STABILITY, INHERITANCE AND MECHANISMS OF RESISTANCE TO *Helicoverpa armigera* (Hub.) IN CHICKPEA (*Cicer arietinum* Linn.)

E.SREE LATHA

M.Sc. (Ag.)

Thesis submitted to the
Acharya N. G. Ranga Agricultural University
College of Agriculture, Rajendranagar in partial fulfillment of
the requirements for the award of the Degree of

Doctor of Philosophy in Agriculture.

DEPARTMENT OF ENTOMOLOGY
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ACHARYA N.G.RANGA AGRICULTURAL UNIVERSITY
RAJENDRANAGAR, HYDERABAD – 500 030

CROP MANAGEMENT AND UTILIZATION
ICRISAT, PATANCHERU
ANDHRA PRADESH-502 324

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CERTIFICATE

Mrs. **E. SREE LATHA** has satisfactorily prosecuted the course of research and that the thesis entitled "**Stability, Inheritance and Mechanisms of Resistance to *Helicoverpa armigera* (Hub.) in Chickpea (*Cicer arietinum* Linn.)**" submitted is the result of original research work and is of sufficiently high standard to warrant its presentation to the examination. I also certify that the thesis or part there of has not been previously submitted by her for a degree of any university.

Place: Hyderabad.

Date : 14.02.03

(Dr. T. B. GOUR)

Major Advisor
Professor
Department of Entomology
College of Agriculture
Rajendranagar.

CERTIFICATE

This is to certify that the thesis entitled "**Stability, Inheritance and Mechanisms of Resistance to *Helicoverpa armigera* (Hub.) in Chickpea (*Cicer arietinum* Linn.)**" submitted in partial fulfillment of the requirements for the degree of Doctor of Philosophy in Agriculture of Acharya N.G. Ranga Agricultural University, Hyderabad, is a record of the bonafied research work carried out by Mrs. **E.Sree Latha** under my guidance and supervision. The Student's Advisory Committee has approved the subject of the thesis.

No part of the thesis has been submitted by the student for any other degree or diploma. The published part has been fully acknowledged. The author of the thesis has duly acknowledged all the assistance and help received during the course of investigation.

(T. B. GOUR)
Chairman of the Advisory Committee.

Chairman : Dr. T.B. Gour,
Professor, Dept. of Entomology
College of Agriculture, ANGRAU
Rajendranagar.

Co-Chairman : Dr. C.L.L. Gowda,
Principal Scientist, Plant Breeding
ICRISAT, Patancheru.

Member : Dr. H.C. Sharma,
Principal Scientist, Entomology
ICRISAT, Patancheru.

Member : Dr. M. Sri ramulu,
Professor, Dept. of Entomology
College of Agriculture , ANGRAU
Rajendranagar.

Member : Dr. T. Nageshwar Rao,
Professor and Head,
Dept. of Genetics and Plant Breeding
College of Agriculture , ANGRAU
Rajendranagar.

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Sree Latha.E

Date: 14/2/2003 **(SREE LATHA. E)**

DECLARATION

I, **E. SREE LATHA**, hereby declare that the thesis entitled " **Stability, Inheritance and Mechanisms of Resistance to *Helicoverpa armigera* (Hub.) in Chickpea (*Cicer arietinum* Linn.)**" submitted to Acharya N.G. Ranga Agricultural University for the degree of **Doctor of Philosophy in Agriculture** is a result of original research work done by me. I also declare that the material contained in this thesis or part there of has not been published earlier in any manner.

Date : 14/2/2003

Place : Hyderabad

Sree Latha. E

(E. SREE LATHA)

ABSTRACT

Name of the author	:	**E. SREE LATHA**
Title of the thesis	:	**"Stability, Inheritance and Mechanisms of Resistance to *Helicoverpa armigera* (Hub.) in Chickpea (*Cicer arietinum* Linn.)"**
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Major advisor	:	**Dr. T. B. GOUR**
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Key words: *Helicoverpa armigera*, Chickpea, Resistance.

The present investigation **"Stability, Inheritance and Mechanisms of Resistance to *Helicoverpa armigera* (Hub.) in Chickpea (*Cicer arietinum* Linn.)"** was taken under laboratory, glasshouse and field conditions at ICRISAT, International Crops Research Institute for the Semi-Arid Tropics, Patancheru during 2000-2002.

Advanced breeding lines (10) from earlier breeding program at ICRISAT and germplasm accessions (28) of chickpea were evaluated for stability of resistance to *H. armigera* under natural infestation. Stability of resistance to *H. armigera* was measured by regression analysis of the data for pod damage and grain yield. Amongst the breeding lines, resistant check ICC 12475 suffered 5% pod damage and showed a stable reaction to *H. armigera* damage followed by ICCV 96752, ICCL 87316, and ICCL 87317 (7 to 9% pod damage). ICCV 95992 was moderately susceptible (10% damage) but was highly stable. ICCL 87220 also showed high stability across seasons while ICCL 87211, ICCV 93122 and ICCL 86102 were unstable in their reaction to *H. armigera*.

Amongst the germplasm lines, least damage was recorded in resistant check ICC 12475 followed by ICC 12478, ICC 12479 and ICC 14876 and all were stable in their reaction to *H. armigera*. ICC 12495 and ICC 12488 were unstable in their reaction to pod borer damage. ICC 4918 and ICC 4958 were susceptible to *H. armigera* damage. ICC 12490 showed high stability across seasons.

Four diallel trials (45 F_1s + 10 parents of 10 x 10 desi and 28 F_1s + 8 parents of 8 x 8 kabuli chickpea) and (45 F_2 s + 10 parents of 10 x 10 desi and 28 F_2 s + 8 parents of 8 x 8 kabuli chickpea) were conducted to know the gene action for *H. armigera* resistance. For pod borer resistance GCA (general combining ability) variance was significant in desi chickpea and additive genetic effects (σ^2A) were greater than non-additive effects (σ^2D) indicating the importance of additive gene action. But on the other hand preponderance of SCA (specific combining ability) for pod borer resistance in the kabuli chickpea indicates that non-additive genetic variation may be important in some sources of resistance.

The importance of GCA in predicting the performance of crosses has been revealed by the general predictability ratio (GPR). GPR was near to unity for pod borer resistance in desi and comparatively less in kabuli chickpea suggesting the importance of GCA in predicting the performance of single cross progenies in desi chickpea. Rank correlation indicated selection of F_1s on the basis of their performance was equally effective as on the basis of their SCA values but for F_2s there were differences. High rank correlations for parents (GCA vs. *per se* performance) indicated effective selection was possible for parents based on their performance.

Mechanisms of resistance (Antibiosis, Antixenosis for oviposition and tolerance) to *H. armigera* in ten desi and eight kabuli chickpea genotypes were studied under laboratory, glass house and field conditions. Reduced larval and pupal weights, and prolonged larval and pupal periods on leaves, pods, artificial diet impregnated with lyophilized leaves and pods of resistant genotypes (ICC 12475, ICC 12476, ICC 12477, ICC 12478, ICC 12479, ICC 14876, ICC 12490, ICC 12491 and ICC 12495) compared to susceptible genotypes (ICC 12426, ICC 3137, ICC 4973 and ICC 4962) indicated that antibiosis is one of the components of resistance to *H. armigera* in chickpea.

Greater feeding in washed leaves compared to unwashed leaves in ICC 12475, ICC 12478, ICC 12479, ICC 14876, ICC 12495 and ICC 12494 suggested that water-soluble compounds in the leaf exudates (malic and oxalic acid) were primarily responsible for the resistance of the genotypes to *H. armigera*. Amounts of leaf exudates in susceptible genotypes (ICC 12426, ICC 3137, ICC 12968, ICC 4962 and ICC 4918) were quite low.

Oviposition studies under no choice, dual choice and multi choice laboratory and multichoice field conditions revealed that desi types (ICC 12475, ICC 12476, ICC 12477, ICC 12478, ICC 12479, ICC 12490 and ICC 14876) were not preferred for oviposition compared to kabuli type genotypes (ICC 12491, ICC 12493, ICC 12494, ICC 12495, ICC 12968, ICC 4973 and ICC 4962).

The loss in yield due to *H. armigera* damage in 18 chickpea genotypes under protected and unprotected field conditions indicated presence of tolerance mechanism in chickpea genotypes. Reduction in grain yield was lowest in resistant check ICC 12475, ICC 4918, ICC 12490, ICC 12493 and ICC 12476 indicating tolerance to pod borer damage in these genotypes. The resistant lines can be used in further breeding programs and the mechanisms responsible for the resistance can be exploited to develop resistant varieties.

LIST OF SYMBOLS, ABBREVIATIONS, AND ACRONYMS

σ^2A	:	Additive variance
σ^2B	:	Dominance variance
σ^2g	:	General combining ability variance
σ^2s	:	Specific combining ability variance
$2\sum gca^2$	:	Additive genetic effects
$2\sum sca^2$	:	Non-additive genetic effect
$<$	:	Less than
$>$	:	Greater than
^0C	:	Degrees Centigrade
/	:	Per
%	:	Per cent
a i	:	Active ingradiant
a.m.	:	Ante meridian
AICPIP	:	All India chickpea improvement project
ANOVA	:	analysis of variance
b_i	:	Slope of the regression line
δi^2	:	Residual mean squares
cm	:	Centimeter
Conc.	:	Concentration
CRD	:	Completely randomized design
et al.	:	And others
F_1	:	First filial generation
F_2	:	Second filial generation
FAO	:	Food and Agricultural Organization
Fig.	:	Figure
g	:	Gram
GCA	:	General combining ability
ha	:	Hectare
HPR	:	Host plant resistance
hr	:	Hour
i.e.	:	That is
IPM	:	Integrated pest management
Kg	:	Kilo gram
l	:	Liter
L:D	:	Light :Dark
LSD	:	Least significance difference
m	:	Meter
mg	:	Milligram
ml	:	Milliliter
mm	:	Millimeter

Contd…

Lst of Symbols Contd.....

NS	:	Not-significant
ORS	:	Over all resistance score
PDS	:	Pod damage score
p.m.	:	Post meridian
Prob.	:	Probability
RBD	:	Randomized block design
RH	:	Relative humidity
SCA	:	Specific combining ability
SED	:	Standard error of difference
Sig.	:	Significant
Sp	:	Soluble powder
Viz.,	:	Namely
Vol.	:	Volume
Vs.	:	Between
Wt	:	Weight

Introduction

CHAPTER-I

INTRODUCTION

Chickpea, *Cicer arietinum* Linn. is the third most important food legume grown in 11 m ha with 9 million ton production (FAO, 2002). It is grown in over 45 countries in all continents of the world. It is a source of high quality protein for the people in developing countries.

The genus *Cicer* originated in South-Eastern Turkey and spread to other parts of world. It is adapted to relatively cooler climates. The largest area of adaptation is in the Indian sub-continent. Two main types are recognized, viz., Desi type with small and brown seed accounts for nearly 90% and kabuli type with bold and cream-colored seed is grown in around 10% area.

Chickpea potential seed yield of about 5 t ha^{-1} has been reported. But the realized seed yield of 850 kg ha^{-1} is a result of lack of widely adapted cultivars and susceptibility to several biotic and abiotic stresses. The crop is highly self-pollinated and basic studies on the crop are limited. Though the Genetics of the crop is not well understood, efforts to investigate variability through molecular markers and to develop a genome map have recently been initiated.

Pod borer, *Helicoverpa armigera* (Hub.) (Noctuidae: Lepidoptera) is most important factor limiting chickpea production worldwide. The pod damage due to this pest is reported to be as high as 85% (Sithanantham *et al.*, 1984). Development of improved cultivars with resistance to *H. armigera* is a cost effective and environmentally benign technology to reduce yield losses (Dua *et al.*, 2002). Stability of resistance is one of the desirable traits of a genotype to be used as a donor parent for incorporating resistance. Although number of sources of resistance (less susceptibility) to *H. armigera* have been reported, stability of resistance across locations and/or seasons is not known.

Chickpea breeding work was initiated at ICRISAT in 1974 and major emphasis was to attempt crosses among germplasm lines received from diverse regions. Constraints to productivity and sources of resistance were identified. Increased use of sources of resistance was made to generate segregating populations and advanced breeding lines. Although number of improved varieties of chickpea has been evolved, the yield of these varieties is not stable over environments due to pests and diseases. Although resistance to important pest, *H. armigera* is available in some of the released varieties and cultivars, the level of resistance varies across seasons and years. The information on genotypes x environment interaction and stability of pod borer resistance in chickpea is limited.

The breeding approach to *H. armigera* resistance in chickpea is an integrated one involving both antixenosis / antibiosis and avoidance. Given that malate mediated resistance is most likely to be quantitatively inherited and the best prospect for increasing resistance using antixenosis and antibiosis mechanisms of resistance. Large genetic variation for the phenological traits has been reported and the breeder can make use of it to avoid the damage caused by the *H. armigera* in chickpea. Therefore, the breeding goal should be to identify, characterize and utilize genetic mechanism that confers durable resistance to *H. armigera* (Dua *et al.*, 2002).

Insecticide application for pod borer is uneconomical under substance farming and is largely beyond the means of resource poor farmers. Therefore, host plant resistance (HPR) assumes a pivot role in controlling *H. armigera* damage either alone or in combination with other methods of control. It has been documented that for each $1 invested in plant resistance farmers have realized a sum of $300 return (Robinson, 1996).

Keeping these in view the present investigation on "Stability, Inheritance and Mechanisms of Resistance to *Helicoverpa armigera* (Hub.) in Chickpea (*Cicer arietinum* Linn.)" was carried out with the following objectives.

1. To know the stability of resistance to *H. armigera* in chickpea genotypes.
2. To find out the gene action for *H. armigera* resistance in desi and kabuli chickpea.
3. To study the mechanisms of resistance to *H. armigera* in chickpea genotypes.

Review of Literature

CHAPTER-II

REVIEW OF LITERATURE

Chickpea, *Cicer arietinum* Linn. is an important pulse crop in India and it accounts for 47.3% of total pulse production. Pod borer, *Helicoverpa armigera (*Hub.*)* is a key pest and the most important limiting factor in the successful cultivation of chickpea (Lateef, 1985 and Reed *et al.,* 1987). The monetary loss due to *H. armigera* damage was estimated up to 2030 million rupees annually in chickpea (Lal *et al.,* 1985). Controlling this pest has proved to be very difficult, particularly in the last decade as insecticide resistance has increased (Armes *et al.,* 1993).

Surveys conducted by ICRISAT entomologists in India during 1977-82 have shown pod damage up to 84.4% with an over all of 7% in different states, and under different farming systems (Bhatnagar, 1980; Bhatnagar and Davies, 1978 and Bhatnagar *et al.,* 1982). Less than 20% of chickpea farmers use insecticide on their crops (Reed *et al.,* 1980). The avoidable loss, expressed as a percentage of the yield of the protected crop, was calculated to be from 9 to 60% (Sithanantham *et al.,* 1984).

The significance of these losses led to the initiation of an intensive pest resistance-screening program in 1976 at ICRISAT (Reed and Pawar, 1982 and Lateef, 1985). About 12,000 chickpea accessions were screened for *H. armigera* resistance at ICRISAT. ICC 506 showed 6% borer damage compared to 20% in high yielding check, ICC 4918 under unsprayed conditions (Gowda *et al.,* 1983).

Several lines were shown to have good levels of resistance/tolerance to *H. armigera* and were incorporated in breeding programs to enhance the levels of borer resistance and high yielding capacity in the progenies. Since 1980, the resistant/tolerant selections and breeding lines have been assessed for their performance along with the borer tolerant selections identified by AICPIP-Entomologists in different agroecological zones in India. ICC 506 and ICCV 7 were consistently found resistant to *H. armigera* across agroecological zones (Lateef and Sachan, 1990).

Insecticide application for pod borer is uneconomical under subsistence farming and is largely beyond the means of resource poor farmers. Therefore, host plant resistance (HPR) assumes a pivot role in controlling *H. armigera* damage either alone or in combination with other methods of control. HPR is an important component of integrated pest management (IPM) and is well suited to the semi-arid tropics. It has been documented that for each $1 invested in plant resistance farmers have realized a $300 return (Robinson, 1996).

2.1 STABILITY OF RESISTANCE

Pod borer, *H. armigera* is one of the important factors limiting chickpea production worldwide. The pod damage due to this pest can be as high as 85%. Development of improved cultivars with resistance to *H. armigera* is a cost effective and environmentally benign technology to reduce yield losses (Dua *et al.*, 2002). Stability of resistance is one of the desirable traits of a genotype to be used as a donor parent for incorporating resistance. Although, number of sources of resistance (less susceptibility) to *H. armigera* have been reported, stability of resistance across locations and/or seasons is not known. Information on genotype x environment (G x E) interaction for *H. armigera* resistance is limited. Therefore, the present studies were planned to collect the information about stability of resistance to *H. armigera* in chickpea in known sources of resistance available in breeding program and genetic resource collection at ICRISAT.

Several approaches have been made to extract parameters of genotypic stability from genotype x environmental interactions. Finlay and Wilkinson (1963) utilized a regression technique proposed by Yates and Cochran (1938) to measure "stability indexes" of barley varieties. They considered linear regression as a measure of stability (i.e., a genotype is more stable with a slope is more than one). Eberhart and Russell

(1966) defined a stable genotype is one having a slope equal to one and a deviation from regression equal to zero. This approach has been extensively used by plant breeders (Reich and Atkins 1970; Kofoid *et al.,* 1978; and Virk *et al.,* 1985). Scientists Breese (1969), Samuel *et al.*, (1978), and Pethani and Kapoor (1985) emphasized that the linear regression should be regarded as a measure of the response of a particular genotype, whereas the deviation around the regression line should be considered as a measure of stability, genotypes with the lowest deviations being the most stable and vice versa.

Eberhart and Russell (1966) reported that the deviation from regression, a second stability parameter, appears very important, as the genotype x environment (linear) sum of squares was not a very large portion of the genotype x environment interaction. Eagles *et al.,* (1977); Fatunla and Frey (1974) and Gonzalez-Rosquel (1976) have found that only 5 to 20% of the genotype x environment sum of squares for random lines were attributable to differential regression values. Witcombe (1988) indicated the invalidity of mean squares for deviation from regression as a measure of stability in certain circumstances such as the deviations from regression caused by differences in disease resistance.

The importance of yield testing of crop genotypes over a range of environments has been recognized by plant breeders (Comstock and Moll, 1963). A cultivar must not only yield well in its area of initial selection, but ideally it also must maintain a high yield level in many environments within its intended area of production.

Singh *et al.,* (1988) studied phenological traits in chickpea and analyzed them for stability following Eberhart and Russell (1966) and indicated the importance of phenological traits for production stability in chickpea.

Vasudevarao and Nigam (1989) used Eberhant and Russell (1966) analysis of variance for stability of yield and indicated significant genotype x environmental interactions in groundnut. The regression of varietal means on environmental indices indicated that the lines with regression coefficients, non-significantly different from unity were stable in performance across the locations.

Gupta and Ndoye (1990) studied stability of yield in pearl millet and suggested that the variety with high deviation from regression as an unstable variety because its performance over environments cannot be predicted.

Sharma and Lopez (1991) studied stability of resistance in sorghum to *Calocoris angustatis* (Heriptera: Miridae) and concluded that the environmental conditions play an important role in determining the interaction between the insects and the host plant.

Baisakh and Naik (1991) studied phenotypic stability of seed yield and maturity in chickpea and observed significant differences due to genotype x environment (G x E) interaction. Linear and nonlinear components in G x E interaction in maturity and non-linear component in yield stability were predominant.

Singh and Singh (1995) reported positive and significant correlation between the mean of the genotypes and responsiveness to different environments for number of pods per plant, 100-grain weight and single plant yield in chickpea and indicated that the genotypes with high mean were in general, better responsive to favorable environments. There was lack of general association between stability of yield and its components, which calls for cautious selection of genotypes based on yield alone.

Singh and Sing (1991), Singh *et al.* (1994) and Singh *et al.* (1995) studied stability of yield and its components in chickpea and selected genotypes with high mean, unit regression slope and a non-significant deviation from regression as the measure for selecting promising genotypes for stability of yield. But in case of pod borer resistance, genotypes with lowest damage, ORS (Overall resistance score) and PDS (Pod damage score), unit regression slope and non-significant deviation from regression were stable and resistant to *H. armigera.*

2.2 INHERITANCE OF RESISTANCE

The concept of combining ability was proposed by Sprague and Tatum (1942) and noted that combining ability can be studied by making all possible single crosses among a set of inbred lines. It is not possible to study the type of gene action of individual genes in quantitative traits. Diallel analysis is one of the most important biometrical techniques available to the plant breeders for evaluating and characterizing genetic variability existing in a crop species.

The diallel cross has proved to be of considerable value to plant breeders in making decisions concerning the type of breeding system to use and in selecting breeding materials that show the greatest promise for success. It has also been used successfully by quantitative genetists attempting to gain a better understanding of the nature of gene actions involved in determining quantitative traits, which are of at most importance in agriculture. Spraque and Tatun (1942) defined "general combining ability" (GCA) as the average performance of the lines in hybrid combinations and "specific combining ability" (SCA) as the derivation of certain crosses from the average performance of the lines.

Total genetic potential is partitioned into general and specific combining effects, while the general combining ability was attributed to additive effect of genes, specific combining ability was attributed to the dominance derivation and epistatic interaction. The theory and analysis of diallel crosses was given by Hayman (1954a and 54b), Griffing (1956), Kempthorne (1957), and Gardner and Eberhart (1966). Diallels have been used primarily to estimate genetic variances when parents are either random individuals or linkage equilibrium, and to estimate general and specific combining ability effects from crosses of fixed lines.

Griffing (1956) while emphasizing the statistical concept of general and specific combining ability, reported that general combining ability involved both additive and additive x additive interaction effects. This was also supported by Sokol and Baker (1977) who reported that the general combining ability includes the effects of additive as well as epistatic gene action. But the inheritance studies using diallel analysis do not promote the estimates of different non- allelic gene actions operating in the inheritance.

