinguishing and desirable traits and their rational inclusion in the scheme of hybridization followed by tapping of best specific cross combinations which would play a vital role in development of resistant varieties. The ability of parents to combine well depends upon complex interaction among genes, which cannot be predicted from yield performance and parent adaptability (Allard, 1960). Resistance/tolerance to pod borer is a complex character controlled by many factors. Understanding the association of various traits and nature of their association with host plant resistance is necessary for effective selection. Further, the selection of parents for hybridization should be on the basis of genetic value which helps to predict gene action i.e. additive and non-additive type of gene action involved in expression of the traits. For the evaluation of genetic makeup of chickpea genotypes and their further use in chickpea improvement program, information regarding their mean performance and combining ability is very helpful. An attempt was therefore made to understand the nature of gene action, combining ability effects of the parents and their variances to obtain an information on the genetics of pod borer resistance along with seed yield which would help in designing the ideal breeding approach for the improvement of seed yield and pod borer resistant chickpea varieties.

MATERIALS AND METHODS

Plant Material

Genetically diverse parents deliberately selected on the basis of their distinguishing characters with high intensity *viz*., HC-5 (suitable for mechanical harvesting and high density planting), ICC-5O6 (pod borer resistant), PKV Harita (high yielding green seed coat type), Chandrapur Chanoli (very small seeded, kabuli type), JG-62 (twin poded), Gulak-1 (pink seed coat type suitable for parching), AKG-10-1 (suitable for mechanical harvesting) and Bushy Mutant (spreading, kabuli type) as males and ICCV- 2 (early, kabuli type) and JAKI- 9218 (high yielding and resistant to wilt) as females to test the performance of males. The crosses were produced in line × tester scheme for obtaining F_1 seeds of 16 crosses at Pulses Research Unit, Dr. Panjabrao Deshmukh Agriculture University, Akola during rabbi 2010-11.

Field Trial

A field trial of 28 genotypes (i.e. ten parents, 16 F_1s and two checks *viz*. PKV kabuli-2 and Digvijay) was conducted with two replications in a Randomized Complete block Design at the research field of Pulses Research Unit, Dr. P.D.A.U., Akola, during rabbi 2011-12. Each genotype was planted in a single row of 4 m length with 30 cm spacing between rows and 15 cm within rows. The five competative plants were randomly selected for recording the observations on larval count at vegetative, flowering and pod formation stages, malic acid content, percent of pod borer damage and seed yield per plant (under unprotected conditions) in parents, F_1s and checks.

Larval count in stages of vegetative, flowering and pod formation

Numbers of larvae on five observational plants from each genotype were counted at vegetative, flowering and pod formation stages.

Malic acid content

Malic acid content in leaves was estimated by determining the titratable acidity of extract of one gram of third, fourth and fifth leaves from the top of the shoot collected at 9.00 hrs. The sample of leaf was placed in distilled water and filtered using Whatman No.1 filter paper. The filtrate was collected and volume was made up to 20 ml and then 5 ml of this aliquot was taken and titrated against 0.05 N NaOH using phenolphthalein as an indicator. Average of three titrated values was used to calculate the percentage of malic acid content using the formula (Girija *et al*., 2008).

Percent of Malic acid = TV×E×N×100/1000×W.

Where, TV=average of three titrated values, E= equivalent weight of malic acid, N=normality of NaOH, W=weight equivalent of the sample

Percentage of pod borer damage

At the maturity stage, all pods were harvested from each of five selected plants of each genotype in each replication and damaged pods were counted using the following formula:

$$\text{Percentage of pod damage} = \frac{\text{Number of damaged pods}}{\text{Total number of pods}} \times 100$$

Statistical Analysis

The analysis of variance was conducted as per procedure given by Panse and Sukhatme (1967) from the data obtained in the field experiments. The appropriate method of data transfer was followed wherever required. In addition, correlation coefficients were calculated between pod damage percentage and different traits. Further, the line × tester analysis was performed as per the standard procedure given by Kempthorne (1957). After ensuring the significance of general combining ability (gca) and specific combining ability (sca) effects and their variances, the additive and non-additive variances were calculated for pod borer damage and seed yield.

RESULTS AND DISCUSSION

Highly significant differences were observed between cultivars for all the traits studied except for larval count at vegetative stage, indicating the presence of substantial genetic variability in the material used for present investigation. Further, the mean performance for seed yield per plant under unprotected condition and other traits revealed that there was not a single parent or a cross that performed better simultaneously for seed yield and other traits (Table 1). The parent JAKI-9218 recorded significantly higher seed yield in unprotected conditions than other genotypes, but it was found at par withtwo crosses *viz*., JAKI-9218×PKV Haritaand ICCV-2×ChandrapurChanoli, whereas, the cross ICCV-2×JG-62 produced significantly lower seed yield per plant. These discrepancies in seed yield per plant were due to the differences in genetic makeup and outbreak by pod borer as well. The parent ICC-506 and crosses involving ICC-506 as one of the parents i.e. ICCV-2×ICC-506 and JAKI-9218×ICC-506 exhibited significantly lower percentages of pod damage. These genotypes had significant differences with each other and were found to be different from others, hence, were considered as resistant. Genotypic differences for pod borer damage were also noticed by Mansur and Mohamed (2014). For malic acid content, the genotype ICC-506 and cross ICCV-2×ICC-506 differed significantly amongst themselves and over the others. Further, the same genotypes recorded a lower number of larvae per plant at flowering and pod formation stages but they were found to be at par with few other genotypes and significantly different from others. In general, the resistant genotypes had significantly higher levels of malic acid content as compared to other genotypes which is in support of previous reports (Yoshida *et al*., 1995 and Girija *et al*., 2008). The malic acid has an antibiotic effect on larvae (Narayanamma, 2005), thereby enhancing resistance against pod borer. A lower number of larvae per plant at flowering and pod formation stage; higher levels of malic acid content and less percent pod damage were also noticed in the other parent i.e. JG-62 in addition to ICC-506, though, it was statistically at par with few genotypes, but significantly different than others also. There were significant genotypic differences in the number of larvae per plant at flowering and pod formation stages in chickpeaas reported by Shankar *et al*. (2014). The contradictory differences due to ovipositional anti-xenosis seemed to determine the size of the larval population and therefore pod damage on a particular genotype (Table 1), which is in the line of views expressed by previous workers (Narayanamma, 2005 and Narayanamma *et al*., 2007).

Further, no significant differences were observed in larval count at vegetative stage among the studied genotypes (Table 1). However, statistically significant differences were observed in larval count at flowering and pod formation stages in some of the genotypes than others as presented in Table 1. It might be due to the activation/induction of hypersensitive response of genes controlling resistance and ultimately activation of antibiosis and non-preference mechanism in some of the genotypes as has been opined formerly by Narayanamma *et al*. (2007) in chickpea. Though, higher and significant percent of pod damage was noticed in the parents ICCV-2 and Gulak-1, the cross between them recorded significantly lower pod damage. This may be due to the presence of heterosis (hybrid vigour) in the desirable direction. This genotypic variation can be exploited in future breeding programs to develop pod borer resistant chickpea varieties as has been suggested by previous workers (Shabbir *et al*., 2014 and Mansour and Mohamed, 2014).

Table 1. Mean performance of genotypes for yield and traits related to pod borer resistance in chickpea.