The genetic interpretation of data from diallel experiments is valid only with certain assumptions: (i) diploid segregation, (ii) homozygous parents, (iii) gene frequencies equal to one-half at all segregating loci, (iv) genes independently distributed between the parents and (v) no non-allelic interaction.

The various methods proposed for the analysis of diallel cross data vary in the assumption made for interpretation. It has been argued (Gilbert 1958; Kempthorne, 1976; and Mayo, 1980) that the assumptions, which must be satisfied for the partitioning of genetic components are too stringent and that a genetically uni-formation but relatively assumption-less analysis such as that of Griffing (1956), is therefore, to be preferred.

2.2.1 STATISTICAL PROCEDURE FOR GRIFFING (1956) MODEL

In this approach, using a suitable statistical model the component variances due to general and specific combining ability are estimated. Griffing (1956) has given four methods of diallel depending on the material involved in the analysis. Among which method 2 involves parents and F_1s only and described the methods of analysis for combining ability considering Eberhart's model I (fixed effect) and model II (random effect). In the method 2 and model I two steps are involved in the analysis of data. The first step consists of analysis of data for testing the null hypothesis that there are no genotypic differences among the F_1s and parents. To test the null hypothesis `F' test is used. The degrees of freedom for GCA was P-1 and for SCA P (P-1)/2, where as P stands for number of parents. Only when the significant differences among these are established, there is need for second step in analysis, i.e., the combining ability analysis.

In this study, the assumption was nonreciprocal differences do not exist and total number of entries analyzed with 'n' lines where n (n+1)/2.

2.2.2 GARDNER AND EBERHART (1966) METHOD

It is advantageous over other methods because:

1. The model assumes arbitary gene frequencies at all loci between parents and is equally applicable to a fixed set of both homozygous varieties as well as those mating at random.
2. Heterosis effects are further sub-divided to provide additional information about the varieties involved and
3. The variety effects, as presented by Gardner and Eberhart depend only on additive and additive x additive gene action regardless of gene frequencies or correlated gene distribution.

When parents are homozygous lines and only the diallel cross is considered Gardner and Eberhart (1966) model is similar to Hayman's (1954a and b) model, but in addition the problem of fixed set of parents was also discussed. So, with a fixed set of homozygous lines as parents, this model is useful in planning the experiments and in analyzing and interpreting the results. Since the gene frequencies of the varieties are arbitrary, this model applies equally well to fixed sets of homozygous varieties. Because F_1 seed is usually very limited with self-pollinating crops, the heterosis expected from single cross hybrids of self-pollinated varieties can probably be better estimated from the variety and F_2 means using this model than from actual comparisons of F_1 and parents.

The statistical model for the case where only the varieties and their diallel crosses are included in the experiment this method was similar to Hayman (1954a) and Griffing (1956) except that heterosis is not subdivided in Griffing's analysis. Hayman does subdivide the heterosis, but he is considering random homozygous lines from same base population about which he wants to draw the calculations. But Gardner and Eberhart (1966) had given clear genetic interpretation for the heterosis.

Griffings (1956) analysis (method 2, model I) is designed for the case of fixed set of parents and their diallel cross lines analysis of variance is the one as Gardner and Eberhart (1966) except that he does not subdivide heterosis, which he calls specific combining ability. Plant breeders and geneticists dealing with open pollinated varieties as well as those dealing with homozygous lines and self fertilizing species have made use of the model proposed by Gardner and Eberhart (1966) and this has been extended to include additive x additive epistasis and to permit multiple alleles at all loci.

Singh *et al.* (1992) analyzed 28 diallel trials in chickpea over eight years and two locations to estimate genetic variances and draw the conclusions. Days to flowering, plant height and seed size were found to be predominantly under additive inheritance and were highly predictable. Both additive and non- additive genetic components were important for seed yield, pods per plant and seeds per pod. Although both general combining ability and specific combining ability varied significantly with generation, components of GCA mean square were invariably much larger than GCA x generation interaction components, indicating either F_1 or the F_2 generation can be used to estimate the GCA components effectively.

Breeding for reduced susceptibility to *H. armigera* in to improved agronomic background of desi and kabuli chickpea genotypes is carried out in close cooperation between breeders and entomologists at ICRISAT. New sources of resistance identified by entomologists and incorporated in breeding program and F_2-F_5 generation of crosses were screened against pod borer under un-sprayed field conditions.

ICRISAT (1981) conducted 6 x 6 desi and 4 x 4 kabuli diallels and indicated additive genetic variance for pod borer resistance. ICRISAT (1982) conducted 6 x 6 diallel with desi short duration cultivars and 6 x 6 diallel with desi medium long duration cultivars and reported additive genetic variance for pod borer resistance. ICRISAT (1983) in 6 x 6 desi and 5 x 5 kabuli diallels reported the preponderance of SCA for borer damage in medium duration desi group conflicts with other data and indicates the non-additive genetic variation may be important in some sources of resistance. ICRISAT, (1984) conducted two desi trials and reported that GCA variances were significant for most of the characteristics suggesting the importance of additive genetic variance. There was preponderance of SCA variance for days to maturity, borer damage and seed yield indicating the importance of non-additive genetic variance for these characters in kabuli chickpea. In desi trials there seemed to be a good agreement between parental means and GCA effects for almost all the characters, but this was not true for the kabuli trial. ICRISAT, (1985) reported that for pod borer damage, the SCA component was in higher magnitude indicating non-additive gene action for borer resistance in chickpea.

Parents ICC 506, ICC 10619 and ICCL 84205 with low borer damage were found useful in the breeding programs for *H. armigera* resistance (Singh *et al.,* 1991). Progenies of plants selected as low borer were less susceptible compared to high borer damage lines and correlation between pod borer damage in F_2 and F_3 progenies was positive (ICRISAT, 1981). Pedigree selection for low borer damage under pesticide free condition was found effective in identifying borer resistant lines. Gowda *et al.* (1995) developed ICCV 7 from a cross between H 208 and BEG 482 and registered it is resistant to gram pod borer. Some of the released varieties like Vishal and Vijay showed higher resistance to borer damage (Deshmukh *et al.*, 1996a and 1996b).

Dhaliwal and Gill (1973), Gupta and Ramanujam (1974), Gowda and Bahl (1978), Singh and Mehra (1980), Malhotra *et al.* (1983), ICRISAT (1981, 82, 83, 84 and 85) demonstrated additive genetic effects (2σ GCA^2) were greater than non- additive effects (σ SCA^2) for days to flowering and 100-seed mass.

Lal (1972), Gupta and Ramanujan (1974), Asawa and Tewari (1976), Sikka (1978), Gowda and Bahl (1978), Singh and Mehra (1980), Singh *et al.*, (1982), Malhotra *et al.* (1983) and Singh and Paroda (1989) reported the importance of both GCA and SCA effects for days to maturity, pods per plant, seed per pod and seed yield and discussed the importance of non-additive genetic effects. But exploitation of non-additive genetic effects in the form of using F_1 hybrids in chickpea is not feasible because of the problems of crossing.

Chaturvedi *et al.* (1997) summarized research finding on *H. armigera* resistance in chickpea and tabulated data on sources and inheritance of resistance based on results from trials during 1936-94 in which he mentioned ICC 506 and ICCV 7 as good - sources for *H. armigera* resistance.

Malhotra and Singh (1997) reported both additive and non-additive genetic effects were important with the preponderance of additive gene action for seed size. Partial dominance of small over large seed size suggesting that seed size is governed by recessive gene. Singh and Gupta (1997) reported the importance of both additive as well as non-additive components of variance for pods perplant, seeds per pod and 100-seed weight. Shivkumar *et al.* (2001) reported the predominance of additive component for flowering and seed weight and non-additive component was predominant for pods per plant, seeds per plant, seeds per pod and seed yield.

The components of variation of F_2 can be estimated by the method of Gardner and Eberhart (1966). The expected statistics for F_2 generation are of the same form as those of F_1s except that combining ability variance is halved by one generation of inbreeding Haymen, 1954b; Mather and Jinks, 1971 and Gardner and Eberhart 1966).

General combining ability (GCA) and specific combining ability (SCA) varies significantly with generation. components of GCA mean squares were invariably much larger than GCA x generation interaction components indicating that either the F_1 and F_2 generation can be used to estimate the GCA components effectively. Combined diallel analysis of F_2s over locations revealed the importance of combining ability x location interactions (Singh *et al.*, 1992).

2.3 MECHANISMS OF RESISTANCE

Plant resistance to pests is an economically and ecologically preferred alternative to other pest management strategies, particularly synthetic pesticides. Host plant resistance is simple, convenient, cheap and usually works well in combination with other forms of pest management, although it can have severe implications for the efficacy of some alternative pest management strategies such as bio-pesticides. In some cases, serious incompatibility does occur between natural plant resistance and other pest management approaches, so there is a great need to understand fully the mechanisms involved in resistance to ensure that antagonistic effects can be avoided (Stevenson *et al.*, 2002).

During the course of evolution, plants acquire several defense mechanisms against insect pests to reduce the damage. The major mechanisms are antixenosis (non-preference), antibiosis, tolerance and escape potential (Painter, 1951). To date more antibiosis, than antixenosis or tolerance has been reported in legume crops (Clement *et al.*, 1994).

Many morphological characteristics or non-preference tactics have been used to breed for resistance to *H. armigera* to reduce pest abundance and damage. Multiple types of resistance (tolerance, antixenosis and escape) are reported in chickpea (Clement *et al.*, 1992). Several morphological and phenological traits such as shape of the pod, pod wall thickness, foliar colour and crop duration seems to influence the *H. armigera* infestation in chickpea (Ujagir and Khare 1987 and 1988).

2.3.1 ANTIBIOSIS

Chickpea varieties differ in their susceptibility to *H. armigera* due to d`ifferences in antibiosis mechanism (Singh and Sharma 1970). Work on antibiosis to *H. armigera* in chickpea has been reported by Dubey *et al.* (1981), Jayaraj (1982), Srivastava and Srivastava (1989 and 1990), Cowgill and Lateef (1996), Sison *et al.*, (1996); Yoshida *et al.* (1995) and Yoshida (1997). The present investigation is a further contribution on antibiosis to pod borer in chickpea.

The acid exudates (pH 1-3) with high concentration of malic acid secreted from the glandular hairs on leaves, stems and pods is responsible for *H. armigera* resistance in chickpea (Sahasrabudha, 1914). Lateef (1985) suggested the amount of acid exudates on leaves as an useful criteria for distinguishing relatively resistant genotypes from susceptible ones. Rembold (1981) confirmed it and recommended it as a marker to identify resistance in chickpea.

Chickpea exudates contain malate and oxalates as the main components and there were characteristic differences in amounts, depending on the variety, diurnal cycles and growth stage. Varieties with highest amount of malic acid had the highest resistance to *H. armigera* (Rembold *et al.*, 1989). Low amount of acidity in the leaf exudates of genotype ICC 14665 was associated with susceptibility to *H. armigera* (Srivastava and Srivastava 1989; Bhagawat *et al.*, 1995). However resistance expressed by PDE – 3-3, PDE 7-3 and PDE 7-3 and ICC 506 was attributed to factors other than the acidity while that of PDE 7-2 appeared due to high acidity (Patnaik and Senapati, 1995).

Yoshida *et al.*, (1995) reported that genotypes resistant to *H. armigera* accumulated more oxalic acid on the leaves than the susceptible genotypes. Oxalic acid showed significant growth inhibition of *H. armigera* larvae when included in semi-artificial diet. The effective accumulation of oxalic acid is considered to be one of the mechanisms of *H. armigera* resistance in chickpea.

Tripati and Sharma (1985) studied different food plants to *H. armigera* and found that chickpea was the most preferred food plant. Srivastava and Srivastava (1989) reported that the low amount of acidity in the extracting genotypes was found to be associated with susceptibility to *H. armigera,* and there is a positive correlation between the number of eggs laid and number of larvae present on susceptible genotypes ICC 3137, K 850 and ICC 1043.

Srivastava and Srivastava (1989) studied the relative preference of *H. armigera* larvae reared on different chickpea genotypes and reported that antibiosis also has a role in *H. armigera* resistance in some genotypes. The high acidity was found to be associated with the resistance against *H. armigera.* Srivastava and Srivastava (1990) reported large genotypic variation in larval survival, larval weight, pupal weight, egg viability, adult longevity and HOW's growth index among genotypes. Larval weight contributed maximum to the variation, followed by larval period, pupal weight and pupal period.

A high percentage of crude filter, non reducing sugars and low percentage of starch have been found to be related with low incidence of *H. armigera* in cultivar GL 645 while a high percentage of cellulose, hemicelluloses and lignin in the pod wall inhibit the pod damage. In less susceptible genotypes (Desi 3108, GI 1002 and LCG 3508) the chemical components such as malic acid, sugar, crude fiber, cellulose and lignin in the plant parts are responsible for their resistance (Chabra *et al.,* 1990). Patnaik (1996) reported the adverse effects on growth and development of *H. armigera* was apparent from low growth index values in the resistant cultivar, ICC 506. Significant variation in the content of trypsin inhibitors and the *H. armigera* gut protinase inhibitor among chickpea genotypes provided biochemical basis for adoption of *H. armigera* to the protein inhibitors of *Cicer* species (Patankar *et al.,* 1999).

Cowgill and Lateef (1996) screened five short-medium duration desi and five medium- long duration kabuli chickpea genotypes in the laboratory for antibiosis to *H. armigera*. Larvae were reared either on chickpea leaves or on pods containing green seeds. Significant variation among the desi genotypes was found for pupal weight and larval survival. Pupae resulting from larvae reared on either pods or leaves of ICCV 7 weighed substantially less than those reared on the susceptible controls, ICC 4918 and ICC 3137. Pupae of larvae reared on leaves of ICC 506 weighed substantially less than those reared on ICC 3137. There was no variation in the measured parameters for larvae reared on the kabuli chickpea genotypes. In general, pupae of larvae reared on chickpea pods were heavier and developed more quickly than those reared on chickpea leaves.

2.3.2 ANTIXENOSIS FOR OVIPOSITION

Oviposition in *H. armigera* usually starts some hours after dusk initially alternating with feeding, later becoming the predominant activity until soon after midnight (Pearson and Darling, 1958). Moths are highly selective in their choice of host plant in a suitable condition of development (Hardwick, 1965).

On chickpea the eggs are laid mostly on leaves on underside when the plants are still very small. In contrast to other hosts, oviposition on chickpea declines from the onset of flowering (King, 1994).

The physiological state of an insect is a product of numerous interacting variations like age, feeding status and egg load etc. Egg load is one of several factors that may affect host selection behavior (Singer 1982; Fitt, 1986; Blaney and Simmonds, 1990 and Courtney and Kobota, 1990). Females with higher egg load may be less discriminating and more accepting of low ranking host plant (Minkenberg *et al.*, 1992 and Prokopy *et al.*, 1994). Mustapha *et al.* (1998) reported that female moths were less discriminating against cowpea (a low ranked host) relative to maize (a high ranked host) when egg load increased. Sison *et al.* (1993) conducted studies on the ovipositional preference of *H. armigera* among short duration pigeon pea genotypes and reported that flower colour influences the choice for oviposition. Sison *et al.* (1996) reported antixenosis as one of the mechanisms of resistance to *H. armigera* in chickpea.

Srivastava and Srivastava (1989) reported oviposition non-preference as the cause of observed differences in pod damage among eight chickpea genotypes. They found direct relation ship between the number of eggs laid and larval abundance. This clearly shows that ovipositional non-preference was mainly responsible for resistance expressed by the host genotypes, rather than larval preference and antibiosis. These results agree with results of Lateef (1985).

Cowgill and Lateef (1996) screened seven genotypes in the field for ovipositional non-preference to *H. armigera.* Fewer eggs were recorded on ICC 506, than the susceptibility controls. These observations were confirmed by the laboratory studies.

2.3.3 TOLERANCE

Tolerance provides plants the ability to produce satisfactory yield in the presence of a pest population that would otherwise result in significant damage in the susceptible plants. Tolerant cultivars do not suppress pest populations, and thus do not exert a selection pressure on the pest population. Effects of tolerance are cumulative as a result of interacting plant growth responses, such as plant vigour, inter and intra plant growth compensation, mechanical strength and organism, and nutrient and growth regulation and partitions. Plants with tolerance mechanism of resistance have a great value in pest management; as such plants prevent the evolution of new insect biotypes capable of feeding on resistant cultivars. The antixenotic or antibiotic mechanisms of resistance can be delayed or minimized by using tolerance as a polygenic resistance (Tingey, 1981).

Singh *et al.*, (1985) estimated the grain yield loss due to *H. armigera* using chemical protection method. The mean reduction in the pest population in the protected crop over the unprotected one ranged from 61.1 to 81.1%. The avoidable loss in grain yield by applying single spray of endosulfan was 60 to 87.5%. The economic input level was estimated at 1.5% pod damage.

Yelshetty *et al.*, (1996) compared the percentage pod damage at maturity of each trial with that of the control and converted to pest susceptibility rating (PSR) on a scale of 1 to 9) as suggested by Lateef and Reed (1983). The lower PSR values indicated the lower level of pod borer attack on genotypes and better tolerance to pod borer.

Materials and Methods

CHAPTER-III

MATERIALS AND METHODS

The laboratory, glasshouse and field studies were conducted at International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Patancheru, India, during 2000-2002, to evaluate the "Stability, Inheritance and Mechanisms of Resistance to *Helicoverpa armigera* (Hub.) in Chickpea (*Cicer arietinum* Linn)". The latitude and longitude are 17°27'N and 78°28'E respectively and altitude is 545 m above mean sea level. Materials utilized in conducting the experiments and various methods employed during the course of investigation are given in this chapter.

3.1 STABILITY OF RESISTANCE TO *H. armigera* IN CHICKPEA

The material for the study of stability of resistance to *H. armigera* included 28 chickpea germplasm lines and 10 *H. armigera* resistant lines derived from earlier breeding program at ICRISAT.

3.1.1 LAYOUT OF THE EXPERIMENT

The 28 *H. armigera* resistant chickpea lines and 10 breeding lines were sown on 18th October, 2000. Second planting of breeding lines was done on 9th November, 2000. The genotypes were grouped in to 18 (including four new entries ICC 12494, ICC 3137, ICC 4973 and ICC 4962) *H. armigera* resistant germplasm lines and 24 breeding lines and were sown on 1st November, 2001 and 22nd November, 2001. ICC 12475 and ICC 4918 were used as resistant and susceptible checks respectively in each of the trails.

Each of the trials was conducted in randomized block design with three replications. Plot size was four rows of 2 m long i.e.2.4 x 2 m planted at 30 x 10 cm row-to-row and plant-to-plant spacing (Plates 1,2,3 and 4). Totally 18 germplasm and 24 breeding lines were screened. Among these 10 lines were tested for 4 seasons, 28 lines for 3 seasons and four for two seasons. The lines tested for four seasons and three seasons were analyzed separately for their stability of resistance.

Table 1:. **Characteristics of the chickpea genotypes evaluated for stability of resistance to *H. armigera*, at ICRISAT, patancheru, 2000-02.**

Genotype	Pedigree	Days to 50% flow.	Days to maturity	Seeds per pod	100 seed Wt. (g)
Germplasm lines					
ICC 12475	BEG 78, ICC 506	55.4	104.4	1.21	16.07
ICC 4918	ICC 4918 (Annigeri)	50.9	107.0	1.19	19.93
ICC 12476	ICC 6663 HR (NEC-764)	67.1	114.7	1.19	15.77
ICC 12477	ICC 10460 HR (RPSP-194)	54.2	110.4	1.17	12.87
ICC 12478	ICC 10667 HR (62-10-3)	58.1	114.9	1.09	15.04
ICC 12479	ICC 10619 HR (G 130)	59.5	109.4	1.11	14.79
ICC 12490	ICC 4935 HR (C-235)	70.0	116.9	1.40	11.47
ICC 3137	P-3659-2	64.3	119.2	1.10	25.25
ICC 12491	ICC 10870 HR (JM-2575)	62.5	117.8	1.17	18.66
ICC 12492	ICC 5264 HR (GL-645)	63.6	122.8	1.28	16.49
ICC 12493	ICC 5264 HR (GL-645)	70.9	121.1	1.28	16.57
ICC 12494	P-52-P1-359038	68.3	119.2	1.22	18.56
ICC 12495	ICC 7559 HR (P-9626)	72.4	121.4	1.17	23.33
ICC 12496	ICC 2696 HR (P-2774-1)	58.9	114.7	1.36	19.67
ICC 14876	ICCV 7/H-208 x BEG-482	59.6	104.8	1.08	14.07
ICC 4962	ICC 4962	69.5	114.2	1.18	18.46
ICC 4973	ICC 4973	71.8	110.8	1.34	18.55
ICC 12480	ICC 1381 HR (P-1234-1)	62.5	110.0	1.12	17.1
ICC 12481	ICC 9526 HR (P-52)	62.3	115.3	1.27	14.09
ICC 10817	2-61-1	51.5	113.2	1.05	23.59
Breeding lines					
ICCC 4	ICC 11525 (H-208 x T-3)	73.3	110.8	1.18	13.94
ICC 12426	ICC 12426 (P 481 x (JG-62 x P-1630) (ICCL 80074)	54.6	102.0	1.36	19.23
ICC 12968	ICCL-82001 (OCCX-752770-13P-2P-BP-BP-BP) (K-850 x GW-5/7) x P-458) x L-550 x Guamuchil	34.1	94.0	1.10	23.95

Contd.....

Contd.......Table 1

Genotype	Pedigree	Days to 50% flow.	Days to maturity	Seeds per pod	100 seed Wt. (g)
ICC 12482	(K-850 x Chafa) HR	59.5	103.8	1.16	16.57
ICC 12483	(H-208 x BEG-482) HR	63.3	104.3	1.07	15.66
ICC 12484	(K-850 x N-59) HR	64.8	106.0	1.06	18.04
'CC 12485	(H-208 x N-59) HR	60.0	107.3	1.07	15.37
CC 12486	(GW-5/7 x H-223) HR	70.6	112.3	1.36	15.24
CC 12487	(H-208 x N-59) HR	72.8	112.2	1.30	14.57
CC 12488	(H-208 x RS-11) HR	76.6	113.3	1.37	11.09
CC 12489	(H-208 x RS-11) HR	73.1	114.7	1.37	11.66
CCL 86102	ICCX-790197-23PLB-11PLB-BPLB-(ICCC 4) H-208 x T-3 x ICC 506-EB-EB)	53.5	99.0	1.18	16.54
CCL 86111	ICCX-800757-6PLB-1PWR-1PLB-EB (BDNG-3 x ICC 6663-EBH)	65.6	104.5	1.01	21.06
CCL 87211	ICCX-810844-BP-18P-1P-BP [(ICC 4918 x JG-74) x ICC 4918] x ICC 4918	49.8	103.5	1.29	20.33
CCL 87220	ICCX-800034-BP-BP-13P-1P-BP (ICCL 78004 x BDN-9-3)	55.5	102.7	1.05	16.05
CCL 87314	ICCX-800584-32P-1P-3PLB-3PUY-BP (JG-74 x ICC 506-EB)	61.8	103.7	1.07	18.09
CCL 87315	ICCX-800584-32P-1P-4PLB-1PLB-BP (JG-74 x ICC 506-EB)	61.1	103.5	1.06	17.73
CCL 87316	ICCX-800584-32P-1P-3PLB-5PLB-BP (JG-74 x ICC 506-EB)	65.8	105.5	1.06	18.60
CCL 87317	ICCX-800584-1P-2P-1PUY-BPLB (JG-74 x ICC 506-EB)	64.0	107.7	1.15	16.94
CCV 93122	ICCX-8500123-BP-7P-3P-BP-B (ICC 4918 x ICC 506EB) x ICC 4918 x ICC 12237	60.8	107.0	1.11	19.28
CCV 95992	ICCX-860031-BP-BP-47P-BP (ICCX-850044 x ICCX-860027) (Avarodhi x ILC-151) x (ICCC-42 x ICC 1069)	54.5	103.5	1.09	20.83
CCV 96752	ICCX-890109-BP-19PLB-2P-BP [ICC 506-9EB x (H-208 x RS-11)] x [H-208 x BEG-482) x ICCL 86111	62.0	108.0	1.13	16.10
CC 15996	--	62.6	105.8	1.44	17.30

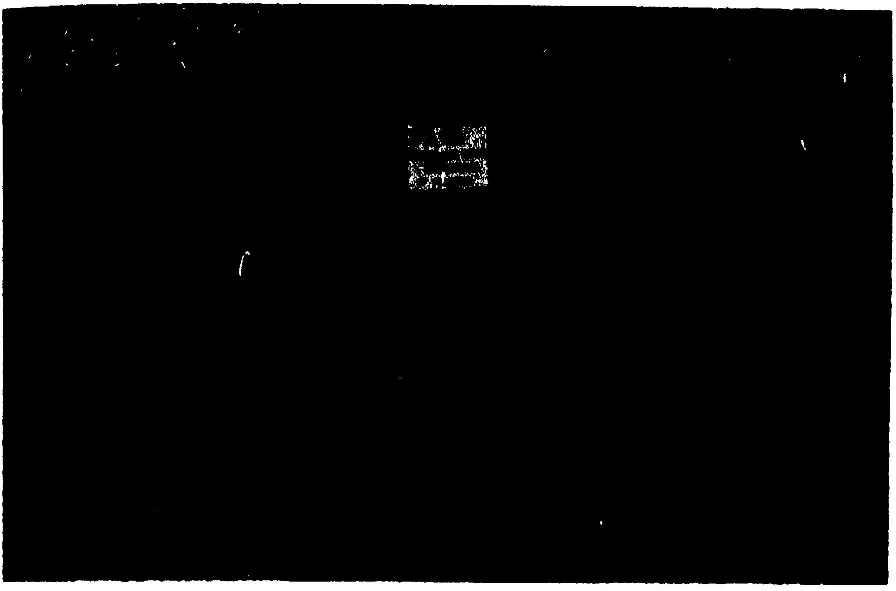


Plate1: **Evaluation of stability of resistance to *H. armigera* (Hub.) in chickpea germplam lines, (2001-02 first planting), ICRISAT, Patancheru.**

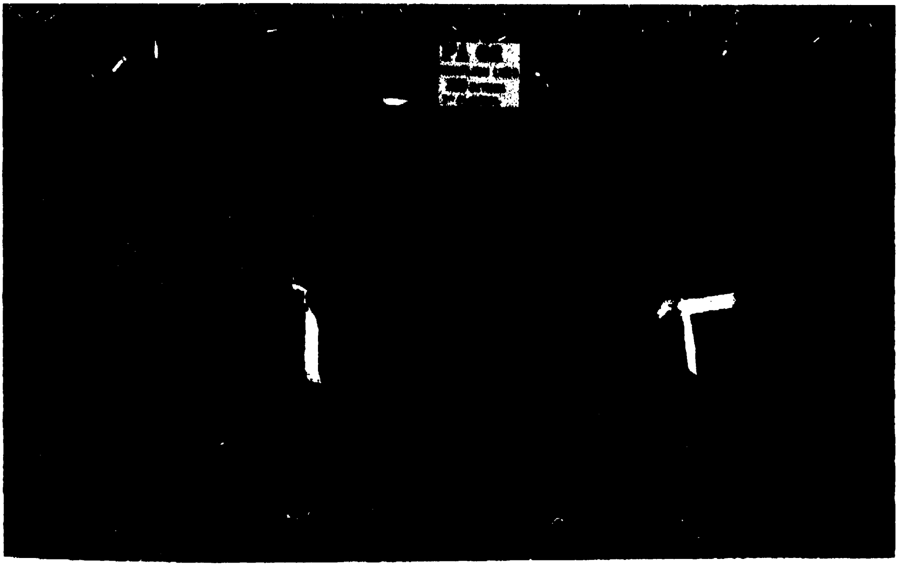


Plate 2 : **Evaluation of stability of resistance to *H. armigera* (Hub.) in chickpea germplam lines, (2001-02 second planting), ICRISAT, Patancheru.**

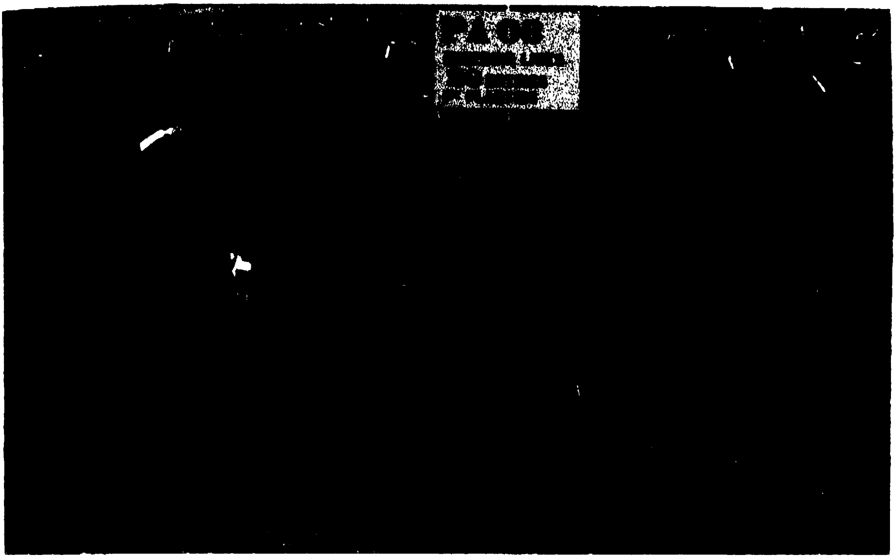


Plate 3 : **Evaluation of stability of resistance to *H. armigera* (Hub.) in chickpea breeding lines, (2001-02 first planting), ICRISAT, Patancheru.**

Plate 4 :.**Evaluation of stability of resistance to *H. armigera* (Hub.) in chickpea breeding lines, (2001-02, second planting), ICRISAT, Patancheru.**

3.1.2 COLLECTION OF DATA ON DIFFERENT CHARACTERS

3.1.2.1 Plant count two weeks after emergence

The total plants present in 1.5 m in two middle rows were counted leaving 0.25 m both the ends.

3.1.2.2 Tagging of the plants

Ten random plants (five in each row) in middle two rows were tagged for observations.

3.1.2.3 Egg and larval counts

Number of eggs and larvae were counted during vegetative, flowering and pod formation stage of the crop on 10 tagged plants.

3.1.2.4 Days to initiation of flowering/poding

Days to initiation of flowering and days to initiation of poding were recorded for 10-tagged plants.

3.1.2.5 Days to 50 % flowerin

Number of days from planting to 50% of the plants producing their first flowers in the plot was recorded as days to 50% flowering.

3.1.2.6 Days to maturity

Number of days from planting to 75 % maturity of the plot was recorded as days to maturity.

3.1.2.7 Insect damage scores

a) Overall resistance score (ORS)

Overall resistance score (to *H. armigera*) *damage* during the flowering stage of genotypes was recorded. The plants were visually rated for leaf feeding on 1 to 9 damage scale: 1 = < 10%, 2 = 11 to 20%, 3 = 21 to 30%, 4 = 31 to 40%, 5 = 41 to 50%, 6 = 51 to 60%, 7 = 61 to 70%, 8 = 71 to 80% and 9 = > 80% leaf area damaged.

b) Pod damage score (PDS)

Pod damage scores were recorded on 1 to 9 scale before harvesting when the crop reached the maturity stage. 1 = No pods damaged, 2 = <01%, 3 = 01 to 05%, 4 = 05 to 10%, 5 = 10 to 15%, 6 = 15 to 20%, 7 = 20 to 25% 8 = 25 to 40%, 9= >40% pods damaged.

3.1.2.8 Plant stand at harvest

The total number of plants present in 1.5 m in middle two rows were counted at the time of harvest.

3.1.2.9 Pod borer damage (%)

H. armigera damage to chickpea during poding stage was quantified by expressing the number of pods bored as a percentage of the total pods.

3.1.2.10 Pods per plant.

Total number of pods in a plant were counted.

3.1.2.11 Seeds per plant

Total number of seeds in a plant were counted.

3.1.2.12 Seeds per pod = Number of seeds per plant / Number of pods per plant

3.1.2.13 Yield per plant

Ten tagged plants were harvested individually and average yield was taken as yield per plant in each plot.

3.1.2.14 Yield per plot

Seed yield in a plot after threshing was weighed, to this yield of the ten sampled plants of same plot was added to get the net yield per plot. Yield kg ha^{-1} was calculated based on net plot yield.

3.1.2.15 100 seed weight

100 seeds weight was calculated based on seed number and seed weight.

3.1.2 STATISTICAL ANALYSIS

All the parameters were analyzed using one-way ANOVA in randomized block design. For the 10 breeding lines stability analysis was done for four seasons and for the 28 germplasm lines for three seasons using Eberhart and Russell (1966) method and stability statistics were analyzed.

3.2 INHERITANCE OF RESISTANCE TO *H.armigera* IN CHICKPEA

Four diallel trials (45 F_1s + 10 parents of 10 x 10 desi types and 28 F_1s + 8 parents of 8 x 8 kabuli types) and (45 F_2 s + 10 parents of 10 x 10 desi types and 28 F_2 s + 8 parents of 8 x 8 kabuli types) were conducted in insecticide-free conditions in the post rainy season 2001-02 at ICRISAT, Patancheru, in a randomized block design with three replications (Plates 5,6,7 and 8).

The crosses were made among the parents (less susceptible and highly susceptible lines) during 2000-01 season in field and in glasshouse. Healthy buds, that were going to open on the same day were hand emasculated in the morning (0830 to 1000 hrs) and evening (1500 to 1630 hrs). Buds emasculated in morning were pollinated in the evening, and buds emasculated in evening were pollinated next day morning. Different coloured threads were used to differentiate the crosses (Plate 9). After maturity, the pods resulting from crossing were harvested and seed was collected and used as F_1 seed. The seed harvested from F_1 was used as F_2.

For F_1 s the plot size was one row of 2 m long and 30 cm apart (Plates 5 and 7) . Days to 50% flowering, days to maturity and yield were recorded for plots. Seed yield per plant, number of pods per plant, number of seeds per plant, 100 seed weight, seeds per pod and pods damaged by *H. armigera*, were recorded on five random plants per plot.

For F_2s the plot size was 4 rows of 2 m long and 30 cm apart (Plates 6 and 8). Days to 50% flowering, days to maturity and yield were recorded for plots. Seed yield per plant, total number of pods per plant, total number of seeds per plant, 100 seed weight, seeds per pod and pods damaged by *H. armigera* were recorded on 30 random plants per plot.

Plot means were used for combining ability analysis, according to Griffings (1956) method 2, model I and Gardner and Eberahart (1966).

Plate 5 : **Desi chickpea 10 x 10 diallel (45 F_1s + 10 parents) for *H.armigera* (Hub.) resistance, ICRISAT, Patancheru, 2001-02.**

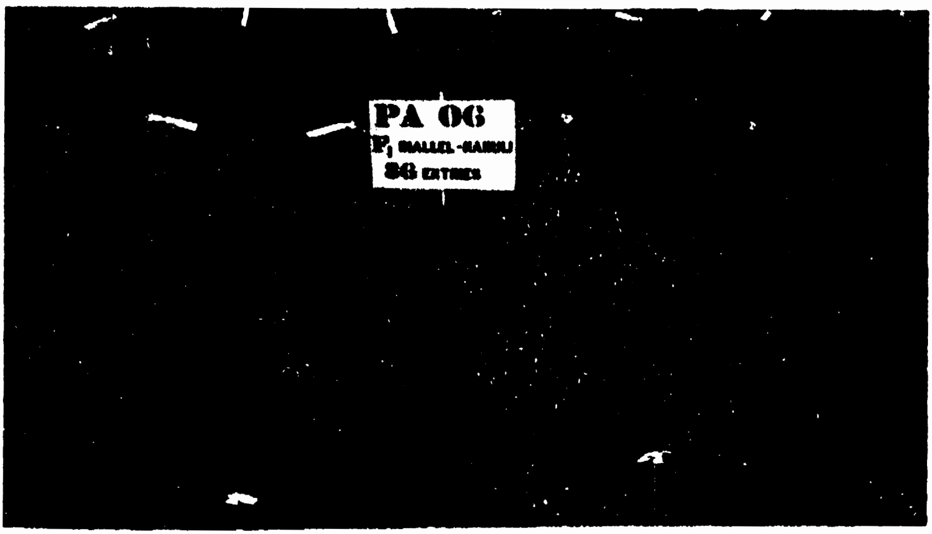


Plate 6 : **Kabuli chickpea 8 x 8 diallel (28 F_1s + 8 parents) for *H. armigera* (Hub.) resistance, ICRISAT, Patancheru, 2001-02.**

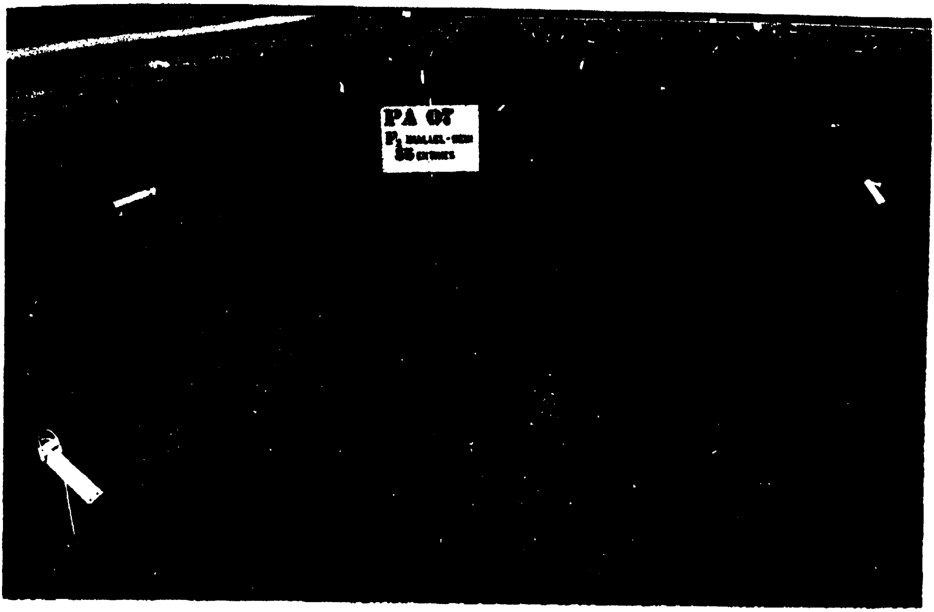


Plate 7 : **Desi chickpea 10 x 10 diallel (45 F_2 s + 10 parents) for *H. armigera* (Hub.) resistance, ICRISAT, Patancheru. 2001-02.**

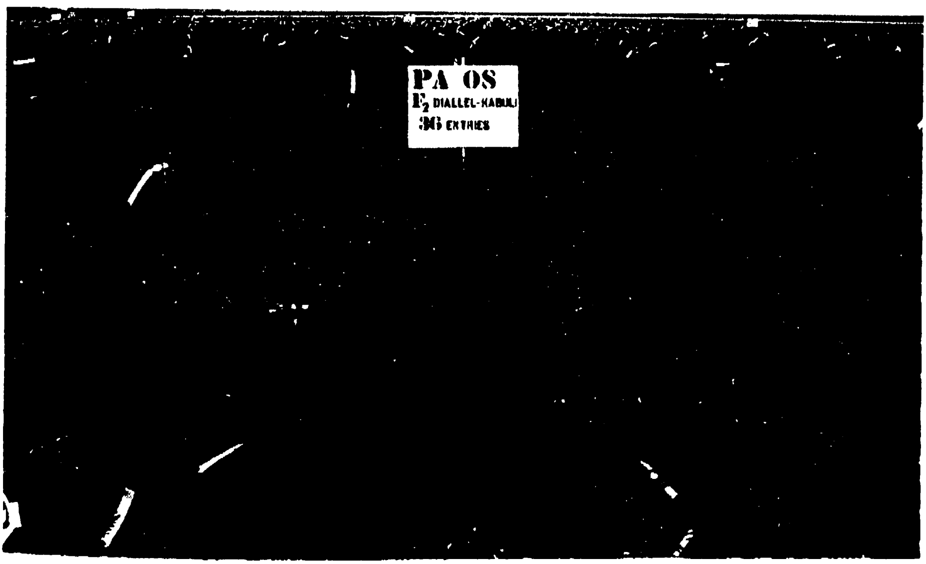


Plate 8 : **Kabuli chickpea 8 x 8 diallel (28 F_2s+ 8 parents) for *H. armigera* (Hub.) resistance, ICRISAT, Patancheru, 2001-02.**

Plate 9 : **Crosses among the chickpea parents, ICRISAT, Patancheru, 2000-01.**

3.3 MECHANISMS OF RESISTANCE TO *H. armigera* IN CHICKPEA

3.3.1 INSECT CULTURE

Larvae and adults of *H. armigera* used in feeding tests and oviposition experiments in the laboratory were obtained from a laboratory culture maintained at ICRISAT, Patancheru, India. The culture was established from, and regularly supplemented with field-collected larvae. Larvae were reared on a chickpea based diet (Armes *et al.*, 1993) at 27°C. Adults were kept at 25°C in a cage and mappyliners were provided as a substrate for oviposition. The moths have provided 10% honey solution on absorbent cotton for oviposition.

3.3.2 ANTIBIOSIS

3.3.2.1 Survival and development of H. armigera on chickpea Leaves

Neonate *H. armigera* were fed on chickpea leaves of 18 test genotypes (ICC 12475, ICC 12476, ICC 12477, ICC 12478, ICC 12479, ICC 12490, ICC 14876, ICC 4918, ICC 12426, ICC 3137, ICC 12491, ICC 12492, ICC 12493, ICC 12494, ICC 12495, ICC 12968, ICC 4973 and ICC 4962) grown in the field during the 2000-01 and 2001-02 postrainy seasons at ICRISAT, Patancheru, India. Larvae were held individually in plastic jars (11 cm diameter and 13 cm height) at 25°C and fed on fresh leaves. Larval weights were recorded 10th and 20th day of release. Data were also recorded on larval duration, number of larvae pupated, pupal weight, pupal period, adult emergence and fecundity. The food was changed everyday. The experiment was conducted in a completely randomized design with 18 genotypes as treatments. There were five replications and each replication had 10 larvae.

3.3.2.2 Survival and development of H. armigera on Pods

Neonate larvae were fed with tender chickpea leaves and flowers for seven days and later on with tender pods of 18 test genotypes as described above. There were five replications in CRD and each replication had 10 larvae under observation. Observations were recorded as described above.

3.3.2.3 Artificial diet for H armigera

To raise the *H armigera* culture in the laboratory; 75 g of chickpea flour, 12 g yeast, 1.175 g L-ascorbic acid, 1.25 g methyl –4-hydroxylbenzoate, 0.75 g sorbic acid and 2.875 g aureomycin were weighed in a electronic balance and were taken in a hand held mixer. 1 ml of formaldehyde, 2.5 ml of vitamin stock solution and 112.5 ml of water were added to it and mixed thoroughly. Meanwhile, 4.375 g of agar-agar was boiled with 200 ml of water and added to the diet and mixed thoroughly to get even consistency. The diet was then poured into small plastic cups and allowed to cool in a laminar flow cabinet.

3.3.2.4 Impregnation of H. armigera artificial diet with lyophilized leaves and pods

To study the antibiosis component of resistance, freeze dried powder of leaves and pods of chickpea was impregnated in the artificial diet of *H. armigera.* Chickpea branches with tender, green leaves and tender green pods with developing seeds were collected from pesticide-free plots. The leaves and pods were frozen at –20°C and lyophilized. The dried leaves and pods were powdered in a blender to get fine powder (<80 μm) (Plate 10).

To know the amount of lyophilized leaf or pod powder to be used in antibiosis studies, involving artificial diet different concentrations of resistant (ICC 12475) and susceptible (ICC 4918) checks were incorporated into the artificial diet (10, 15, 20, 25 and 30 g of lyophilized powder + 65, 60, 55, 50 and 45 g of chickpea flour, respectively). Thirty neonate larvae were reared individually at 27°C under photoperiod of 12:12 (L:D)h.