Genotypes	Seed yield/ plant(g)	Larval count at vegetative stage	Larval count at flowering stage	Larval count at pod formation stage	Percent malic acid content	Percent pod damage
Crosses						
JAKI-9218 X HC-5	12.56^{fghi}	1.00(1.220)	3.50 (1.996)^{bcd}	5.50 (2.447)^{bcdef}	0.65 (1.072)^{ijk}	10.02 (3.243)^{hijk}
JAKI-9218 X ICC-506	16.92^{cde}	0.50(0.970)	1.50 (1.403)^{ef}	3.50 (1.996)^{f}	0.81 (1.146)^{c}	4.01 (2.122)^{m}
JAKI-9218 X PKV Harita	20.10^{ab}	1.00(1.220)	3.50 (1.996)^{bcd}	5.50 (2.447)^{bcdef}	0.61 (1.053)^{kl}	11.08 (3.402)^{gh}
JAKI-9218 X Chandrapur Chanoli	10.02^{hij}	2.00(1.58)	5.50 (2.447)^{ab}	7.50 (2.827)^{ab}	0.54 (1.018)^{m}	21.93 (4.736)^{a}
JAKI-9218 X JG-62	14.66^{ef}	0.50(0.970)	3.50 (1.996)^{bcd}	5.50 (2.447)^{bcdef}	0.64 (1.067)^{ijk}	11.70 (3.493)^{fg}
JAKI-9218 X Gulak-1	18.36^{bcd}	1.00(1.220)	3.50 (1.996)^{bcd}	4.50 (2.233)^{def}	0.65 (1.071)^{ijk}	11.16 (3.415)^{gh}
JAKI-9218 X AKG-10-1	16.74^{cde}	0.50(0.970)	1.50 (1.403)^{ef}	4.50 (2.233)^{def}	0.76 (1.122)^{cde}	9.04 (3.088)^{ijk}
JAKI-9218 X Bushy Mutant	16.94^{cde}	1.00(1.220)	4.50 (2.233)^{ab}	5.50 (2.447)^{bcdef}	0.65 (1.073)^{ijk}	13.26 (3.709)^{ef}
ICCV-2 X HC-5	17.42^{bcde}	1.00(1.220)	3.50 (1.996)^{bcd}	6.00 (2.542)^{abcde}	0.66 (1.077)^{hijk}	11.14 (3.412)^{gh}
ICCV-2 X ICC-506	15.04^{ef}	0.50(0.970)	2.50 (1.726)^{cde}	3.50 (1.996)^{f}	0.95 (1.203)^{b}	5.60 (2.467)^{l}
ICCV-2 X PKV Harita	14.88^{ef}	1.00(1.220)	2.50 (1.726)^{cde}	4.00 (2.108)^{ef}	0.68 (1.086)^{ghij}	9.55 (3.170)^{ijk}
ICCV-2 X Chandrapur Chanoli	19.72^{abc}	1.00(1.220)	3.50 (1.996)^{bcd}	4.50 (2.233)^{def}	0.72 (1.105)^{defg}	10.03 (3.244)^{hijk}
ICCV-2 X JG-62	9.42^{j}	1.00(1.220)	1.50 (1.403)^{ef}	4.50 (2.233)^{def}	0.76 (1.122)^{cde}	9.34 (3.137)^{ijk}
ICCV-2 X Gulak-1	17.24^{bcde}	0.50(0.900)	2.50 (1.726)^{cde}	5.00 (2.345)^{cdef}	0.76 (1.123)^{cde}	9.19 (3.113)^{ijk}
ICCV-2 X AKG-10-1	10.56^{ghij}	1.50(1.400)	4.50 (2.233)^{ab}	5.5 (2.447)^{bcdef}	0.69 (1.091)^{fghi}	12.98 (3.671)^{ef}
ICCV-2 X Bushy Mutant	11.10^{ghij}	1.50(1.400)	3.50 (1.996)^{bcd}	6.50 (2.644)^{abcd}	0.75 (1.118)^{cdef}	16.00 (4.061)^{bc}
Males						
JAKI-9218	22.64^{a}	1.00(1.22)	2.50 (1.726)^{cde}	5.00 (2.345)^{cdef}	0.72 (1.102)^{efgh}	11.41 (3.451)^{gh}
ICCV-2	13.12^{fg}	1.50(1.40)	6.00 (2.550)^{a}	8.50 (2.999)^{a}	0.46 (0.980)^{n}	23.56 (4.905)^{a}
Females						
HC-5	10.06^{hij}	0.50(0.907)	2.50 (1.726)^{cde}	5.00 (2.335)^{cdef}	0.73 (1.108)^{defg}	9.00 (3.082)^{jk}
ICC-506	14.54^{ef}	0.00(0.710)	1.00 (1.225)^{f}	3.50 (1.996)^{f}	1.04 (1.241)^{a}	3.12 (1.902)^{n}
PKV Harita	13.54^{fg}	1.00(1.220)	2.00 (1.581)^{def}	4.50 (2.233)^{def}	0.69 (1.090)^{ghi}	10.40 (3.301)^{ghi}
Chandrapurchanoli	9.84^{ij}	1.00(1.220)	3.50 (1.996)^{bcd}	6.00 (2.542)^{abcde}	0.76 (1.122)^{cde}	14.82 (3.913)^{cd}
JG-62	14.74^{ef}	1.00(1.220)	2.50 (1.726)^{cde}	4.50 (2.233)^{def}	0.78 (1.130)^{cd}	8.72 (3.035)^{k}
Gulak-1	12.96^{fgh}	1.00(1.220)	4.00 (2.121)^{abc}	6.50 (2.644)^{abcd}	0.56 (1.031)^{lm}	17.64 (4.259)^{b}
AKG-10-1	18.58^{bc}	1.00(1.220)	3.50 (1.996)^{bcd}	6.00 (2.550)^{abcde}	0.63 (1.064)^{ijk}	13.71 (3.769)^{de}
Bushy Mutant	11.06^{ghij}	1.00(1.220)	2.50 (1.726)^{cde}	5.50 (2.447)^{bcdef}	0.74 (1.112)^{defg}	10.30 (3.283)^{ghij}
Checks						
PKV Kabuli-2	12.16^{fghij}	2.00(1.580)	5.50 (2.447)^{ab}	7.00 (2.739)^{abc}	0.54 (1.021)^{m}	23.86 (4.935)^{a}
Digvijay	15.56^{de}	1.50(1.400)	3.50 (1.996)^{bcd}	6.50 (2.644)^{abcd}	0.63 (1.062)^{jk}	16.75 (4.153)^{b}
General mean	14.856	1.000	3.21	5.360	0.698	12.120
SE (m) ±	0.768**	0.136^{ns}	0.121**	0.119**	0.006**	0.055**
LSD Value	3.000	--	0.475	0.4688	0.0276	0.2175
Heritability (*Broad Sense*)	90.53	34.85	75.70	62.06	96.72	98.80