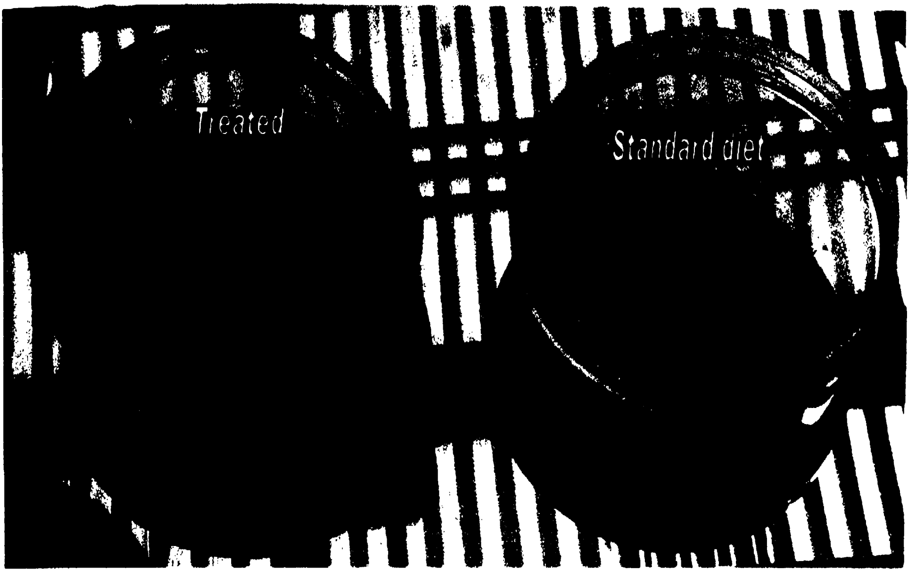


Plate 10 : **Growth and development of *H. armigera* (Hub.) in artificial diet impregnated with lyophilized chickpea leaves, ICRISAT, Patancheru, 2000-02.**

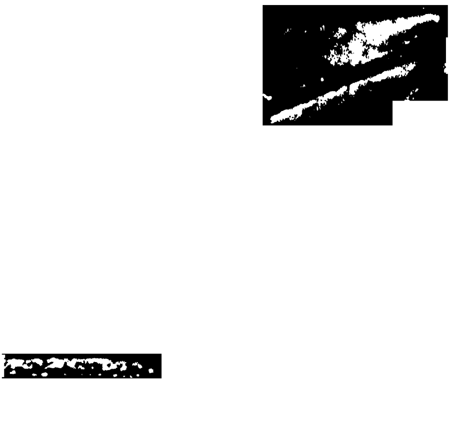


Plate 11 : **Glandular hairs secreting acids (oxalic and malic acid) in chickpea.**

Maximum differences between the susceptible and resistant genotypes in larval survival and larval weight was observed when 20 g of lyophilized leaf or pod powder was incorporated into the artificial diet along with 55 g of chickpea flour. This concentration was used to test 18 genotypes to assess the level of antibiosis towards survival and development of *H. armigera.*

Data was recorded on larval weight, larval duration, number of larvae pupated, pupal weight, pupal period and adult emergence. Data on percent pupation and percent adult emergence were converted to respective angular values, and subjected to analysis of variance.

3.3.3 RELATIVE SUSCEPTIBILITY OF CHICKPEA GENOTYPES TO *H. armigera* UNDER NO-CHOICE CAGED CONDITIONS

Chickpea plants were grown in the greenhouse in plastic pots (30 cm diameter, 30 cm deep). The pots were filled with red soil, black soil and farmyard manure (2 : 1 : 1). In each pot, 15 seeds were sown at 7 cm depth. The plants were watered as and when needed. Ten seedlings with similar growth were retained in each pot 10 days after seedling emergence. The greenhouse was cooled by desert coolers to maintain the temperature at 28 ± 5°C, and relative humidity of 76 ± 5 %.

Eighteen genotypes (ICC 12475 (resistant check), ICC 12476, ICC 12477, ICC 12478, ICC 12479, ICC 12490, ICC 14876, ICC 4918 (susceptible check), ICC 12426, ICC 3137, ICC12491, ICC 12492, ICC 12493, ICC 12494, ICC 12495, ICC 12968, ICC 4973 and ICC 4962) were screened in this experiment. There were three replications in randomized complete block design.

Five plants in each pot were infested 15 days after seedling emergence. Plants were covered with a plastic jar cage (11 cm diameter, and 26 cm height) with two wire mesh screened windows (4 cm diameter) on the sides. The top of the plastic jar cage was covered with the lid fitted with the wire mesh screen. Twenty neonate larvae were counted in the laboratory, placed in 25 ml plastic cups, and taken to the greenhouse for infestation. The

Plate 12 : **Relative susceptibility of 18 chickpea genotypes to *H armigera* under no-choice caged conditions in glasshouse, ICRISAT, Patancheru, 2001-02.**

Plate 13 : **Susceptibility of chickpea genotypes to *H armigera* under no-choice caged conditions in glasshouse, ICRISAT, Patancheru, 2001-02.**

larvae were released inside the cage on the plants, and the lower end (up to 2 cm) of the cage was pushed into the soil. Five plants outside the cage in the same pot served as a un-infested control (Plate 13). The cages were removed after the completion of the experiment, and observations were recorded (Plate 14). The experiment was again repeated during flowering stage (40 days after sowing) of the plants to test their susceptibility.

The first infestation was done 15 days after sowing as mentioned above and the second infestation was done during the flowering stage (40 days after sowing) on the infested plants.

Observations were recorded six days after infestation. The plants were visually rated for leaf feeding on a 1 to 9 damage scale. (1 = < 10%, 2 = 11 to 20%, 3 = 21 to 30 %, 4 = 31 to 40%, 5 = 41 to 50%, 6 = 51 to 60%, 7 = 61 to 70%, 8 = 71 to 80% and 9 = > 80% leaf area damaged). The plants grown till maturity and data on number of plants survived, and seed yield (g) on infested and un-infested plants was recorded.

3.3.4 RELATIVE PREFERENCE OF *H. armigera* LARVAE TOWARDS WASHED AND UNWASHED CHICKPEA LEAVES

The chickpea genotypes were grown in the glasshouse as mentioned above to test the feeding preferance by the *H. armigera* larvae. Plastic cups of 9.5 cm diameter were used in this experiment had a filter paper and moistened with water attached to the lid to keep the chickpea leaves in a tugid condition. Agar-agar (3.5 %) was boiled and poured into cups to a depth of 2.5 cm and allowed to gelate. The solidified agar-agar was used as the substratum for inserting the chickpea branches (5 cm long with 2 fully expanded leaves). A washed (with tap water for 1 minute) and unwashed branch of each genotype was inserted into the agar-agar medium at the opposite ends. Care was taken to see that the branches did not touch the inner walls of the cup. Ten neonate *H. armigera* larvae were released on the agar-agar at the center of each cup (Plate 11).

The experiment was conducted in a completely randomized design with 10 replications and 18 genotypes as treatments. Observations pertinent to leaf feeding score on

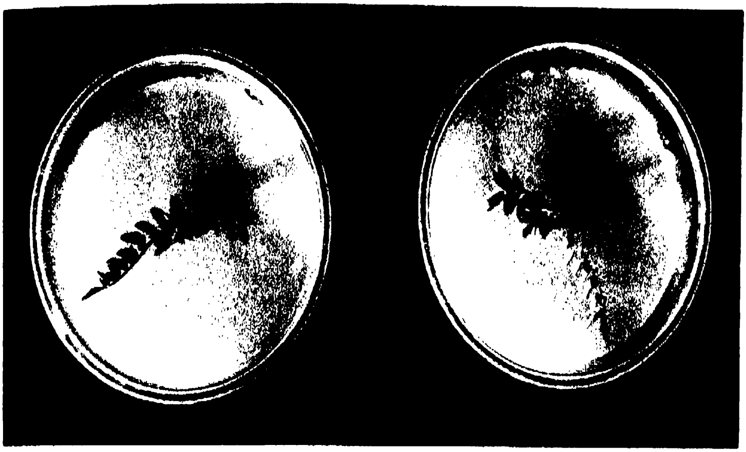


Plate 14 : **Relative preference of *H. armigera* neonate larvae towards washed and unwashed chickpea leaves inserted in agar-agar, ICRISAT, Patancheru, 2001-02.**

0 to 9 scale (0 = no damage, 1 = < 10% leaf area damaged and 9 = > 80% leaf area damaged), number of larvae survived and number of larvae present on each twig were recorded three days after initiating the experiment.

The same experiment was repeated separately with washed and unwashed leaves (no-choice conditions) with ten replications. Data were recorded on the number of larvae survived, and the weight gained by the larvae three days after release.

3.3.4.1 Statistical Analysis

Data was subjected to factorial analysis to know the significance differences between washed and unwashed leaves, and the genotypes tested. Students 't' test was used to know the significance of the differences between the treatments (washed and unwashed) for each genotype.

3.3.5 ANTIXENOSIS FOR OVIPOSITION

The oviposition preference of *H. armigera* moths towards different genotypes of chickpea was studied under no choice, dual-choice and multi-choice conditions in the laboratory at 25 ± 2^0C temperature and 65 to 90% RH.

For oviposition tests, fresh flowering branches (20 cm) brought from the field, were placed in a conical flask (150 ml) filled with water and plugged with cotton wool. Three branches from a genotype (one straight and the other two in opposite directions) were placed in each conical flask.

For no-choice tests, a conical flask with chickpea branches of a genotype was placed at the center of cage. For dual choice tests, two flasks one with branch of a test genotype and the other with branches from a susceptible check (ICC 4918) were placed in a wooden cage 30 x 30 x 30 cm. Three sides of the cage were fitted with a glass, while the one covered with muslin cloth for aeration and facilitate release of moths inside the cage. A cup containing

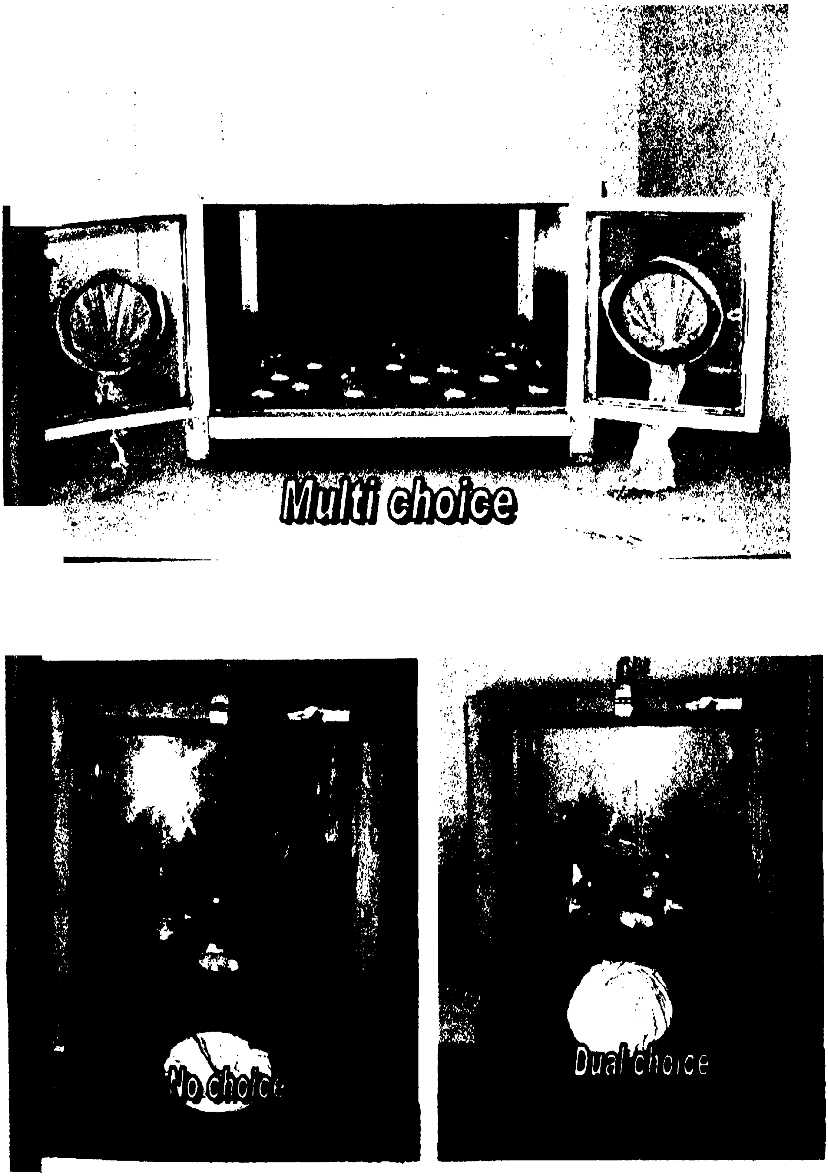


Plate 15 : **Relative oviposition preference of *H. armigera* moths towards 18 chickpea genotypes under laboratory conditions, ICRISAT, Patancheru, 2001-02**

cotton wool soaked with sucrose solution (10%) was placed in the center of each cage as a feed for adults. The chickpea plant branches offered anoviposition site were replaced every alternate day.

Five pairs of moths were released inside each cage. The eggs laid on chickpea branches were counted, removed gently with the help of camel hairbrush, and placed in a petri dish. The oviposition studies were conducted till the females continued to lay eggs.

Nonpreference for ovirposition under multi-choice conditions was studied by keeping all the 18 test genotypes (ICC 12475 (resistant check), ICC 12476, ICC 12477, ICC 12478, ICC 12479, ICC 12490, ICC 14876, ICC 4918 (susceptible check), ICC 12426, ICC 3137, ICC 12491, ICC 12492, ICC 12493, ICC 12494, ICC 12495, ICC 12968, ICC 4973 and ICC 4962) inside a wooden cage (80 x 70 x 60 cm). Conical flasks containing chickpea branches were arranged inside the wooden cage in completely randomized block design. Thirty pairs of adults were released inside the cage. Moths were provided with sucrose solution in a cotton swab. Throughout the experiment, the moths were allowed to oviposit on the test genotypes for three consecutive nights. To avoid predation by the ants, tangle foot ^{R} glue was applied to all the four legs of the wooden table. Experiment was replicated three times (Plare 15).

Relative ovipositional preference =

$$\frac{\text{No of eggs laid on standard variety x No. of eggs laid on test variety}}{\text{No of eggs laid on test variety + No. of eggs laid on standard variety}} \times 100$$

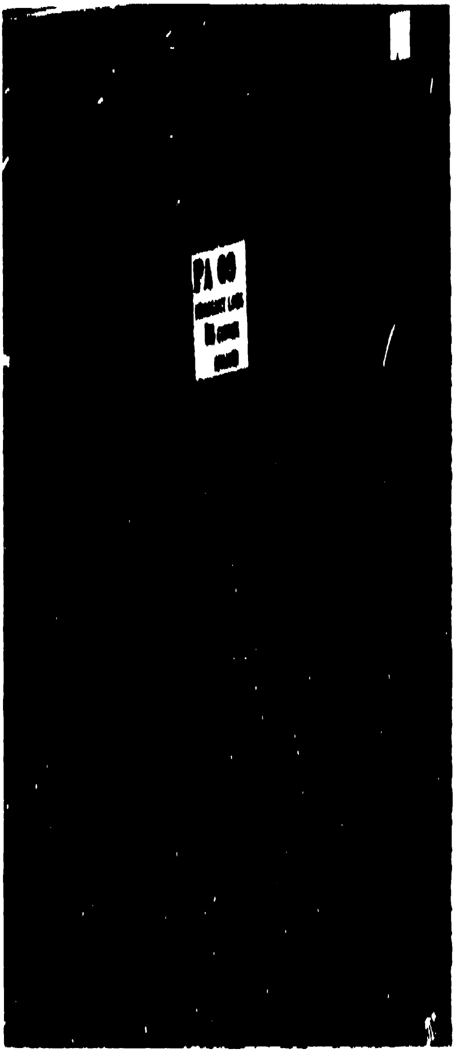
Number of eggs laid were transformed to square root values ($\sqrt{0.5 + x}$), and the data were subjected to ANOVA under no-choice and multi-choice conditions.Two tailed student "t" test was performed on the mean number of eggs laid on the test genotypes to test the null hypothesis under dual-choice conditions.

3.3.6 TOLERANCE

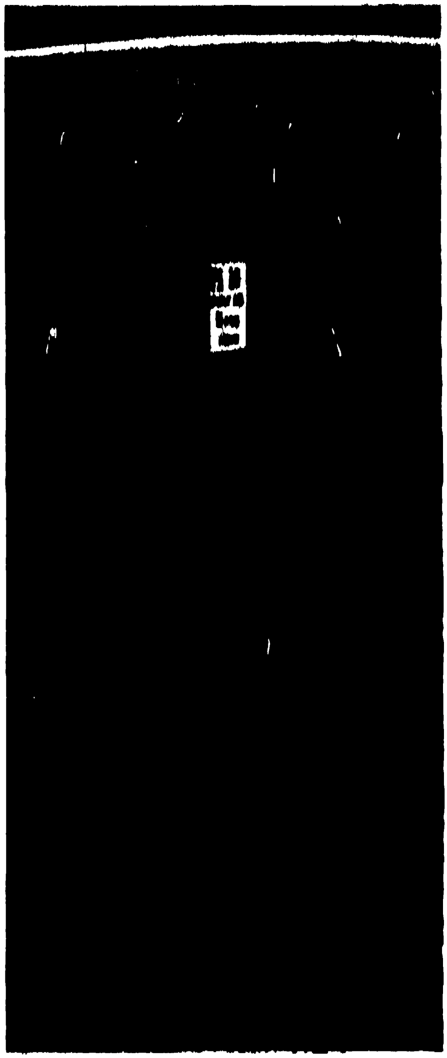
To study the tolerance component of resistance in chickpea to pod borer, *H. armigera,* field experiment was conducted at ICRISAT, Patancheru, 2001-02. The loss in yield of 18 chickpea genotypes (ICC 12475, ICC 12476, ICC 12477, ICC 12478, ICC 12479, ICC 12490, ICC 14876, ICC 4918, ICC 12426, ICC 3137,ICC12491, ICC 12492, ICC 12493, ICC 12494, ICC 12495, ICC 12968, ICC 4973 and ICC 4962) was studied by comparing the grain yield under protected and unprotected crops. The two treatments with respect to larval population and various components of yield were compared by using split plot analysis (P = 0.05). Trial was conducted with three replications, plot size was four rows of 2 m long (2.4 x 2 m) planted at 30 x 10 cm row-to-row and plant-to-plant spacing (Plate 17).

The egg and larval counts were taken during vegetative stage and continued at weekly intervals until harvest of the crop. Data were recorded for pod damage (%), yield per plant, 100 seed weight, and seeds per pod on ten tagged plants in the middle two rows. Seed yield per plot was recorded after harvest. Avoidable loss due to *H. armigera* damage was calculated (Taneja and Nawanze, 1989).

To provide protection from *H. armigera* damage insecticide application was under taken as and when needed. Egg and larval counts were recorded on 10-tagged plants in the middle two rows 1 day before, and 1 and 3 days after spraying in the protected plots, the following spray schedule was under taken.



Protected crop



Unprotected crop

Plate 16 : ***H. armigera*** **(Hub.) damage under protected and unprotected conditions in chickpea, ICRISAT, Patancheru, 2001-02.**

Table 2 : **Spray schedule in protected plots for *H. armigera* tolerance studies, ICRISAT, Patancheru, 2001-02.**

Date of Sowing of the crop: 1/11/2001.

Date of spray	Chemical	Quantity of chemica/plot	Water used /plot
21/11/2001	Acephate:Sandovit	100 mg:100ml	40 l
05/12/2001	Acephate: Sandovit	100 mg:100ml	40 l
20/12/2002	Acephate: Sandovit	100 mg:100ml	40 l
31/12/2001	Acephate	150 mg	60 l
16/01/2002	Acephate	150 mg	60 l
06/02/2002	Acephate	150 mg	60 l

Sandovit was used as adjuvant to facilitate uniform application.

Acephate 75 SP was applied @ 0.5 kg (0.37 kg a.i) in 200 l / ha during vegetative stage.

Acephate 75 SP was applied @ 0.75 kg (0.55 kg a.i) in 300 l / ha during flowering and poding stage.

Results

CHAPTER-IV

RESULTS

The laboratory, glasshouse and field studies were conducted at International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Patancheru, India, during 2000-2002, to evaluate the **"Stability, Inheritance and Mechanisms of Resistance to *Helicoverpa armigera* (Hub.) in Chickpea (*Cicer arietinum* Linn)"**. The data collected and results obtained during the study are presented in this chapter.

4.1 STABILITY OF RESISTANCE TO *H. armigera IN CHICKPEA*

4.1.2 ANALYSIS OF VARIANCE

Stability of resistance to *H. armigera* (Hub.) in chickpea (28 germplasm lines and 10 breeding lines) was evaluated under field conditions at ICRISAT, Patancheru during 2000-02. The results on stability of resistance and yield are presented.

The mean values of genotypes for different characters namely days to 50% flowering, days to maturity, seed per pod, pods per plant, 100-seed weight, yield per plant, yield kg ha^{-1}, number of eggs and larvae present during vegetative, flowering and poding stage, pod borer damage percentage, overall resistance score (ORS) and pod damage score (PDS), the analysis of variance values 'F' probability, mean, standard error of deviation (SED), least significant difference (LSD) and coefficient of variation (CV%) were given (Tables 3.1, 3.2, 4.1,4.2, 4.3, 4.4, 5.1, 5.2, 5.3, 5.4, 6.1, 6.2, 6.3 and 6.4).