Means within columns with different letters are significantly different at the 0.01 probability level.
Values shown in parenthesis are transformed values**.**
^{NS} =Non significant.
** = significant at P 0.01.

It has been revealed from the correlation studies of various traits that malic acid content had highly significant negative correlation with percentage of pod damage and larval count in all stages (Table 2). Naranayamma *et al*. (2013[a]) also noticed a negative correlation in malic acid content with leaf feeding by *H. armigera* larvae at flowering and maturity stages in chickpea. In addition, highly significant and positive association of larval count at vegetative, flowering and pod formation stages with percentage of pod damage confirms the results of Girija *et al*. (2008). However, a non-significant association of seed yield under unprotected conditions with other traits was noticed which may be due to the differences amongst the various genotypes for the intensity of damage by pod borer and the resistance reaction and genetic potential for seed yield of various genotypes. A high heritability in broad sense (h^2 b.s.) was also detected for all the traits studied except for larval count at the vegetative stage which indicated that these traits would

Table 2. Association among the traits related to pod borer resistance in chickpea.

Parameters	Larval count at pod formation stage	Larval count at flowering stage	Larval count at vegetative stage	Percent malic acid content	Seed yield per plant
Percent pod damage	0.934**	0.878**	0.852**	-0.819**	-0.266^{ns}
Larval count at pod formation stage		0.847**	0.747**	-0.793**	-0.287^{ns}
Larval count at flowering stage			0.776**	-0.792**	-0.144^{ns}
Larval count at vegetative stage				-0.709**	-0.242^{ns}
Percent malic acid content					0.046^{ns}

** = significant at P 0.01
^{ns} =Non-significant

Table 3. Analysis of variance for combining ability.