During 2000 season the germplasm lines were significantly different for all the characters under study, except for number of larvae and yield per plant. Among the breeding lines, there was no significant difference among the genotype for days to 50% flowering, days to maturity, seed per pod, total number of eggs and larvae, damage percentage and yield kg ha^{-1}. Genotypes were significantly different with respect to ORS in both the plantings, while with respect to PDS were significant only during second planting. Seed yield per plant was significantly different in both the plantings.

During 2001 season among the germplasm lines the genotypes were significantly different for all the characters studied except ORS in the first planting. During second planting the genotypes were significantly different at 0.1% probability for all the characters studied and yield $plant^{-1}$ and yield kg ha^{-1} were significant at 5% and 10% probability respectively. Among the breeding lines, the genotypes were significantly different for all the characters except yield $plant^{-1}$ during first planting and total number of eggs and larvae during second planting.

4.1.3 DAYS TO 50 % FLOWERING AND DAYS TO MATURITY

The number of days to 50% flowering was less in second planting compared to first planting because of increased temperatures during late sowings i.e. in the months of December and January.

Early maturing chickpea genotypes : ICC 12968, ICC 4918, ICC 4958, ICC 10817, ICCL 86102 and ICC 12426.

Medium duration : ICC 12475, ICC 12477, ICC 12478, ICC 12479, ICC 14876 ICC 12480, ICC 12481, ICC 12482, ICC 12483, ICC 12484, ICC 12485, ICC 12491, ICC 12496, ICC 15996, ICCL 86111, ICCL 87211, ICCL 87220, ICCL ICCV 93122 87314, ICCL 87315, ICCL 87316, ICCL 87317, ICCV 95992 and ICCV 96752.

Medium-long duration : CCC 4, ICC 12476, ICC 3137, ICC 4962, ICC 4973, ICC 12486, ICC 12487, ICC 12488, ICC 12489, ICC 12490, ICC 12492, ICC 12493, ICC 12494 and ICC 12495.

Table 3.1: **Mean performance (morphological and yield traits) of selected *H. armigera* resistant chickpea germplasm lines 2000-01 rabi (first planting), ICRISAT, Patancheru.**

Genotype	Days to 50% flow.	Days to maturity	Seeds Pod^{-1}	Yield $plant^{-1}$(g)	100-seed Wt. (g)	Pods $plant^{-1}$	Yield kg ha^{-1}
ICCC 4	73	117	1.2	14.2	14.81	103.4	2171
ICC 4958	55	110	0.9	11.2	34.47	45.5	2002
ICC 10817	48	111	1.0	12.1	25.78	64.5	2174
ICC 12426	58	113	1.3	16.0	20.52	76.4	2382
ICC 12476	71	117	1.2	12.3	17.96	86.1	1700
ICC 12477	56	113	1.2	15.9	14.16	133.8	2111
ICC 12478	57	116	1.0	14.4	16.18	98.4	2133
ICC 12479	63	114	1.1	13.9	15.97	100.1	2123
ICC 12480	66	112	1.1	13.1	18.93	81.3	2595
ICC 12481	63	119	1.3	14.0	14.19	98.3	1795
ICC 12482	61	112	1.1	13.8	17.9	86.0	2229
ICC 12483	66	113	1.0	12.2	16.97	95.4	2054
ICC 12484	67	116	1.0	15.8	19.76	101.9	2194
ICC 12485	60	117	1.0	13.8	16.67	102.5	1943
ICC 12486	65	121	1.3	13.3	15.96	82.1	2044
ICC 12487	71	119	1.3	13.8	15.43	88.1	2217
ICC 12488	75	120	1.4	15.1	11.21	108.7	1732
ICC 12489	70	124	1.3	12.3	12.62	86.8	1999
ICC 12490	74	121	1.4	12.7	11.32	87.2	1652
ICC 12491	62	119	1.1	11.7	20.09	67.9	1529
ICC12492	58	125	1.3	12.1	16.26	65.7	1548
ICC 12493	75	124	1.3	11.9	14.10	75.6	1597
ICC 12495	78	125	1.1	12.7	24.22	58.6	1484
ICC 12496	58	115	1.4	12.6	20.98	65.0	1626
ICC 12968	34	108	1.1	12.3	26.87	52.9	1803
ICC 14876	64	113	1.1	13.9	14.78	102.7	2089
ICC 15996	63	114	1.4	15.1	18.16	74.9	2534
Controls							
ICCL 86111 (MR)	70	113	1.0	14.3	23.56	80.6	2625
ICC 4918 (S)	52	114	1.2	17.3	22.52	88.7	2255
ICC 12475 (R)	63	115	1.3	16.1	17.54	91.8	2385
Mean	63	116	1.2	13.7	18.33	85.0	2024
F (Prob.at 5%)	<.001	<.001	<.001	0.201	<.001	<.001	<.001
SED	4.6	2.5	0.10	1.95	1.95	12.4	230.4
LSD	9.2	4.9	0.20	3.90	3.90	24.8	461.3
CV%	8.8	2.6	8.1	17.5	13.5	17.9	13.9

MR - Moderately resistant; R-Resistant check, S-Susceptible check

Table 3.2 : **Mean performance (*Helicoverpa* pod damage scores) of selected *H. armigera* resistant chickpea germplasm lines 2000-01 rabi (first planting), ICRISAT, Patancheru.**

	Eggs plant^{-1}($\sqrt{x}$ + 0.5)				Larvae plant^{-1}($\sqrt{x}$ + 0.5)				Damage score (0-9 scale)		Pod damage (%)	
Genotype	Veg. stage	Flow. stage	Pod. stage	Total eggs	Veg. stage	Flow. stage	Pod. stage	Total larvae	ORS	PDS	Actual	Angular transformed
ICCC 4	0.71	0.71	0.71	2.12	1.26	1.84	1.97	5.07	2.7	5.7	26.08	30.67
ICC 4958	1.27	0.71	0.71	2.69	1.03	1.83	2.32	5.18	5.5	4.2	31.62	33.64
ICC 10817	0.71	0.71	0.71	2.12	1.25	1.55	1.90	4.71	4.8	2.5	21.56	27.46
ICC 12426	1.14	0.71	0.71	2.55	1.21	1.61	2.56	5.38	5.0	4.3	23.06	28.69
ICC 12476	0.73	0.71	0.71	2.14	1.20	1.77	1.92	4.89	2.3	4.5	15.18	21.99
ICC 12477	0.71	0.71	0.71	2.12	1.27	1.66	1.88	4.81	4.2	3.0	23.25	28.42
ICC 12478	0.71	0.71	0.71	2.12	1.00	1.82	2.32	5.15	2.2	4.7	10.66	18.56
ICC 12479	0.75	0.71	0.71	2.17	1.11	1.68	2.07	4.86	2.2	3.8	15.43	23.08
ICC 12480	0.73	0.71	0.71	2.14	1.35	1.82	2.38	5.55	2.0	3.3	20.99	27.23
ICC 12481	0.73	0.71	0.71	2.14	1.31	1.70	1.86	4.86	3.2	5.0	24.48	29.46
ICC 12482	0.71	0.71	0.71	2.12	1.35	1.72	2.26	5.32	2.3	4.0	22.34	28.05
ICC 12483	0.80	0.71	0.71	2.22	1.33	1.76	2.02	5.10	3.3	2.7	20.78	27.10
ICC 12484	0.71	0.71	0.71	2.12	1.22	1.57	1.94	4.73	3.3	3.3	24.68	29.62
ICC 12485	0.73	0.71	0.71	2.14	1.00	1.61	2.17	4.78	3.8	4.7	22.19	27.92
ICC 12486	0.71	0.71	0.71	2.12	1.25	1.79	2.10	5.14	3.2	5.0	16.16	23.28
ICC 12487	0.75	0.71	0.71	2.17	1.16	1.90	2.14	5.20	2.5	4.3	16.18	23.37
ICC 12488	0.73	0.71	0.71	2.15	1.02	1.64	2.21	4.88	5.8	4.7	9.80	17.41
ICC 12489	0.71	0.71	0.71	2.12	1.18	1.78	1.85	4.81	4.7	4.7	16.97	24.22
ICC 12490	0.75	0.71	0.71	2.17	1.31	1.77	1.89	4.97	2.8	4.7	13.96	20.76
ICC 12491	0.94	0.71	0.71	2.35	1.27	1.61	2.32	5.20	5.8	4.3	21.55	26.85
ICC 12492	0.87	0.71	0.71	2.28	1.20	1.86	2.02	5.08	4.8	5.7	12.78	20.47
ICC 12493	0.86	0.71	0.71	2.27	1.22	1.94	1.93	5.09	4.8	5.7	13.25	21.20
ICC 12495	0.99	0.71	0.71	2.40	1.34	2.04	2.26	5.64	6.7	6.3	10.89	18.64
ICC 12496	0.82	0.71	0.71	2.24	1.31	1.72	1.91	4.94	5.5	5.2	24.59	29.68
ICC 12968	0.76	0.71	0.71	2.17	1.20	1.65	2.39	5.23	5.2	3.5	21.01	27.28
ICC 14876	0.71	0.71	0.71	2.12	1.15	1.71	2.20	5.06	3.0	3.0	16.19	23.65
ICC 15996	0.73	0.71	0.71	2.15	1.10	1.49	2.03	4.62	3.3	5.7	22.11	27.98
Controls												
ICCL 86111 (MR)	0.71	0.71	0.71	2.12	1.24	1.86	2.19	5.29	2.3	4.3	17.06	24.05
ICC 4918 (S)	1.15	0.71	0.71	2.57	1.20	1.50	2.35	5.04	5.0	4.3	27.14	31.40
ICC 12475 (R)	0.71	0.71	0.71	2.12	0.89	1.47	1.98	4.34	2.0	3.2	14.35	22.19
Mean	0.80	0.71	0.71	2.21	1.20	1.72	2.11	5.03	3.8	4.3	19.21	25.48
F (Prob.at 5%)	<.001	NS	NS	<.001	0.08	0.73	0.62	0.47	<.001	<.001	<.001	<.001
SED	0.090			0.092	0.132	0.216	0.291	0.391	0.82	1.04	4.721	3.491
LSD	0.180			0.184	0.270	0.432	0.582	0.772	1.64	1.98	9.463	6.982
CV%	13.7			5.0	13.6	15.4	16.9	9.4	26.2	27.4	30.1	16.8

MR - Moderately Resistant; R-Resistant check; S-Susceptible check; NS - Not significant; ORS – Overall resistance score; PDS - Pod damage score.

Table 4.1: **Mean performance (morphological and yield traits) of selected *H. armigera* resistant chickpea breeding lines 2000-01 rabi (first planting), Patancheru.**

Genotype	Days to 50% flow.	Days to maturity	Seed pod^{-1}	Yield $plant^{-1}$(g)	100-seed Wt. (g)	Pods $plant^{-1}$	Yield kg ha^{-1}
ICCL 86102	56	113	1.3	18.36	19.9	96.4	2565
ICCL 87211	54	114	1.2	20.41	24.1	101.6	2340
ICCL 87220	59	114	1.0	17.17	14.7	94.3	2132
ICCL 87314	60	111	1.0	19.73	17.8	107.4	2232
ICCL 87315	58	112	1.0	18.7	16.1	99.5	2108
ICCL 87316	64	114	1.0	19.2	17.9	99.6	2361
ICCL 87317	59.	114	1.1	18.82	15.7	84.9	2278
ICCV 93122	61	116	1.1	20.27	14.3	88.4	1975
ICCV 95992	58	114	1.1	22.25	20.4	96.8	2766
ICCV 96752	65	117	1.1	17.30	17.5	100.0	2425
Controls							
ICC 4918 (S)	53	113	1.2	17.81	13.9	79.3	2180
ICC 12475 (R)	53	115	1.1	16.33	20.5	111.0	2267
Mean	58.4	114.2	1.11	18.86	17.71	10.29	2303
F (Prob.at 5%)	0.15	0.23	0.05	<.001	0.09	0.67	0.22
SED	4.8	1.9	0.09	0.98	3.08	14.55	250
LSD	9.9	3.9	0.20	2.04	6.40	30.18	519
CV%	10.0	2.0	10.4	6.4	21.3	18.4	13.0

R-Resistant check, S-Susceptible check

Table 4.2: Mean performance (*Helicoverpa* pod damage scores) of selected *H. armigera* resistant chickpea breeding lines 2000-01 rabi (first planting), ICRISAT, Patancheru.

Genotype	Eggs plant^{-1} ($\sqrt{x+0.5}$)				Larvae plant^{-1} ($\sqrt{x+0.5}$)				Pod damage score (0-9) scale		Pod damage (%)	
	Veg. stage	Flow. stage	Pod. stage	Total eggs	Veg. stage	Flow. stage	Pod. stage	Total larvae	ORS	PDS	Actual	Angular transformed
ICCL 86102	0.71	0.71	0.71	2.16	1.10	1.63	1.37	4.47	3.0	3.5	10.87	19.00
ICCL 87211	0.88	0.71	0.71	2.16	1.10	1.65	1.72	4.18	5.3	3.5	9.38	17.02
ICCL 87220	0.74	0.71	0.71	2.12	1.07	1.72	1.60	4.10	3.3	3.5	9.96	17.64
ICCL 87314	0.71	0.71	0.71	2.29	1.05	1.90	1.76	4.46	4.0	3.5	14.57	22.03
ICCL 87315	0.96	0.71	0.71	2.16	1.05	1.82	1.55	4.39	4.0	2.0	10.69	19.05
ICCL 87316	0.71	0.71	0.71	2.12	1.05	1.85	1.47	4.71	4.7	3.2	9.19	16.59
ICCL 87317	0.88	0.71	0.71	2.38	1.00	1.83	1.32	4.42	3.8	3.0	7.65	16.02
ICCV 93122	1.02	0.71	0.71	2.12	1.13	1.59	1.93	4.37	6.3	4.7	15.87	23.36
ICCV 95992	0.86	0.71	0.71	2.29	1.23	1.85	1.59	4.14	4.7	2.3	8.87	17.06
ICCV 96752	0.96	0.71	0.71	2.43	1.20	1.79	1.36	4.65	2.7	3.2	5.28	12.75
Controls												
ICC 4918 (S)	0.74	0.71	0.71	2.27	1.10	1.72	1.66	4.66	4.5	5.3	15.38	22.6
ICC 12475 (R)	0.74	0.71	0.71	2.38	1.12	1.54	1.52	4.35	2.7	2.0	5.27	13.23
Mean	0.83	0.71	0.71	2.20	1.10	1.75	1.57	4.40	4.1	3.3	10.25	18.00
F(Prob.at 5%)	0.481	NS	NS	0.891	0.922	0.142	0.432	0.09	<.001	0.181	0.370	0.322
SED	0.16			0.23	0.14	0.13	0.26	0.38	0.6	1.1	4.65	4.31
LSD	0.33			0.47	0.28	0.26	0.52	0.78	1.2	2.3	9.69	8.95
CV%	29.9			12.4	15.2	8.9	19.2	10.6	16.9	41.0	8.5	29.3

S – Susceptible check, R – Resistant check; NS - Not significant; ORS - Overall resistant score; PDS - Pod damage score.

Table 4.3: **Mean performance (morphological and yield traits) of selected *H. armigera* resistant chickpea breeding lines 2000-01 rabi (second planting), ICRISAT, Patancheru.**

Genotype	100-seed Wt. (g)	Seeds pod^{-1}	Yield $plant^{-1}$ (g)	Pods $plant^{-1}$	Yield kg ha^{-1}
ICCL 86102	15.44	1.058	14.52	89.33	2189
ICCL 87211	17.94	1.331	25.99	115.77	1613
ICCL 87220	15.51	1.397	12.71	79.67	1926
ICCL 87314	17.45	1.081	13.44	78.57	2132
ICCL87315	16.12	1.041	13.6	84.43	2130
ICCL 87316	17.29	1.045	13.26	76.7	2221
ICCL 87317	17.23	1.081	13.89	81.53	2324
ICCV 93122	18.96	1.155	11.9	60.13	2220
ICCV 95992	20.01	1.154	16.11	85.47	1895
ICCV 96752	16.07	1.117	11.36	65.87	1875
Controls					
ICC 4918 (S)	18.38	1.158	16.73	101.2	2099
ICC 12475 (R)	14.7	1.073	12.11	77.2	2044
Mean	17.09	1.041	14.63	83.0	2056
F(Prob.at 5%)	0.003	0.298	0.001	0.019	0.351
SED	1.116	0.1413	2.247	12.41	256.3
LSD	2.31	0.2931	4.661	25.75	531.5
CV%	7.2	15.2	18.8	18.3	15.3

R-Resistant check, S-Susceptible check

Table 4. 4 : Mean performance (*Helicoverpa* pod damage scores) of selected *H. armigera* resistant chickpea breeding lines 2000-01 rabi (second planting), ICRISAT, Patancheru.

Genotypes	Eggs plant^{-1} ($\sqrt{x + 0.5}$)			Larvae plant^{-1} ($\sqrt{x + 0.5}$)			Pod damage scores (0-9 Scale)		Pod damage (%)	
	Veg. Stage	Flow. stage	Total eggs	Veg. stage	Flow. stage	Total larvae	ORS	PDS	Actual	Angular transformed
ICCL86102	0.71	0.71	1.41	1.12	1.43	2.56	3.3	1.8	3.60	19.19
ICCL 87211	0.71	0.71	1.41	1.09	1.27	2.36	6.0	3.7	5.29	21.13
ICCL 87220	0.71	0.71	1.41	1.02	1.60	2.62	4.0	2.7	7.53	22.53
ICCL 87314	0.71	0.71	1.41	1.13	1.42	2.54	4.3	2.8	8.54	23.68
ICCL 87315	0.75	0.71	1.46	1.24	1.46	2.69	4.0	2.0	6.47	22.54
ICCL 87316	0.71	0.75	1.46	1.11	1.83	2.94	5.0	2.7	3.99	19.82
ICCL 87317	0.71	0.71	1.41	1.08	1.42	2.49	4.7	1.8	5.22	21.16
ICCV 93122	0.71	0.73	1.44	1.20	1.60	2.79	6.3	4.3	7.10	22.58
ICCV 95992	0.71	0.75	1.46	1.11	1.52	2.63	6.0	3.3	5.01	21.05
ICCV 96752	0.71	0.71	1.41	1.14	1.34	2.48	3.7	3.2	4.08	19.14
Controls										
ICC 4918 (S)	0.71	0.73	1.44	1.14	1.49	2.63	5.3	4.0	8.99	24.64
ICC 12475 (R)	0.71	0.71	1.41	1.12	1.22	2.34	2.8	1.8	3.36	17.7
Mean	0.72	0.72	1.40	1.12	1.47	2.50	4.6	2.9	5.76	21.2
F (Prob.at 5%)	0.48	0.66	0.74	0.51	0.41	0.40	<.001	<.001	0.31	0.228
SED	0.022	0.034	0.032	0.082	0.225	0.236	0.72	0.62	2.432	2.43
LSD	0.044	0.068	0.074	0.170	0.450	0.471	1.44	1.25	5.034	5.00
CV%	3.0	4.7	2.8	8.7	18.3	10.5	17.8	24.2	21.6	13.9

R-Resistant check, S-Susceptible check; ORS - Overall resistant scores; PDS - Pod damage score

Table 5.1: **Mean performance (morphological and yield traits) of selected *H. armigera* resistant chickpea germplasm lines 2001-02 rabi (first planting), ICRISAT, Patancheru.**

Genotype	Days to 50% flow.	Days to maturity	Seeds pod^{-1}	Yield plant^{1}(g)	100-sced Wt. (g)	Pods plant^{-1}	Yield kg ha^{-1}
ICC3137	71.3	123.3	1.1	6.5	26.7	35.7	901
ICC 4958	47.7	115.0	1.1	13.9	34.6	48.4	1468
ICC 4962	82.7	128.3	1.3	9.9	18.8	46.6	1040
ICC 4973	75.7	120.0	1.3	15.4	19.0	79.0	1573
ICC 10817	49.3	113.3	1.1	10.6	21.7	53.6	1541
ICC 12476	75.7	118.3	1.4	10.3	13.4	66.4	1701
ICC 12477	52.7	113.3	1.2	10.8	11.9	86.3	1821
ICC 12478	56.3	114.3	1.1	11.4	15.0	80.1	1732
ICC 12479	56.3	113.3	1.2	10.7	15.0	69.7	1823
ICC 12480	63.7	116.3	1.2	11.2	15.3	70.1	1668
ICC 12481	69.7	120.0	1.4	10.8	14.1	66.2	2030
ICC 12490	77.7	116.7	1.5	10.0	12.0	67.1	1561
ICC 12491	65.7	118.3	1.2	9.2	17.5	55.3	1322
ICC 12492	78.7	126.7	1.1	9.2	16.6	58.4	1405
ICC 12493	76.7	128.3	1.3	9.5	15.3	58.4	1558
ICC 12494	77.7	120.0	1.3	10.6	21.0	50.7	1395
ICC 12495	75.7	121.7	1.2	10.3	23.0	46.7	1372
ICC 12496	58.0	115.0	1.5	11.1	19.6	57.2	1348
Controls							
ICC 4918 (S)	46.3	111.7	1.2	10.9	21.1	62.5	1550
ICC 12475 (R)	51.3	111.0	1.2	12.9	15.9	76.8	2145
Mean	65.4	118.3	1.2	10.8	18.4	61.8	1548
F (Prob.at 5%)	<.001	<.001	<.001	<.001	<.001	<.001	<.001
SED	5.12	4.01	0.056	1.62	1.74	8.61	169.5
LSD	10.25	8.02	0.12	3.33	3.40	17.41	343.2
CV%	9.5	4.1	4.3	18.6	5.1	17.1	13.4

R-Resistant check, S-Susceptible check

Table 5.2 : **Mean performance (*Helicoverpa* pod damage scores) of selected *H. armigera* resistant chickpea germplasm lines 2001-02 rabi (first planting), ICRISAT, Patancheru.**

Genotype	Eggs plant^{-1}($\sqrt{x+0.5}$)				Larvae plant^{-1}($\sqrt{x+0.5}$)				Damage scores (0-9) scale		Pod damage (%)	
	Veg. stage	Flow. stage	Pod. stage	Total eggs	Veg. stage	Flow. stage	Pod. stage	Total larvae	ORS	PDS	Actual	Angular transformed
ICC 3137	1.34	1.32	0.83	3.48	1.32	1.39	1.59	4.30	7.3	7.3	37.31	37.61
ICC 4958	1.07	1.31	0.73	3.12	1.22	1.47	1.33	4.02	5.2	4.7	23.41	28.89
ICC 4962	1.21	1.14	0.81	3.16	1.39	1.68	1.59	4.66	6.3	7.3	15.89	23.28
ICC 4973	1.23	0.98	0.85	3.06	1.25	1.38	1.28	3.90	5.8	6.3	16.68	24.11
ICC 10817	0.81	0.92	0.77	2.49	1.16	1.37	0.90	3.43	3.2	4.5	15.16	22.9
ICC 12476	0.95	0.77	0.71	2.42	0.95	1.34	1.13	3.42	3.5	4.7	13.64	21.46
ICC 12477	0.75	0.71	0.71	2.17	0.98	1.08	1.02	3.08	3.3	3.0	11.88	20.12
ICC 12478	0.73	0.90	0.98	2.61	1.21	1.33	1.15	3.70	3.0	3.3	12.23	20.4
ICC 12479	0.77	0.74	0.77	2.28	0.95	1.17	0.99	3.11	2.8	3.3	11.83	20.05
ICC 12480	0.86	0.88	0.71	2.45	1.04	1.18	1.19	3.42	3.8	3.3	14.63	22.33
ICC 12481	1.07	1.01	0.75	2.83	1.03	1.17	1.12	3.32	3.7	4.0	18.77	25.64
ICC 12490	1.02	1.02	0.95	2.98	1.09	1.16	1.35	3.61	5.2	5.0	13.17	21.22
ICC 12491	0.89	1.02	0.80	2.71	1.14	1.24	1.23	3.62	5.0	5.2	22.41	28.25
ICC 12492	1.10	1.07	0.84	3.01	1.26	1.05	1.28	3.59	3.5	5.0	15.17	22.91
ICC 12493	1.15	1.29	1.06	3.49	1.15	1.16	1.16	3.48	3.3	6.0	14.87	22.43
ICC 12494	1.33	1.16	0.73	3.21	1.13	1.40	1.20	3.73	5.7	7.3	19.23	25.98
ICC 12495	1.18	1.30	0.75	3.24	1.14	1.41	1.11	3.66	4.8	7.3	17.84	24.98
ICC 12496	0.97	1.08	1.00	3.05	1.05	1.51	1.32	3.87	5.8	5.5	28.47	32.09
Controls												
ICC 4918 (S)	1.32	1.22	0.85	3.40	1.40	1.40	1.21	4.02	5.3	5.3	29.86	33.11
ICC 12475 (R)	0.97	0.92	0.71	2.59	0.99	0.94	1.11	3.04	2.2	2.0	8.51	16.47
Mean	1.04	1.04	0.81	2.89	1.14	1.29	1.21	3.65	5.3	5.0	18.05	24.7
F(prob. at 5%)	<.001	<.001	0.08	<.001	0.08	<.001	0.06	<.001	0.02	<.001	<.001	<.001
SED	0.173	0.167	0.116	0.309	0.155	0.168	0.185	0.311	5.22	0.81	3.191	2.47
LSD	0.350	0.332	0.231	0.691	0.309	0.331	0.370	0.633	10.63	1.62	6.475	5.00
CV%	20.6	19.2	17.2	12.9	15.9	15.6	18.2	10.5	121.2	19.0	21.7	12.3

R-Resistant check, S-Susceptible check

Table 5.3: **Mean performance (morphological and yield traits) of selected *H. armigera* resistant chickpea germplasm lines 2001-02 rabi (second planting), ICRISAT, Patancheru.**

Genotype	Days to 50% flow.	Days to maturity	Seeds pod^{-1}	Yield $plant^{-1}$ (g)	100-seed Wt. (g)	Pods $plant^{-1}$	Yield kg ha^{-1}
ICC 3137	57	115	1.11	9.48	23.81	49.73	1350
ICC 4958	56	100	1.02	11.50	30.49	43.77	1555
ICC 4962	68	101	1.41	11.36	18.10	51.33	1558
ICC 4973	59	116	1.20	12.06	18.13	68.93	1954
ICC 10817	50	105	1.03	8.73	21.08	48.10	1288
ICC 12476	62	113	1.21	9.55	13.74	67.87	1613
ICC 12477	55	95	1.16	12.20	11.28	101.83	1723
ICC 12478	53	98	1.06	9.46	12.77	74.17	1384
ICC 12479	53	101	1.10	10.32	12.25	80.70	1551
ICC 12480	54	108	1.27	10.45	15.21	64.27	1848
ICC 12481	59	115	1.32	10.92	13.86	69.17	1985
ICC 12490	60	113	1.37	10.48	11.23	78.57	1734
ICC 12491	56	106	1.25	10.95	16.95	66.03	1332
ICC 12492	59	118	1.17	9.82	16.85	56.67	1542
ICC 12493	58	113	1.31	13.45	22.77	60.87	1791
ICC 12494	60	113	1.32	10.87	16.14	66.40	1582
ICC 12495	55	121	1.10	11.90	21.86	55.33	1601
ICC 12496	53	103	1.30	10.73	17.16	60.33	1515
Controls							
ICC 4918(S)	52	98	1.16	13.10	19.10	72.87	1779
ICC 12475(R)	52	101	1.18	9.65	13.59	64.30	1592
Mean	56	108	1.20	10.85	17.32	65.10	1614
F (Prob.at 5%)	<.001	<.001	<.001	0.47	<.001	<.001	0.07
SED	2.6	6.2	0.046	17.63	2.64	7.20	208.5
LSD	5.3	12.6	0.091	3.56	5.35	14.57	422.2
CV%	5.7	7.1	4.3	19.9	18.7	13.5	15.8

R-Resistant check, S-Susceptible check

Table 5.4: **Mean performance (*Helocoverpa* pod damage scores) of selected *H. armigera* resistant chickpea germplasm lines 2001-02 rabi (second planting), ICRISAT, Patancheru.**

	Eggs plant^{-1} ($\sqrt{x+0.5}$)				Larvae plant^{-1} ($\sqrt{x+0.5}$)				Damage scores (0-9 scale)		Pod damage (%)	
Genotype	Veg. stage	Flow. stage	Pod. stage	Total eggs	Veg. stage	Flow. stage	Pod. stage	Total larvae	ORS	PDS	Actual	Angular transformed
ICC 3137	1.33	1.40	0.71	5.00	1.77	1.78	1.46	3.43	5.00	7.67	30.08	33.24
ICC 4958	1.20	1.14	0.79	3.99	1.62	1.33	1.04	3.12	4.67	3.50	14.52	22.07
ICC 4962	1.26	1.31	0.77	4.96	1.66	1.74	1.56	3.35	5.33	6.00	11.56	19.81
ICC 4973	1.00	1.13	0.71	4.00	1.44	1.33	1.24	2.84	4.00	6.00	18.26	25.29
ICC 10817	1.07	0.97	0.71	3.65	1.41	1.32	0.92	2.74	5.33	5.00	15.11	21.88
ICC 12476	0.79	0.94	0.71	3.64	1.37	1.36	0.91	2.44	3.33	3.33	12.53	20.69
ICC 12477	0.85	0.90	0.84	3.32	1.24	1.12	0.96	2.59	2.67	3.33	7.36	15.43
ICC 12478	0.87	0.81	0.71	3.15	1.24	1.03	0.88	2.38	3.00	2.00	6.43	14.46
ICC 12479	0.73	1.00	0.77	3.17	1.17	1.09	0.91	2.51	3.33	2.83	5.13	12.9
ICC 12480	1.05	0.97	0.71	4.01	1.41	1.34	1.26	2.73	4.33	4.00	16.61	23.87
ICC 12481	0.94	1.02	0.71	4.10	1.46	1.46	1.18	2.67	3.33	3.67	13.54	21.39
ICC 12490	0.83	0.87	0.73	3.73	1.22	1.49	1.02	2.43	3.50	4.67	12.51	20.63
ICC 12491	1.14	1.05	0.73	3.71	1.41	1.34	0.95	2.92	5.33	5.50	20.27	26.61
ICC 12492	1.25	0.97	0.73	3.81	1.30	1.46	1.06	2.95	4.00	5.33	11.34	19.47
ICC 12493	1.49	1.15	0.71	3.90	1.31	1.44	1.15	3.35	3.67	3.83	11.67	19.37
ICC 12494	1.06	1.14	0.77	4.25	1.43	1.48	1.34	2.96	5.67	7.67	22.06	27.95
ICC 12495	1.32	1.02	0.71	4.12	1.30	1.64	1.18	3.05	5.00	6.00	8.43	16.65
ICC 12496	1.20	0.93	0.73	3.78	1.28	1.29	1.21	2.86	7.00	5.67	17.74	24.78
Controls												
ICC 4918 (S)	1.21	1.30	0.71	3.78	1.41	1.33	1.05	3.22	5.33	5.50	17.26	24.51
ICC 12475 (R)	0.79	0.79	0.71	2.52	0.96	0.83	0.73	2.29	1.67	2.33	6.80	14.14
Mean	0.07	1.04	0.73	3.80	1.37	1.36	1.10	2.80	4.28	4.69	13.96	21.6
F(Prob.at 5%)	0.00	0.10	0.64	0.00	0.05	<.001	<.001	0.00	<.001	<.001	<.001	<.001
SED	0.181	0.186	0.061	0.35	0.191	0.166	0.149	0.284	0.771	0.711	3.652	3.151
LSD	0.359	0.370	0.119	.7.05	0.382	0.331	0.292	0.569	1.572	1.432	7.345	6.375
CV%	20.1	21.5	9.4	13.8	16.8	14.8	16.0	12.0	22.2	18.5	32.0	18.1

R-Resistant check, S-Susceptible check, ORS - Overall resistant score; PDS - Pod damage score.

Table 6.1: **Mean performance (morphological and yield traits) of selected *H. armigera* resistant chickpea germplasm lines 2001-02 rabi (first planting), ICRISAT, Patancheru.**

Genotype	Days to 50% flow.	Days to maturity	Seeds pod^{-1}	Yield plant^{-1} (g)	100-seed Wt. (g)	Pods plant^{-1}	Yield kg ha^{-1}
ICCC 4	74	105	.16	13.81	13.06	115.57	1683
ICC 12426	51	91	.46	15.18	17.93	72.17	1827
ICC 12482	58	96	.19	13.81	15.25	87.17	2283
ICC 12483	61	95	.10	15.88	14.35	116.43	1865
ICC 12484	63	95	.12	13.25	16.32	90.20	2044
ICC 12485	60	97	.11	12.47	14.07	97.13	1651
ICC 12486	76	104	.43	10.00	14.52	58.70	1808
ICC 12487	75	105	.33	15.17	13.71	103.10	1761
ICC 12488	78	106	.37	10.30	10.96	83.67	1490
ICC 12489	76	105	.43	10.64	10.71	82.10	1637
ICC 12968	34	80	.09	9.65	21.04	51.60	1167
ICC 14876	55	96	.10	11.53	13.36	88.50	1729
ICC 15996	62	97	.46	14.96	16.43	82.83	2348
ICCL 86102	50	85	.03	12.75	14.72	89.53	1964
ICCL 87211	46	93	.34	13.27	20.26	68.37	1725
ICCL 87220	52	91	.08	14.19	14.92	102.27	2121
ICCL 87314	63	96	.15	15.39	16.46	96.07	2264
ICCL 87315	64	94	.11	13.73	16.77	86.80	2115
ICCL 87316	67	97	.12	13.92	18.01	83.97	2156
ICCL 87317	69	101	.21	11.77	15.05	74.43	2094
ICCV93122	60	98	.14	12.52	18.30	78.27	1423
ICCV 95992	51	93	.11	14.18	19.42	78.23	2313
ICCV 96752	59	99	.15	12.69	14.90	84.97	1527
Controls							
ICCL 86111 (MR)	61	96	.03	20.71	18.57	89.99	2187
ICC 4918 (S)	50	90	.19	12.13	17.16	79.07	1662
ICC 12475 (R)	51	91	.09	13.31	15.93	83.20	2070
Mean	60	96	1.20	13.35	15.85	85.6	1981
F(Prob.at 5%)	<.001	<.001	<0.001	0.74	<.001	0.04	<.001
SED	3.2	4.9	0.042	3.608	0.702	15.56	205.4
LSD	6.5	9.5	0.084	7.235	1.415	31.25	412.5
CV%	6.1	5.6	4.2	33.0	5.4	22.3	13.4

MR – Moderately resistant, R-Resistant check, S-Susceptible check

Table 6.2 : **Mean performance (*Helicoverpa* pod damage scores) of selected *H. armigera* resistant chickpea breeding lines 2001-02 rabi (first planting), ICRISAT, Patancheru.**

	Eggs plant^{-1} ($\sqrt{x+0.5}$)				Larvae plant^{-1} ($\sqrt{x+0.5}$)				Damage scores (0-9 scale)		Pod damage (%	
Genotype	Veg. stage	Flow. stage	Pod. stage	Total eggs	Veg. stage	Flow. stage	Pod. stage	Total larvae	ORS	PDS	Actual	AT*
ICCC 4	0.91	1.00	0.93	2.93	1.56	1.60	1.25	4.41	5.1	7.3	18.27	25.29
ICC12426	1.15	1.23	0.85	3.28	1.37	1.65	1.02	4.19	4.0	5.6	20.16	26.63
ICC12482	0.89	0.93	0.71	3.31	1.24	1.63	0.98	4.02	3.3	3.6	12.81	20.93
ICC 12483	1.19	1.05	0.71	2.25	1.36	0.99	0.96	3.19	2.5	3.5	14.00	21.87
ICC 12484	1.11	0.99	0.71	2.56	1.18	1.28	1.12	3.50	3.3	4.5	17.58	24.56
ICC 12485	0.96	1.06	0.71	2.80	1.39	1.35	0.93	3.68	4.6	5.0	16.66	24.09
ICC 12486	1.16	1.30	0.71	2.69	1.59	1.58	1.04	3.88	4.8	4.8	17.57	24.71
ICC 12487	1.04	1.17	0.71	2.83	1.36	1.47	1.04	3.79	3.6	5.8	19.77	26.16
ICC 12488	1.11	1.21	0.71	3.31	1.34	1.42	1.26	4.05	4.0	6.3	18.53	25.26
ICC 12489	1.26	1.18	0.71	3.05	1.26	1.35	1.12	3.75	4.6	6.3	14.28	22.18
ICC 12968	1.04	1.22	0.71	3.12	1.41	1.56	0.97	4.17	7.0	5.5	17.66	24.6
ICC 14876	0.94	0.97	0.71	3.07	1.40	1.38	0.79	3.76	3.3	4.3	10.72	18.77
ICC 15996	0.91	1.09	0.73	3.14	1.36	2.08	0.85	4.46	4.6	5.6	24.37	29.47
ICCL 86102	1.07	1.24	0.71	2.65	1.30	1.27	0.79	3.45	2.6	2.1	6.49	14.51
ICCL 86111	1.01	1.16	0.71	2.90	1.25	1.37	1.09	3.59	4.6	4.0	19.71	26.21
ICCL 87211	1.05	0.91	0.98	3.19	1.59	1.11	1.03	3.20	5.6	7.6	19.99	33.16
ICCL 87220	1.12	0.89	0.71	3.04	1.38	1.50	0.96	3.84	3.6	4.3	13.13	21.22
ICCL 87314	0.96	1.08	0.71	2.80	1.29	1.50	0.84	4.12	2.5	3.0	14.70	22.52
ICCL 87315	1.09	0.89	0.71	2.49	1.39	1.32	0.82	3.66	3.0	3.1	15.66	23.27
ICCL 87316	1.02	1.13	0.73	2.86	1.24	1.09	1.00	3.22	2.5	3.3	11.84	19.61
ICCL 87317	1.11	1.26	0.71	2.49	1.48	1.21	1.00	3.42	2.3	3.1	13.48	21.3
ICCV 93122	0.94	1.29	0.71	2.98	1.62	1.34	1.01	3.57	5.7	6.8	23.68	28.9
ICCV 95992	0.97	1.07	0.71	3.22	1.64	1.20	1.00	3.67	3.3	3.3	14.45	22.29
ICCV 96752	1.16	1.12	0.75	3.28	1.44	1.70	1.03	4.33	2.8	4.3	11.85	20.00
ICC 4918 (S)	1.25	1.29	0.71	2.85	1.55	1.69	0.99	4.33	5.0	5.3	23.09	28.63
ICC 12475 (R)	0.96	0.77	0.71	2.99	1.25	1.32	0.95	3.79	1.5	2.50	8.24	16.65
Mean	1.05	1.10	0.74	2.29	1.39	1.42	0.99	3.81	3.87	4.68	16.49	23.50
F(Prob.at 5%)	0.44	0.03	0.11	0.05	0.14	<.001	0.19	0.002	<.001	<.001	<.001	<.001
SED	0.15	0.15	0.08	0.30	0.16	0.17	0.16	0.30	0.76	0.84	3.78	2.92
LSD	0.29	0.30	0.17	0.61	0.31	0.35	0.31	0.60	1.53	1.69	7.59	5.86
CV%	17.0	16.5	13.7	12.7	13.6	15.0	13.6	9.6	24.2	22.0	28.1	15.2

R-Resistant check, S-Susceptible check; ORS - Overall resistant scores; PDS - Pod damage score, AT*-Angular transformed.

Table 6.3 : **Mean performance (morphological and yield traits) of selected *H. armigera* resistant chickpea breeding lines 2001-02 rabi (second planting), ICRISAT, Pataancheru.**

Genotype	Days to 50% flow.	Days to maturity	Seeds pod^{-1}	100-seed Wt. (g)	Yield $plant^{-1}$(g)	Pods $Plant^{-1}$	Yield kg ha^{-1}
ICCC 4	57	108.	1.129	12.97	11.33	87	1914
ICC 12426	56	108	1.396	16.35	12:98	60	1869
ICC 12482	53	101	1.183	18.69	12.83	83	1888
ICC 12483	55	101	1.042	14.40	11.11	82	1805
ICC 12484	55	108	1.049	14.74	12.87	84	2134
ICC 12485	57	108	1.093	13.13	11.46	86	1749
ICC 12486	62	111	1.327	17.11	9.49	58	1820
ICC 12487	59	106	1.356	13.86	11.67	77	1831
ICC 12488	64	116	1.320	14.46	8.98	71	1714
ICC 12489	64	111	1.412	12.35	9.49	70	1416
ICC 12968	34	107	1.089	10.62	8.77	44	1392
ICC 14876	54	96	1.064	10.64	11.06	87	1862
ICC 15996	55	101	1.532	23.10	13.91	66	2342
ICCL 86102	54	98	1.133	12.45	13.22	86	2105
ICCL 87211	54	100	1.421	14.54	12.41	61	1735
ICCL 87220	56	95	1.190	18.12	13.42	87	2054
ICCL 87314	60	105	1.059	17.47	11.74	72	2158
ICCL 87315	58	98	1.088	14.63	13.77	86	2267
ICCL87316	58	103	1.135	17.69	15.69	88	2399
ICCL 87317	57	101	1.189	16.62	12.82	75	2195
ICCV 93122	56	108	1.146	17.07	10.84	62	1681
ICCV 95992	53	98	1.092	15.97	12.27	68	2191
ICCV 96752	62	115	1.125	18.13	11.85	75	1567
Controls							
ICCL 86111 (MR)	53	98	0.998	16.51	10.05	63	1813
ICC 4918 (S)	52	98	1.210	18.09	13.09	79	2031
ICC 12475 (R)	54	96	1.150	15.24	11.97	75	2168
Mean	56.1	104.1	1.189	15.57	11.89	74.8	1927
F(Prob.at 5%)	<.001	<.001	<.001	<.001	<.001	<.001	<.001
SED	1.91	2.84	0.039	0.657	1.26	7.2	181.2
LSD	3.85	5.71	0.079	1.313	2.53	14.5	363.9
CV%	4.2	3.3	4.1	5.2	13	11.8	11.5

MR – Moderately resistant, R-Resistant check, S-Susceptible check

Table 6.4 : Mean performance (*Helcoverpa* pod damage scores) of selected *H. armigera* resistant chickpea breeding lines 2001-02 rabi (second planting), ICRISAT, Patancheru.