Sources of variations	df	Mean squares					
		Seed yield/plant	Larval count at vegetative stage	Larval count at flowering stage	Larval count at pod formation stage	Malic acid content (%)	Pod damage (%)
Replications	1	0.695	0.0370	0.1035	0.0286	0.0003	0.0005
Treatments	25	25.193**	0.0770	0.2140**	0.1230**	0.0060**	1.0300**
Parents	9	34.507**	0.0720	0.2523**	0.1510**	0.0090**	1.2940**
Crosses	15	20.202**	0.0667	0.1910**	0.1030**	0.00360**	0.6930**
Parents vs Crosses	1	16.220**	0.0070	0.0376	0.0790	0.0001	0.2650**
Error	25	1.234	0.0372	0.0296	0.0288	0.0001	0.0062
σ^2D		2.2269	0.01247	0.03681	0.0096	0.001238	0.1457
σ^2H		7.493	-0.0151	0.004	0.0251	0.000005	0.1294

df= Degrees of freedom
*, ** = significant at P 0.05 and 0.01, respectively.

easily be transmitted to subsequent generations (Table 1). Although, all these traits are not directly useful for the development of resistant cultivars, they will certainly facilitate the development of varieties, which would be relatively stable against the environmental influences and possess desirable level of these constituent or traits for enhancing the resistance. Sarwar (2013[b]) also concluded that the pod infestation, larval population and grain yield could be used as selection criteria of a resistant genotype. The trait like malic acid content can also be tagged with suitable markers which can facilitate the laboratory evaluation of segregating generations for pod borer resistance through marker assisted selection.

Analysis of variance for combining ability revealed that the differences among the parents and crosses were highly significant for all the traits except larval count at vegetative stage (Table 3). This indicates the presence of adequate amount of variation in parents and crosses. So also, both kinds of gene effects were important in controlling the inheritance of these traits. The ratio of sca/gca was greater than one for seed yield per plant, larval count at vegetative and pod formation stages and percentage of pod damage, thereby signifying the preponderance of non-additive variance in the expression of these characters, whereas, additive variance was found to be predominant in the expression of larval count at flowering stage and in malic acid content. The importance of both additive and non-additive genetic variations was also reported by Sreelatha *et al*. (2008) for pod borer resistance in kabuli chickpea.

The perusal of data on general combining ability estimates (Table 4) revealed that only one parent *viz*., Gulak-1 was found to be good general combiner for seed yield per plant. However, regarding traits related with pod borer resistance, the parent ICC-506 among the males was the best general combiner with significant gca effects in desirable direction for most of the traits studied i.e. larval count at flowering and pod formation stages; malic acid content and the percentage pod damage. Among the females, ICCV-2 recorded

Table 4. Estimates of gca and sca effects of parents and crosses for different traits in chickpea.