	Eggs plant^{-1} ($\sqrt{x + 0.5}$)				Larvae plant^{-1} ($\sqrt{x + 0.5}$)				Damage scores (0-9 Scale)		Pod damage (%)	
Genotype	Veg. stage	Flow. stage	Pod. stage	Total eggs	Veg. stage	Flow. stage	Pod. stage	Total larvae	ORS	PDS	Actual	Angular transformed
ICCC 4	1.16	1.07	0.73	2.96	1.39	1.57	1.11	4.07	5.5	6.6	12.69	20.71
ICC 12426	0.97	0.87	0.71	2.54	1.20	1.09	1.11	3.40	5.1	4.5	17.08	24.08
ICC 12482	1.37	1.12	0.71	3.20	1.57	1.47	1.09	4.14	4.3	3.6	11.61	19.60
ICC 12483	1.17	0.93	0.71	2.81	1.38	1.13	1.01	3.51	3.6	2.6	3.81	11.13
ICC 12484	1.10	0.89	0.71	2.69	1.27	1.39	1.03	3.68	3.0	4.6	14.88	22.56
ICC 12485	0.91	0.75	0.71	2.37	1.47	1.29	1.02	3.77	4.3	4.6	11.22	19.57
ICC 12486	0.80	0.83	0.73	2.36	1.39	1.26	1.09	3.75	4.3	4.3	15.29	22.88
ICC 12487	0.83	0.81	0.71	2.35	1.37	1.27	0.95	3.59	4.3	5.1	6.57	14.73
ICC 12488	0.97	0.92	0.83	2.73	1.29	1.37	0.91	3.57	4.0	5.6	11.40	19.71
ICC 12489	1.02	0.77	0.71	2.50	1.19	1.18	1.01	3.38	3.8	4.3	10.21	18.57
ICC 12968	1.05	0.84	0.75	2.65	1.21	1.03	0.97	3.21	5.0	5.1	19.12	25.91
ICC 14876	1.06	0.99	0.71	2.76	1.31	1.15	0.93	3.39	2.6	2.6	5.39	13.38
ICC15996	1.04	0.89	0.71	2.63	1.45	1.40	1.11	3.95	2.6	4.0	14.78	22.60
ICCL 86102	1.27	0.87	0.71	2.85	1.51	1.58	1.20	4.29	2.1	1.3	6.89	14.62
ICCL 87211	1.13	0.90	0.71	2.74	1.29	1.22	1.06	3.57	3.6	4.0	16.10	23.53
ICCL 87220	0.89	0.91	0.71	2.51	1.28	1.27	1.08	3.63	2.0	3.0	10.79	18.89
ICCL 87314	0.94	0.89	0.71	2.54	1.31	1.45	1.13	3.89	2.1	2.3	11.70	19.94
ICCL 87315	1.16	0.87	0.71	2.74	1.34	1.25	1.04	3.63	2.1	2.6	11.33	19.62
ICCL 87316	1.34	0.83	0.71	2.87	1.29	1.34	1.01	3.64	3.0	2.6	8.39	16.63
ICCL 87317	1.04	1.05	0.75	2.85	1.43	1.32	1.15	3.90	2.1	1.8	9.98	17.29
ICCV 93122	1.18	1.04	0.71	2.93	1.33	1.33	1.04	3.70	4.8	5.0	15.20	22.73
ICCV 95992	1.09	0.87	0.71	2.67	1.34	1.27	1.16	3.77	4.0	2.3	9.72	17.90
ICCV 96752	0.90	1.15	0.75	2.81	1.38	1.29	0.95	3.62	3.3	3.6	6.38	14.60
Controls												
ICCL 86111 (MR)	1.07	1.00	0.71	2.78	1.40	1.40	1.00	3.79	3.3	3.3	11.69	19.77
ICC4918 (S)	1.04	1.00	0.81	2.86	1.47	1.25	1.11	3.83	4.5	4.0	13.90	21.74
ICC 12475 (R)	1.16	1.02	0.71	2.89	1.54	1.34	1.04	3.91	1.3	2.0	4.05	11.08
Mean	1.06	0.93	0.72	2.71	1.36	1.30	1.05	3.71	3.51	3.67	11.16	18.99
F(Prob.at 5%)	0.82	0.75	0.69	0.54	0.77	0.22	0.87	0.38	<.001	<.001	<.001	<.001
SED	0.24	0.17	0.05	0.29	0.16	0.16	0.13	0.33	0.70	0.62	3.01	2.80
LSD	0.48	0.34	0.10	0.59	0.33	0.33	0.27	0.67	1.40	1.22	6.05	5.60
CV%	27.7	22.1	8.8	13.2	14.7	15.3	15.4	11.0	24.4	20.9	33.1	18.0

MR – Moderately resistant, R-Resistant check, S-Susceptible check; ORS - Overall resistant score; PDS - Pod damage score

4.1.4 POD BORER RESISTANCE CHARACTERS

4.1.4.1 Eggs and larvae

During 2000 season germplasm lines were significantly different for egg number during vegetative stage and lowest number of eggs were recorded on ICCC 4, ICC 10817, ICC 12477, ICC 12478, ICC 12482, ICC 12484, ICC 12486, ICC 12489 and ICC 14876 along with resistant check ICC 12475. The breeding lines did not significantly differ for number of eggs and larvae.

During 2001 season among germplasm lines lowest number of eggs and larvae were recorded on ICC 12477, ICC 12479, ICC 12476, ICC 12480 and ICC 10817 which were on par with resistant check ICC 12475. Among the breeding lines lowest egg and larval counts were recorded on ICC 12483, ICC 12484, ICCL 87315 and ICCL 87317 along with resistant check ICC 12475.

4.1.4.2 Over all resitance (ORS) and pod damage (PDS) scores

During 2000 season, among the germplasm lines lowest ORS was recorded in resistant check ICC 12475 followed by ICC 12478, ICC 12479 and ICC 12490. Lowest PDS was recorded in ICCL 10817 followed by ICC 12483, ICC 12477, ICC 14876 and ICC 12475. Among the breeding lines lowest ORS was recorded in ICC 12475 followed by ICCV 96752, ICCL 87220 during first planting. During second planting ICCL 86102 and ICCV 96752 recorded lowest ORS and PDS along with ICC 12475. Mean ORS was greater than mean PDS. During 2001 season among the germplasm lines ICCL 12477, ICC 12478, ICC 12479 and ICC 12480 were on par with resistant check ICC 12475. Among the breeding lines ICCL 86102, ICCL 87314 and ICCL 87317 recorded less ORS and PDS along with resistant check ICC 12475.

4.1.4.3 Pod borer damage (%)

During 2000 season among germplasm lines low pod borer damage was recorded in ICC 12488 (9.8%), ICC 12478 (10.7%), ICC 12495 (10.9%), ICC 12492 (12.8%), ICC 12493 (13.3%) and ICC 12490 (14.0%) which were on par with resistant check ICC 12475 (14.4). Among the breeding lines ICCV 96752 (5.3%) and resistant check ICC 12475 (5.3%) recorded least damage.

During 2001 season first planting, among the germplasm lines least pod borer damage was recorded in the resistant check ICC 12475 (8.5%) followed by ICC 12479 (11.8%), ICC 12477 (11.9%) and ICC 12478 (12.2%). In the second planting least damage was in ICC 12479 (5.1%), followed by ICC 12478 (6.4%), ICC 12475 (6.8%) and ICC 12476 (7.4%) which were on par with each other. Among the breeding lines the damage percentages of ICCL 86102 (6.9%), ICCL 87316 (11.8%) and ICCV 96752 (11.8%) were on par with resistant check ICC 12475 (8.2%) during first planting, and ICC 12483 (3.8%), ICC 14876 (5.4%) and ICCV 96752 (6.4%) were on par with ICC 12475 (4.1%) during second planting.

4.1.5 YIELD AND ITS COMPONENTS

4.1.5.1 100-seed weight

Among all the genotypes ICC 4958, ICC 10817, ICC 12495, ICC 12968, ICCL 86111, ICCV 95992, ICC 3137, ICC 12494, ICC 12493 and ICCL 87211 were bold seeded (33 to 17 g/100 seed).

5.1.5.2 Seeds per pod

ICC 12488, ICC 12490, ICC 12496, ICC 15996, ICC 12476, ICC 12481, ICC 4962, ICC 12426, ICCL 87211, ICC 12486 and ICC 12489 recorded $\geq$1.4 seeds/pod, while the trial mean was 1.2 seeds/pod.

4.1.5.3 Yield per plant

Highest yield plant^{-1} was recorded in ICC 4918, ICC 12475, ICC 12426, ICC 12484 and ICC 15996 during 2000 season and were on par with each other. Among breeding lines ICCL 87211, ICC 12475, ICCV 95992 and ICC 4918 recorded high yields.

During 2001 season ICC 4973, ICC 4958 and resistant check ICC 12475 recorded high yields and were on par with each other in the first planting and in second planting ICC 12493, ICC 4918, ICC 12477 and ICC 4973 recorded high yields. Highest yied during both the plantings was recorded in ICC 4973. Among breeding lines ICCL 86111, ICC 12483, ICC 12426 and ICC 12487 recorded highest yields plant^{-1} and were on par with each other in first planting, and during second planting ICCL 87316, ICC 15996, ICCL 87315 and ICCL 87220 out yielded resistant check ICC 12475 and were on par with each other.

4.1.5.4 Yield kg ha^{-1}

During 2000 season ICCL 86111, ICC 12480 and ICC 15996 out yielded resistant check ICC 12475 but were statistically not different. Among the breeding lines the genotypes were not significantly different from each other. Many genotypes recorded higher yields than resistant check ICC 12475, but were not statistically different.

During 2001 season among germplasm lines ICC 12475, ICC 12481 and ICC 12479 recorded significantly high yields in first planting and in second planting ICC 12481 and ICC 4973 recorded high yields. ICC 12481 and ICC 4973 recorded high yields. Many breeding lines out yielded resistant check ICC 12475. ICC 15996, ICCV 95992, ICCL 87315 and ICCL 87316 recorded significantly high yields during both the plantings, but were on par with resistant check ICC 12475.

4.1.6 STABILITY PARAMETERS

Stability statistics for yield components and pod borer resistance were analyzed and results were presented in Tables 7.1, 7.2, 7.3 and 7.4 for germplasm lines and 8.1, 8.2, 8.3 and 8.4 for breeding lines.

4.1.6.1 Seeds per pod and 100 seed weight

The G x E interaction was not significant for seeds per pod and 100-seed weight. Seeds per pod were more in ICC 4918, ICCL 87211 and ICCL 87220. In ICCL 87211 "b" was significantly greater than 1. Among the breeding line 100-seed weight varied from 15.3 gm (ICCL 87317) to 19.3 gm (ICCL 86102). Among the germplasm lines 100 seed weight varied from 11 (ICC 12488 and ICC 12489) to3 33g (ICC 14958).

4.1.6.2 Seed yield per plant

Seed yield plant^{-1} was significantly different due to genotype (G), environment (E) and genotype x environment (G x E) interaction among breeding lines, but was not significant in germplasm lines. Among the breeding lines stable and high plant yield was recorded in ICCV 95992 with slope "b" equal to 1 and residual mean squares "δi^2" equal to zero indicating that it was highly stable in its performance. ICCL 87211 recorded highest yield, but was not stable (with high `δi^2' value and 'b' significantly greater than 1) indicating its adaptation to high yielding environments.

Among the 28 accessions tested for three seasons, highest yields were recorded in ICC 15996, ICCL 86111 and ICC 12426. ICC 15996 and ICC 12426 were stable with unit slope and low `$\delta i^2$', but ICCL 86111 with high `δi^2' was unstable.

Table 7. 1: **Mean pod borer damage (%) and estimates of stability parameters for 28 chickpea germplasm lines tested for three seasons (2000-02), ICRISAT, Patancheru.**

	Pod borer damage (%)					Pod borer damage (Angular transformed)				
Genotype	Mean	bi	SEbi	δi^2	t value)	Mean	bi	SEbi	δi^2	t (value)
ICCC 4	19.0	1.715	0.5949	10	1.202	25.6	1.533	0.5166	5	1.03
ICC 4958	23.2	2.255	0.4927	7	2.547	28.5	1.902	0.3992	3	2.26
ICC 10817	17.3	0.729	0.6860	13	-0.395	24.5	0.640	0.6391	8	-0.56
ICC 12426	20.1	0.787	0.1767	1	-1.203	26.6	0.685	0.1638	0	-1.92
ICC 12476	13.8	0.340	0.1169	0	-5.650	21.8	0.340	0.1244	0	-5.3
ICC 12477	14.2	1.958	1.0243	29	0.935	21.6	1.965	0.9573	17	1.01
ICC 12478	9.8	0.690	0.4234	5	-0.732	18.1	0.872	0.4675	4	-0.27
ICC 12479	10.8	1.408	0.0931	0	4.380	18.8	1.690	0.0698	0	9.88
ICC 12480	17.4	0.421	0.7708	16	-0.751	24.6	0.350	0.7196	10	-0.9
ICC 12481	18.9	1.426	0.3845	4	1.107	25.6	1.279	0.3415	2	0.82
ICC 12482	15.6	1.254	0.9721	26	0.261	23.0	1.156	0.9256	16	0.17
ICC 12483	12.9	2.288	0.2819	2	4.570	20.1	2.651	0.1811	1	9.12
ICC 12484	19.0	1.204	0.6450	11	0.317	25.8	1.051	0.5737	6	0.09
ICC 12485	16.7	1.437	0.3559	3	1.228	23.9	1.363	0.325	2	1.12
ICC 12486	16.3	0.182	0.2517	2	-3.251	23.8	0.180	0.23	1	-3.57
ICC 12487	14.2	1.569	0.9654	26	0.589	21.7	1.761	0.9147	16	0.83
ICC 12488	13.3	0.082	1.2517	43	-0.734	21.2	0.091	1.2545	29	-0.72
ICC 12489	13.8	0.912	0.1106	0	-0.797	21.7	0.937	0.1157	0	-0.54
ICC 12490	13.1	0.188	0.0560	0	-14.508	21.0	0.192	0.0621	0	81.00
ICC 12491	21.4	0.223	0.1864	1	-4.169	27.6	0.195	0.1519	0	-13.02
ICC 12492	13.1	0.303	0.4251	5	-1.639	21.2	0.332	0.4219	3	-5.30
ICC 12493	13.3	0.296	0.3146	3	-2.238	21.3	0.319	0.3098	2	-1.58
ICC 12495	12.4	0.623	1.1603	37	-0.325	20.4	0.726	1.1592	25	-2.20
ICC 12496	23.6	1.167	0.8881	22	0.188	29.0	1.010	0.6912	9	-0.24
ICC 12968	19.3	0.159	0.4243	5	-1.981	26.0	0.126	0.3798	3	0.01
ICC 14876	10.8	1.414	0.3543	3	1.168	18.8	1.658	0.3501	2	-2.30
ICC 15996	20.4	1.179	0.6639	12	0.27	26.7	1.075	0.5407	5	1.88
Controls										
ICCL 86111 (MR)	16.2	0.9	0.6369	11	-0.157	23.6	0.906	0.5692	6	0.14
ICC 4918(S)	24.8	1.577	0.8455	20	0.683	29.7	1.343	0.6435	8	0.53
ICC 12475(R)	98.9	1.315	0.4731	6	0.667	16.9	1.673	0.5097	5	1.32

MR – Moderately resistant; R-Resistant check; S-Susceptible check; bi-Slope of the regression line; SEbi-Standard error of 'bi'; δi^2-residual mean squares.

Table 7.2 : **Mean pod borer damage scores and estimates of stability parameters for 28 chickpea germplasm lines tested for three seasons (2000-02), ICRISAT, Patancheru.**

Genotype	Overall resistance score (0-9 scale)					Pod damage score (0-9 scale)				
	Mean	bi	SEbi	δi^2	t (value)	Mean	bi	SEbi	δi^2	t (value)
ICCC 4	4	2.23	2.74	3	4.80	7	1.61	1.87	1	0.32
ICC 4958	5	-0.15	0.94	0	-1.66	4	1.60	0.64	0	0.92
ICC 10817	4	-2.28	1.22	1	-0.53	4	0.43	3.86	3	-0.15
ICC 12426	5	-1.33	0.56	0	-0.76	5	2.02	0.71	0	1.44
ICC 12476	3	1.15	0.87	0	14.50	4	1.62	1.39	0	0.45
ICC 12477	3	-0.56	1.62	1	-2.04	3	-0.38	0.42	0	-3.33
ICC 12478	3	0.78	0.77	0	8.90	3	0.86	3.82	3	-0.04
ICC 12479	3	0.46	1.25	1	1.26	3	0.32	1.43	0	-0.47
ICC 12480	3	1.52	2.30	2	2.97	4	-0.77	0.83	0	-2.13
ICC 12481	3	0.58	0.04	0	0.42	4	-0.12	2.04	1	-0.55
ICC 12482	3	0.60	2.20	2	1.20	4	-0.17	0.54	0	-2.16
ICC 12483	3	-1.17	0.72	0	-0.58	3	1.38	0.31	0	1.22
ICC 12484	3	0.11	0.42	0	-1.29	4	0.40	2.10	1	-0.29
ICC 12485	4	0.89	0.35	0	1.88	5	0.55	0.12	0	-3.61
ICC 12486	4	1.73	0.90	0	3.76	5	0.49	0.89	0	-0.57
ICC 12487	4	0.87	1.93	1	1.74	5	1.52	1.60	1	0.33
ICC 12488	5	-1.72	1.70	1	4.57	6	1.61	1.87	1	0.32
ICC 12489	4	0.28	1.06	0	-0.80	5	3.14	0.21	0	10.36
ICC 12490	4	2.74	0.04	0	1.03	5	0.55	0.12	0	-3.61
ICC 12491	5	-0.89	0.35	0	-3.97	5	0.04	1.77	1	-0.55
ICC 12492	4	-1.41	0.60	0	-3.93	5	-0.72	0.67	0	-2.58
ICC 12493	4	-1.52	0.96	0	-8.73	5	2.66	2.16	1	0.77
ICC 12495	6	-1.77	1.48	1	51.73	7	2.04	0.04	0	25.29
ICC 12496	6	1.50	1.13	7	0.07	5	-0.03	0.75	0	-1.37
ICC 12968	6	2.38	0.85	0	0.44	5	1.39	2.83	2	0.14
ICC 14876	3	0.53	0.54	0	-0.35	3	2.59	0.08	0	19.04
ICC 15996	4	1.92	1.31	1	0.13	5	1.92	2.08	1	0.44
Controls										
ICCL 86111 (MR)	3	2.63	0.46	0	1.48	4	0.6	1.37	0	-0.29
ICC 4918 (S)	5	0.31	0.31	0	3.33	5	0.31	1.83	1	-0.38
ICC 12475 (R.)	2	-0.41	0.68	0	-4.28	2	2.54	4.20	4	0.37

MR – Moderately resistant; R-Resistant check; S-Susceptible check; bi-Slope of the regression line; SEbi-Standard error of bi; δi^2-residual mean squares.

Table 7.3: **Mean yield and estimates of stability parameters for 28 chickpea germplasm lines tested for three Seasons (2000-02), ICRISAT, Patancheru.**

Genotype	Yield kg ha^{-1}	bi	SEbi	δi^2	t (value)	Yield g $plant^{-1}$	bi	SEbi	δi^2	t (value)
ICCC 4	1923	1.268	0.603	22003	0.44	11.7	5.363	2.551	1	1.71
ICC 4958	1675	1.640	0.170	1759	3.75	13.3	2.181	1.163	0	1.02
ICC 10817	1668	2.484	0.849	43636	1.75	10.3	2.877	0.807	0	2.32
ICC 12426	2026	1.778	0.034	71	22.69	11.7	2.761	2.651	1	0.66
ICC 12476	1671	0.130	0.259	4078	-3.35	12.3	7.784	2.2938	1	2.96
ICC 12477	1885	1.111	0.336	6839	0.33	11.4	3.378	3.150	2	0.75
ICC 12478	1750	1.859	1.092	72173	0.79	12.4	-0.496	3.865	3	-0.39
ICC 12479	1832	1.408	0.852	43867	0.48	12.0	3.912	9.679	20	0.30
ICC 12480	2037	2.802	0.381	8806	4.72	11.1	-7.029	1.678	1	-4.78
ICC 12481	1937	-0.711	0.094	544	-18.03	12.1	0.336	0.293	0	-2.26
ICC 12482	2133	0.421	1.158	81044	-0.50	12.9	7.532	0.806	0	8.10
ICC 12483	1908	0.718	0.207	2610	-1.36	12.6	1.783	0.364	0	2.15
ICC 12484	2124	0.361	0.241	3527	-2.65	14.8	5.537	1.357	0	3.34
ICC 12485	1781	0.820	0.242	3546	-0.74	12.3	3.486	0.287	0	8.64
ICC 12486	1891	0.765	0.002	0	-86.01	11.4	1.893	0.242	0	3.68
ICC 12487	1936	1.407	0.133	1069	3.06	14.2	5.053	2.197	1	1.84
ICC 12488	1645	0.463	0.622	23419	-0.86	10.0	1.031	0.231	0	0.13
ICC 12489	1684	1.537	0.711	30582	0.75	9.3	1.296	0.296	0	1.00
ICC 12490	1649	0.039	0.496	14885	-1.94	12.7	0.428	1.697	1	-0.34
ICC 12491	1394	0.672	0.004	1	-83.12	12.5	0.471	7.197	11	-0.07
ICC 12492	1498	0.266	0.381	8798	-1.92	11.6	1.716	0.328	0	2.18
ICC 12493	1649	-0.224	0.682	28104	-1.80	14.5	2.515	2.629	1	0.58
ICC 12495	1486	0.024	0.658	26190	-1.48	12.2	-6.415	3.766	3	-1.97
ICC 12496	1496	0.669	0.448	12146	-0.74	10.8	-7.723	3.107	2	-2.81
ICC 12968	1454	1.768	0.561	19069	1.37	14.9	-0.838	0.722	0	-2.54
ICC 14876	1893	0.992	0.334	6767	-0.02	14.0	-16.962	5.233	6	-3.43
ICC 15996	2408	0.626	0.047	138	-7.82	10.0	0.1230	1.290	0	-0.68
Controls										
ICCL 86111 (MR)	2208	2.021	1.175	83522	0.87	13.5	-1.2530	2.939	2	-0.77
ICC 4918(S)	1861	1.991	0.562	19113	1.76	10.8	1.0840	1.079	0	0.08
ICC 12475(R)	2208	0.896	0.238	3438	-0.44	14.3	8.1750	2.8992	2	2.47

MR-Moderately resistant; R-Resistant check; S-Susceptible check; bi-Slope of the regression line; SEbi-Standard error of 'bi', δi^2-residual mean squares.