Parents/crosses	Seed yield/ plant	Larval count at vegetative stage	Larval count at flowering stage	Larval count at pod formation stage	Percent malic acid content	Percent pod damage
gca effects of parents						
Females						
JAKI-9218	0.754	-0.016	0.042	0.033	-0.018 *	0.059
ICCV-2	-0.754	0.016	-0.042	-0.033	0.018 *	-0.059
SE(gi)	0.231	0.051	0.039	0.043	0.002	0.017
Males						
HC-5	0.305	0.035	0.104	0.144	-0.024 **	-0.015
ICC-506	0.680	-0.220	-0.329 **	-0.359 *	0.078 **	-1.048 **
PKV Harita	1.230	0.035	-0.031	-0.074	-0.027 **	-0.055
Chandrapur Chanoli	-0.570	0.215	0.331 **	0.179	-0.034 **	0.647 **
JG-62	-2.555**	-0.093	-0.194	-0.011	-0.002	-0.028
Gulak-1	3.575**	-0.093	-0.031	-0.061	-0.002	-0.080
AKG-10-1	-0.890	-0.003	-0.074	-0.011	0.011	0.037
Bushy Mutant	-1.775*	0.125	0.224	0.194	-0.002	0.542 **
SE(gi)	0.566	0.102	0.078	0.087	0.005	0.035
sca effects of crosses						
JAKI-9218 x HC-5	-2.994**	0.016	-0.042	-0.081	0.016 *	-0.142 *
JAKI-9218 x ICC-506	0.621	0.016	-0.204	-0.033	-0.007	-0.229 **
JAKI-9218 x PKV Harita	1.581	0.016	0.093	0.137	0.003	0.058
JAKI-9218 xChandrapur Chanoli	-4.799**	0.196	0.186	0.264 *	-0.024 **	0.686 **
JAKI-9218 x JG-62	1.536	-0.112	0.256 *	0.074	-0.012	0.121 *
JAKI-9218 x Gulak-1	-0.014	0.143	0.093	-0.091	-0.007	0.093
JAKI-9218 x AKG-10-1	1.861*	-0.202	-0.459 **	-0.141	0.036 **	-0.349 **
JAKI-9218 x Bushy Mutant	2.206*	-0.074	0.078	-0.131	-0.007	-0.239 **
ICCV-2 x HC-5	2.994**	-0.016	0.042	0.081	-0.016 *	0.142 *
ICCV-2 x ICC-506	-0.621	-0.016	0.204	0.033	0.007	0.229 **
ICCV-2 x PKV Harita	-1.581	-0.016	-0.093	-0.137	-0.003	-0.058
ICCV-2 x Chandrapur Chanoli	4.799**	-0.196	-0.186	-0.264 *	0.024 **	-0.686 **
ICCV-2 x JG-62	-1.536	0.112	-0.256 *	-0.074	0.012	-0.121 *
ICCV-2 x Gulak-1	0.014	-0.143	-0.093	0.091	0.007	-0.093
ICCV-2 x AKG-10-1	-1.861*	0.202	0.459 **	0.141	-0.036 **	0.349 **
ICCV-2 x Bushy Mutant	-2.206*	0.074	-0.078	0.131	0.007	0.239 **
SE(sij)	0.801	0.144	0.110	0.123	0.006	0.049

*, ** = Significant at P 0.05 and 0.01, respectively

significant positive gca effects for malic acid content representing to be a good general combiner for the respective traits. Similar results were reported by Sreelatha *et al*. (2008) and Narayanamma *et al*. (2013[b]) in chickpea for pod borer damage and Singh and Singh (2009) in pigeonpea for pod fly resistance. Since gca effects are the manifestation of additive properties of genes, parents selected based on gca effects will be useful for developing breeding lines with high grain yield (Narayanamma *et al*., 2013[b]) and desirable levels of the trait of interest. Based on gca effects, the genotypes ICC-506 and ICCV-2 have good genetic potential for their utilization in further breeding programs for genetic improvement of pod borer resistance in chickpea by using them as one of the parents in hybridization and isolating desirable segregants for resistance to pod borer. Most promisingly, the parent ICC-506 can be extensively utilized in the hybridization program to accelerate the pace of genetic improvement for pod borer resistance in chickpea.

On the basis of specific combining ability estimates, the cross JAKI-9218×AKG-10-1 was found to be the best specific combination for seed yield per plant, larval count at flowering stage, malic acid content and percentage of pod borer damage followed by cross ICCV-2×Chandrapur Chanoli for seed yield per plant, larval count at pod formation stage, malic acid content and percentage of pod borer damage, JAKI-

9218×Bushy Mutant for seed yield per plant and percent pod borer damage. Significant sca effect for pod borer damage was also reported by Narayanamma *et al*. (2013[b]). However, the crosses having high specific combining ability effects will be useful if the parents involved are also good general combiners especially in the self-pollinated crops. Hence, there were only two combinations viz., ICCV-2×Chandrapur Chanoli and JAKI-9218×ICC-506 having significant sca effects at least for one trait related with pod borer resistance, along with one of the parents with good gca effects and high mean performance for the trait concerned indicating the opportunity for obtaining improvement for pod borer resistance by isolating desirable segregation in subsequent generations through simple selection as these traits were predominantly controlled by additive variance. Further, despite the fact that both the parents showed high gca effects for malic acid content the cross ICCV-2×ICC-506 showed low sca effects for the same trait. Thus, it is divulged that the combination involving both the parents with high gca effects need not necessarily result into high sca effects, which might be due to internal cancellation of gene effects in this combination.

Perusal of data on the basis of mean performance, general combining ability effects of the parents and specific combining ability effects of the crosses for seed yield and other characters suggests that the parents ICC-506 and ICCV-2; the crosses ICCV-2×Chandrapur Chanoli and JAKI-9218×ICC-506 hold promise for genetic improvement of seed yield and pod borer resistance. More precisely, the parent ICC-506 and cross ICCV-2×Chandrapur Chanoli may be considered as the most promising. In present investigation, both additive and non-additive gene actions were important in governing most of the traits especially seed yield. Lack of sufficient variability (due to strictly inbreeding behavior) is one of the reasons for limited progress in increasing chickpea productivity to a desired level (Sreelatha *et al*., 2003). The use of conventional breeding methods such as pedigree, single seed descent and bulk methods is associated with the weakness of causing rapid homozygosity and low genetic variability, especially in the presence of linkage blocks and inverse relationships among the desirable traits (Clegg *et al*., 1972). Therefore, superior transgressive segregation may be obtained from this material either through biparental mating or diallel selective mating (Jensen, 1970) as multiple parents input central gene pool for isolating high yielding lines with pod borer resistance in advanced generations. Further, Malhotra *et al*. (1980) opined that diallel selective mating among the parents based on gca may result in breaking up some undesirable linkages and in turn releases greater genetic variability. The mean performance should be used as one the criteria for the selection of superior general combiners because the parents exhibiting high mean performance generally proved to be good general combiners for the respective traits. Advanced studies on mechanisms of pod borer resistance and elucidating its genetics will be most useful for increasing the levels of pod borer resistance in chickpea varieties.

ACKNOWLEDGEMENT

The technical support and guidance of Dr. P.B. Ghorpade, Ex-Principal Scientist and Dr. D.B. Dhumale, Ex-Professor of Agril. Botany for the present investigation is highly acknowledged.

REFERENCES

Allard R.W. (1960). Principles of PlantBreeding. John Wiley and Sons. Inc., New York and London.

Anonymous. (2013). Directorate of Economics and Statistics, Department of Agriculture and Cooperation, Govt of India, 2012-13.

Clegg M.T., Allard R.W., and Kahiar A.L. (1972). Is the gene unit of selection? Evidance from two experimental plant populations, *Proceedings of the National Academy of Sciences of the United States*, 69: 2474-2478.

Girija P. M., Salimath, Patil S. A., Gowda C. L. L., and Sharma H. C. (2008). Biophysical and biochemical basis of host plants resistant to pod borer (Helicoverpa armigera H.) in chickpea (Cicer arietinum L.). *Indian Journal of Genetics and Plant Breeding*, 68: 320-323.

Jensen N. F. (1970). A diallel selective mating system for breeding. *Crop Science*, 10: 629-635.

Kempthorne O. (1957). AnIntroduction to Genetic Statistics. John Wiley and Sons, New York.

Malhotra R. S., Gupta P. K., and Arora N. D. (1980). Diallel analysis over environments in mungbean. *Indian Journal of Geneticsand Plant Breeding*, 40: 64-66.

Mansour A. E. A. and Mohamed A. A. (2014). Evaluation of different chickpea genotypes for resistance against pod borer, Helicoverpa armigera (Hub.) (Lepdoptera: Noctuidae) under field conditions, Sudan. *International Journal of Agriculture Innovations and Research*, 2: 1147-1149.

Narayanamma V. L. (2005). Genetics of resistance to pod borer, *Helicoverpa armigera*. [Ph.D. Thesis.] Acharya N. G. Ranga Agricultural University, Hyderabad, India.

Narayanamma V. L., Sharma H. C., Gowda C. L. L., and Sriramulu M. (2007). Mechanisms of resistance to *Helicoverpa armigera* and introgression of resistance genes into F_1 hybrids in chickpea. *Arthropod-Plant Interactions*, 1: 263-270.

Narayanamma V. L., Sharma H.C., Vijay P.M., Gowda C. L. L., and Sriramulu M. (2013[a]). Expression of resistance to the pod borer *Helicoverpa armigera* (Lepidoptera: Noctuidae), in relation to high performance liquid chromatography fingerprints of leaf exudates of chickpea. *International Journal of Tropical Insect Science*, 33: 276-282.

Narayanamma V. L., Gowda C. L. L., Sriramulu M., Ghaffar M.A., and Sharma H.C. (2013[b]). Nature of gene action and maternal effects for pod borer, *Helicoverpa armigera* resistance and grain yield in chickpea, *Cicer arietnum*. *American Journal of Plant Sciences*, 4: 26-37.

Panse V. G., and Sukhatme P. V. (1967). *Statistical Methods for Research Workers*, I.C.A.R., New Delhi.

Sarwar M. (2013[a]). Survey on screening resistance resources in some chickpea (*Cicer arietinum* L.) genotypes against gram pod borer *Helicoverpa armigera* (Hubner) (Lepidoptera : Noctuidae) pest. *International Journal of Agriculture Sciences*, 3 : 455-458.

Sarwar M. (2013[b]). Exploration on resources of resistance in chickpea (*Cicerarietinum* L.) genotypes to gram pod borer *Helicoverpaarmigera* (Hubner) (Lepidoptera). *African Journal of Agricultural Research*, 8: 3431-3435.

Sarwar M., Ahmad N., and Tofique M. (2011). Identification of susceptible and tolerant gram (*Cicer arietinum*L.) genotypes against gram pod borer (*Helicoverpa armigera*) (Hubner). *Pakistan Journal of Botany*, 43: 1265-1270.

Shabbir M.Z., Arshad M., Husain B., Nadeem I., Ali S., Abbasi A., and Ali Q. (2014). Genotypic response of chickpea (*Cicer arietinum* L.) for resistance against gram pod borer (*Helicoverpa armigera*). *Advancementsin Life Sciences*, 2: 23-30.

Shankar M., Munghate R. S., Babu T. Ramesh, Sridevi D., and Sharma H.C.(2014). Population density and damage by pod borers, *Helicoverpa armigera* and *Spodoptera exigua* in a diverse array of chickpea genotypes under natural infestation in the field. *Indian Journal of Entomology*, 76: 117-127.

Sharma H.C., Singh B.U., Hariprasad K.V., and Bramel P.J. (1999). Host plant resistance to insects in integrated pest management for safer environment. *Proceedings, Academy of Environmental Biology*, 8: 113-136.

Singh O., and Singh M.N. (2009). Combining ability analysis in pigeonpea. *Journal of Food Legumes*, 22: 30-33.

Sreelatha E., Gaur T. B., Gowda C. L. L., Ghaffar M. A., and Sharma H. C. (2003). Stability of resistance to *Helicoverpa armigera* in chickpea. In: Sharma R.N., Shrivastava G. K., Rathore A. L., Sharma M. L., Khan M.A. (ed.): Chickpea Research for the Millennium: Proceedings of the International Chickpea Conference, Raipur : 138-142.

Sreelatha E., Gowda C. L. L., Gour T. B., Sharma H. C., Ramesh S., and Upadhyaya H. D. (2008). Genetic analysis of pod borer (*Helicoverpa armigera*) resistance and grain yield in desi and kabuli chickpeas (*Cicer arietinum*) under Unprotected Conditions. *Indian Journal of Genetics and Plant Breeding*, 68: 45-48.

Yoshida M., Cowgill S. E., and Wightman J. A. (1995). Mechanism of resistance to *Helicoverpa armigera* Hub. in Chickpea: Role of Oxalic Acid in Leaf Exudate as an Antibiotic Factor. *Journal of Economic Entomology*, 88:1783-1786.