Table 7.4 : **Mean 100- seed weight and seeds pod^{-1} and estimates of stability parameters for 28 chickpea germplasm lines tested for three seasons (2000-02), ICRISAT, Patancheru.**

	100 -seed weight					Seeds Pod^{-1}				
Genotype	Mean (g)	bi	SEbi	δi^2	t (value)	Mean	bi	SEbi	δi^2	t (value)
ICCC 4	14	0.826	0.105	0	-1.66	1.2	-0.731	1.743	0	-0.99
ICC 4958	33	1.155	1.483	7	0.10	1.0	2.574	1.034	0	1.52
ICC 10817	23	2.040	0.081	0	12.80	1.0	1.896	0.901	0	0.99
ICC 12426	19	0.958	0.473	1	-0.09	1.4	3.703	1.804	0	1.50
ICC 12476	15	1.978	0.469	1	2.08	1.3	3.592	0.659	0	3.93
ICC 12477	12	1.219	0.035	0	6.22	1.2	0.692	0.249	0	-1.23
ICC12478	15	1.198	0.706	2	0.28	1.1	1.474	0.323	0	1.47
ICC 12479	14	1.264	0.886	2	0.30	1.1	2.631	0.084	0	19.42
ICC 12480	16	1.681	0.243	0	2.80	1.2	1.214	3.085	0	0.07
ICC 12481	14	0.109	0.087	0	-10.22	1.3	2.500	0.170	0	8.79
ICC 12482	16	1.361	0.025	0	13.97	1.2	0.867	0.750	0	-0.18
ICC 12483	15	1.558	0.229	0	2.43	1.1	1.271	0.491	0	0.55
ICC 12484	18	1.337	0.550	1	0.61	1.2	2.249	0.096	0	13.01
ICC 12485	15	1.249	0.128	0	1.94	1.1	1.278	0.797	0	0.35
ICC12486	15	0.675	0.091	0	-3.55	1.4	2.985	0.232	0	8.56
ICC 12487	14	1.188	0.349	0	0.54	1.3	0.907	1.585	0	-0.06
ICC 12488	11	0.215	0.101	0	-7.73	1.4	0.205	1.412	0	-0.56
ICC 12489	11	0.893	0.124	0	-0.86	1.4	2.157	1.500	0	0.77
ICC 12490	12	-0.086	0.336	0	-3.23	1.4	0.961	1.812	0	-0.02
ICC 12491	18	1.346	0.006	0	50.13	1.2	1.478	3.015	0	0.16
ICC 12492	17	-0.226	0.071	0	-17.24	1.2	-3.441	2.274	0	-1.95
ICC 12493	17	-2.765	2.554	20	-1.47	1.2	-1.082	0.040	0	-50.91
ICC 12495	23	0.891	0.319	0	-0.34	1.1	2.401	0.545	0	2.57
ICC 12496	19	1.359	0.743	2	0.48	1.4	2.755	1.9300	0	0.91
ICC 12968	24	2.052	1.190	4	0.88	1.1	-0.619	0.593	0	-2.73
ICC 14876	14	0.918	0.213	0	-0.39	1.1	0.640	0.302	0	-1.19
ICC 15996	17	0.766	0.164	0	-1.43	1.5	0.021	2.2207	0	-0.44
Controls										
ICCL 86111(MR)	20	2.412	0.230	0	6.13	1	0.797	0.143	0	-1.41
ICC 4918 (S)	21	1.241	0.601	1	0.4	1.2	-0.593	1.758	0	-0.91
ICC 12475 (R.)	16	1.188	0.419	1	0.45	1.2	-4.782	2.922	0	-1.98

MR – Moderately resistant; R-Resistant check; S-Susceptible check; bi-Slope of the regression line; SEbi-Standard error of bi, δi^2-residual mean squares.

Table 8.1: Mean pod borer damage (%) and estimates of stability parameters for 10 chickpea breeding lines tested for four seasons (2000-02), ICRISAT, Patancheru.

	Pod borer damage (%)					Pod borer damage (Angular transformed)				
Genotype	Mean	bi	SEbi	δi^2	t (value)	Mean	bi	SEbi	δi^2	t (value)
ICCL 86102	7.1	0.28	0.49	12	-1.47	15	0.454	0.5602	13	-0.97
ICCL 87211	15.2	2.534	0.666	21	2.303	22	2.157	0.5781	14	2.00
ICCL 87220	10.2	0.57	0.066	0	-6.51	19.0	0.583	0.0637	0	-6.54
ICCL 87314	12.4	0.623	0.264	3	-1.43	20.5	0.62	0.2318	2	-1.64
ICCL 87315	11.1	0.936	0.055	0	-1.17	19.2	0.941	0.0512	0	-1.15
ICCL 87316	8.4	0.796	0.12	1	-1.7	16.5	0.952	0.1366	1	-0.35
ICCL 87317	9.0	0.864	0.175	1	-0.78	17.2	0.942	0.1905	2	-0.31
ICCV 93122	16.1	1.685	0.286	4	2.397	23.2	1.511	0.2398	2	2.13
ICCV 95992	9.5	0.963	0.071	0	-0.52	17.7	1.031	0.074	0	0.41
ICCV 96752	6.9	0.801	0.216	2	-0.92	14.9	.914	.266	3	.32
Controls										
ICC 4918 (S)	15.5	1.445	0.146	1	3.053	22.8	1.231	0.1363	1	1.69
ICC12475 (R)	5.2	0.504	0.134	1	-3.7	12.8	0.664	0.1961	2	-1.72

R-Resistant check; S-Susceptible check; bi-Slope of the regression line; SEbi-Standard error of 'bi';
δi^2-Residual mean squares.

Table 8.2 : Mean pod borer damage scores and estimates of stability parameters for 10 chickpea breeding lines tested for four seasons (2000-02), ICRISAT, Patancheru.

	Over all resistance score (0-9 scale)					Pod damage score (0-9 scale)				
Genotype	Mean	bi	SEbi	δi^2	t (value)	Mean	bi	SEbi	δi^2	T (value)
ICCL 86102	2	0.518	1.0494	1	-0.459	3	0.659	0.083	0	-4.104
ICCL 87211	5	3.015	1.055	1	1.91	5	1.095	0.6116	1	0.155
ICCL 87220	3	1.203	0.1774	0	1.145	3	0.93	0.5135	0	-0.136
ICCL 87314	3	0.357	0.5192	0	-1.239	3	1.414	0.2205	0	1.877
ICCL 87315	2	0.648	0.5033	0	-0.7	3	1.128	0.2734	0	0.468
ICCL 87316	3	0.54	0.1533	0	-2.998	4	1.482	0.5174	0	0.931
ICCL 87317	2	1.088	0.4062	0	0.216	3	1.593	0.2192	0	2.707
ICCV 93122	5	1.709	0.5771	0	1.229	6	0.889	0.2536	0	-0.438
ICCV 95992	3	0.379	0.6383	0	-0.972	5	1.324	0.5459	0	0.594
ICCV 96752	4	0.715	0.428	0	-0.665	3	0.157	0.4226	0	-1.995
Controls										
ICC 4918 (S)	5	1.092	0.5059	0	0.181	5	0.323	0.3144	0	-2.154
ICC12475 (R)	2	0.736	0.2495	0	-1.058	2	1.006	0.1984	0	0.031

R - Resistant check; S - Susceptible check; bi - Slope of the regression line; Sebi - Standard error of 'bi', δi^2 - Residual mean squares.

Table 8.3 : Mean yield and estimates of stability parameters for 10 chickpea breeding lines tested four seasons (2000-02) ICRISAT, Patancheru.

Genotype	Yield g plant^{-1}	bi	SEbi	δi^2	t (value)	Yield Kg ha^{-1}	bi	SEbi	δi^2	t (value)
ICCL 86102	15.1	1.45	0.213	1	2.09	2206.0	1.707	0.14	1232	5.219
ICCL 87211	18.9	2.42	1.487	33	0.95	1853.2	2.005	0.64	27754	1.562
ICCL 87220	13.7	0.19	0.238	1	-3.4	2058.3	0.176	0.43	12407	-1.92
ICCL 87314	14.6	0.95	0.478	3	-0.1	2196.5	0.033	0.29	5694	-3.32
ICCL 87315	14.3	0.5	0.158	0	-3.2	2155.0	-0.13	0.34	7941	-3.28
ICCL 87316	15.2	0.61	0.498	4	-0.8	2284.7	0.462	0.43	12584	-1.24
ICCL 87317	13.5	0.69	0.202	1	-1.5	2222.8	0.405	0.38	9832	-1.55
ICCV 93122	12.4	0.58	0.207	1	-2	1824.7	1.190	1.41	132962	0.135
ICCV 95992	15.7	1.55	0.153	0	3.63	2291.3	1.728	1.20	96325	0.608
ICCV 96752	13.4	1.12	0.432	3	0.28	1848.5	2.65	0.57	21425	2.129
Controls										
ICC 4918(S)	14.0	0.26	0.607	5	-1.2	1993.0	1.19	0.68	31110	0.279
ICC 12475(R)	14.5	1.68	0.515	4	1.32	2137.3	0.576	0.26	4371	-1.66

R-Resistant check, S-Susceptible check, bi-Slope of the regression line, SEbi-Standard error of bi, δi^2-residual mean squares.

Table 8.4: Mean 100-seed weight and seeds pod^{-1} and estimates of stability parameters for 10 chickpea breeding Lines tested for four seasons (2000-02), ICRISAT, Patancheru.

	100-seed weight (g)					Seeds pod-1				
Genotype	Mean	bi	SEbi	δi^2	t (value)	Mean	bi	SEbi	δi^2	t (value)
ICCL 86102	19.3	1.288	0.5072	1	0.568	1.1	-4.58	2.8674	0	-1.95
ICCL 87211	17.9	0.264	0.9987	2	-0.737	1.2	3.171	0.3861	0	5.62
ICCL 87220	17.1	1.407	1.3524	4	0.301	1.2	3.026	4.5239	0	0.45
ICCL 87314	16	1.59	1.0048	2	0.587	1.1	1.617	1.6413	0	0.38
ICCL 87315	18.7	2.62	1.1514	3	1.407	1.1	1.193	0.7905	0	0.24
ICCL 87316	16.9	2.355	1.0114	2	1.339	1.1	2.192	0.8887	0	1.34
ICCL 87317	15.3	0.222	0.6408	1	-1.214	1.1	1.476	1.6206	0	0.29
ICCV 93122	15.9	0.549	1.0507	2	-0.429	1.1	2.735	0.9316	0	1.86
ICCV 95992	18.6	-0.359	0.7977	1	-1.703	1.1	0.334	0.9436	0	-0.71
ICCV 96752	16.5	0.413	0.7349	1	-0.798	1.1	0.154	0.4958	0	-1.71
ICC 4918 (S)	18.1	0.776	1.1752	3	-0.191	1.2	0.356	0.6284	0	-1.02
ICC12475 (R)	17.1	0.874	0.2671	0	-0.47	1.1	0.326	1.0313	0	-0.65

R - Resistant check; S - Susceptible check; bi -Slope of the regression line, Sebi - Standard error of bi,
δi^2 - residual mean squares.

4.1.6.3 Yield kg ha^{-1}

The G x E interaction was not significant among breeding lines, but was significant in germplasm lines. Among the breeding lines high yields were recorded in ICCV 95992, ICCL 87316, ICCL 87317, ICCL 86102, ICCL 87314 and ICCL 87315. In ICC 86107 'b' is statistically >1. High 'δi^2' value was recorded for ICCV 93122 and SE of b_i >b. Among the germplasm lines high yields were recorded in ICC 15996, ICC 12475, ICCL 86111 (breeding line included in 3 seasons stability analysis) ICC 12484, ICC 12482, ICC 12480 and ICC 12426. Except for ICC 12426 the 'b' values were not significant in others.

4.1.6.4 Overall resistance (ORS) and pod damage scores (PDS)

The G x E interaction was not significant for ORS but was significant (at 10% probability) with respect to PDS. Among the breeding lines least ORS was recorded in resistant check ICC 12475. Among the germplasm lines lowest ORS was recorded for ICC 12475 followed by ICC 12476, ICC 12477, ICC 12478, ICC 12479, ICC 12480, ICC 12481, ICC 12482, ICC 12483, ICC 12484 and ICC 14876. For ICC 12476, 'b' value is significantly greater than 1 indicating its resistance was unstable over seasons and at higher levels of infestation it may support more larvae. In ICC 12495 (ORS 4) 'b' is statistically <1 indicating that it was stable in its resistance, and that it will not support more larvae under high infestation situations.

Among the breeding lines lowest PDS scores were recorded for resistant check ICC 12475, ICCL 86102, ICCL 87315 and ICCL 87317. The slopes were statistically equal to 1 and 'δi^2' values were 0 indicating high stability. Among the germplasm lines lowest PDS was recorded in resistant check ICC 12475 followed by ICC 12477, ICC 12478, ICC 12479 and ICC 14876. In ICC 14876 and ICC 12495 'b' value was significantly greater than 1 and 'δi^2' values were high.

4.1.6.5 Pod borer damage (%)

G x E interaction was not significant in breeding lines, but significant (at 5% probability) in germplasm lines. ICCL 93122 and ICCL 82711 were highly susceptible (along with susceptible check ICC 4918) while the remaining ones were less susceptible. Among the germplasm lines ICC 12478, ICC 12478, ICC 12479 and ICC 14876 recorded low damage percentage along with resistant check ICC 12475, and 'b' is unit and residual mean squares were less. In ICC 12490 b value was <1 and 'δi^2' = 0.

4.2 INHERITANCE OF RESISTANCE TO *H. armigera* IN CHICKPEA

Inheritance of resistance to *H. armigera* in chickpea was studied under field conditions at ICRISAT, 2001-02 and the results are presented.

Analysis of variance

The mean values of 10 parents and 45 F_1s in desi type and 28 F_1s and 8 parents in kabuli type for different characters, namely days to flowering, days to maturity, 100-seed weight, pod borer damage percentage, seeds per pod, number of pods per plant, number of seeds per plant, per plant yield, and yield kg ha^{-1} were presented in Tables 9.1 and 9.2 respectively. It is evident from the tables that the, variation due to treatments were significant for all the characters studied except for days to maturity in desi type trial.

The mean values for different characters of 10 parents and their 45 F_2s in desi trial and 8 parents and their 28 F_2s were presented in Tables 9.3 and 9.4 respectively. It is evident from these tables the variation due to treatments was significant for all the characters studied.

Table 9.1: Characteristics of entries in F_1 desi chickpea 10 x 10 diallel for *H. armigera* resistance, ICRISAT, Patancheru, 2001-02.

Parents	Days to 50% flow.	Days to maturity	100-seed wt. (g)	Seeds pod^{-1}	Pods $plant^{-1}$	Yield $plant^{-1}$ (g)	Yield $plot^{-1}$ (g)	Yield kg ha^{-1}	Pod borer damage (%) Actual	Pod borer damage (%) Angular transformed
ICC 12475(R)	55	106	16.11	1.11	73	11.55	227.1	1514	9.75	17.90
ICC 12476	77	116	13.82	1.20	68	10.16	213.6	1424	7.89	15.04
ICC 12477	65	105	12.46	1.22	133	17.97	180.0	1200	10.41	18.10
ICC 12478	63	108	13.92	1.09	65	9.04	245.0	1634	8.65	14.95
ICC 12479	53	102	13.70	1.13	91	13.09	248.9	1659	6.43	13.16
ICC 12490	69	106	12.48	1.43	76	12.19	172.6	1151	9.47	17.50
ICC 14876	61	109	14.05	1.07	97	13.01	171.6	1144	10.29	18.24
ICC 4918(S)	47	94	18.48	1.29	62	11.54	235.6	1571	20.14	25.49
ICC 12426(S)	61	101	17.13	1.38	49	9.58	161.8	1078	13.96	20.66
ICC 3137(S)	76	112	23.74	1.06	41	7.88	121.4	809	22.69	28.13
F_1 crosses										
ICC 12475 x ICC 12476	67	110	15.76	1.18	108	17.04	240.9	1606	12.35	19.83
ICC 12475 x ICC 12477	57	107	14.90	1.22	107	16.42	267.6	1784	13.71	20.96
ICC 12475 x ICC 12478	56	104	16.04	1.09	120	18.83	282.1	1881	10.81	17.78
ICC 12475 x ICC 12479	61	109	15.23	1.13	122	19.89	188.8	1259	7.11	14.49
ICC 12475 x ICC 12490	67	111	15.66	1.26	96	15.96	282.4	1883	13.95	20.54
ICC 12475 x ICC 14876	61	109	15.70	1.12	101	15.84	215.2	1435	12.79	19.85
ICC 12475 x ICC 4918	55	107	19.31	1.20	115	23.67	282.4	1882	12.64	20.51
ICC 12475 x ICC 12426	59	102	16.75	1.33	138	27.21	224.6	1497	11.03	18.81
ICC 12475 x ICC 3137	68	110	19.25	1.22	104	21.35	241.6	1611	14.53	21.99
ICC 12476 x ICC 12477	75	114	14.21	1.21	102	15.91	238.0	1587	8.27	15.33
ICC 12476 x ICC 12478	75	112	12.77	1.28	142	21.3	123.0	820	8.19	16.05
ICC 12476 x ICC 12479	71	109	14.49	1.21	118	18.27	204.8	1365	9.82	17.77
ICC 12476 x ICC 12490	78	114	12.82	1.35	194	30.17	108.6	724	10.22	18.39
ICC 12476 x ICC 14876	79	115	13.52	1.31	117	18.66	146.1	974	8.69	16.64
ICC 12476 x ICC 4918	73	107	15.77	1.29	114	20.43	178.1	1187	9.68	17.74
ICC 12476 x ICC 12426	76	113	14.66	1.43	91	16.52	192.8	1285	14.39	21.23
ICC 12476 x ICC 3137	78	117	16.03	1.31	134	24.7	110.2	734	11.42	18.93
ICC 12477 x ICC 12478	63	105	13.76	1.14	132	17.39	297.1	1981	16.68	22.92
ICC 12477 x ICC 12479	66	110	12.66	1.16	146	18.09	172.8	1152	14.09	20.82

Conti......

Conti.....table 9.1

F_1 s	Days to 50% flow.	Days to maturity	100-seed Wt. (g)	Seeds pod^{-1}	Pods Plant^{-1}	Yield plant^{-1} (g)	Yield plot^{1} (g)	Yield kg ha^{-1}	Pod borer damage (%) Actual	Pod borer damage (%) Angular transformed
ICC 12477 x ICC 12490	73	112	13.19	1.31	104	15.12	245.7	1638	16.04	23.17
ICC 12477 x ICC 14876	62	110	13.18	1.11	112	14.58	218.7	1458	10.76	18.68
ICC 12477xICC 4918	62	110	16.64	1.20	141	22.09	223.1	1488	18.97	25.11
ICC 12477 x ICC 12426	59	107	16.31	1.24	87	15.57	222.2	1481	14.54	21.98
ICC 12477 x ICC 3137	73	112	16.5	1.23	95	15.81	181.7	1211	16.91	23.67
ICC 12478 x ICC 12479	61	111	14.88	1.11	90	13.65	201.3	1342	7.05	15.01
ICC 12478 x ICC 12490	75	113	12.51	1.38	91	14.25	243.5	1623	9.42	16.73
ICC 12478 x ICC 14876	62	107	15.05	1.13	106	15.76	254.6	1697	15.03	22.32
ICC 12478 x ICC 4918	63	108	16.81	1.22	123	22.46	199.4	1330	11.11	19.06
ICC 12478 x ICC 12426	59	108	17.52	1.24	126	23.44	228.7	1525	13.53	20.74
ICC 12478 x ICC 3137	64	112	19.15	1.11	94	17.15	230.8	1539	12.84	20.22
ICC 12479 x ICC 12490	72	111	12.7	1.33	75	11.39	294.5	1963	9.21	16.19
ICC 12479 x ICC 14876	55	106	13.93	1.11	97	13.61	236.9	1580	11.39	18.59
ICC 12479 x ICC 4918	51	93	17.5	1.17	92	16.06	240.3	1602	15.99	23.02
ICC 12479 x ICC 12426	54	94	17.48	1.16	110	20.57	218.6	1457	12.33	20.01
ICC 12479 x ICC 3137	71	104	17.21	1.14	69	11.61	237.1	1581	13.05	20.62
ICC 12490 x ICC 14876	71	109	12.92	1.47	96	16.82	189.1	1261	7.31	14.65
ICC 12490 x ICC 4918	69	111	16.91	1.28	77	13.46	166.5	1110	15.68	22.41
ICC 12490 x ICC 12426	71	107	17.62	1.46	73	15.51	208.5	1390	14.62	21.17
ICC 12490 x ICC 3137	74	118	17.03	1.35	103	20.36	217.2	1448	14.09	21.85
ICC 14876 x ICC 4918	59	111	16.35	1.36	78	15.12	234.4	1563	10.29	18.13
ICC 14876 x ICC 12426	59	109	15.48	1.05	110	16.41	180.3	1202	10.92	18.12
ICC 14876 x ICC 3137	60	107	15.05	1.08	80	11.70	214.6	1431	10.69	18.49
ICC 4918 x ICC 12426	53	92	19.92	1.27	93	18.50	232.3	1549	21.40	27.18
ICC 4918 x ICC 3137	61	110	21.78	1.22	61	12.82	197.1	1314	23.98	28.98
ICC 12426 x ICC 3137	60	117	21.10	1.31	65	13.92	226.7	1511	20.86	25.94
Parents mean	65	107	15.590	1.2	75	11.60	177.0	1318	12.85	19.74
F (prob. At 5%)	<.001	0.174	<.001	<.001	<.001	<.001	0.003	0.003	<.001	<.001
F_1 Crosses mean	63	109	15.86	1.2	105	17.67	217.0	1473	12.68	20.68
F(prob at 5%)	0.002	0.201	<.001	<.001	<.001	0.002	0.002	0.002	<.001	<.001
SED	6.212	3.8	0.75	0.07	17.85	3.37	34.28	228	3.026	2.64
LSD	12.3	7.7	1.5	0.14	35.43	6.69	67.95	453	5.99	5.24
CV(%)	11.7	5.5	5.8	7.2	21.9	25	19.7	19.7	29.2	15.8

Table 9. 2 : Characteristics of entries in F_1 kabuli chickpea 8 x 8 diallel for *H. armigera* resistance, ICRISAT, Patancheru, 2001-02.

Parents	Days to 50% flow.	Days to maturity	100-Seed Wt. (g)	Seeds pod⁻¹	Pods Plant⁻¹	Yield plant⁻¹(g)	Yield plot⁻¹(g)	Yield kg ha⁻¹	Pod borer damage (%) Actual	Pod borer damage (%) Angular transformed
ICC 12491	62	105	17.97	1.14	65	11.56	149.8	998	12.84	20.55
ICC 12492	68	112	17.65	1.10	74	12.56	172.8	1152	10.11	18.23
ICC 12493	82	118	13.87	1.28	56	8.74	165.3	1102	13.90	21.84
ICC 12494	77	120	16.69	1.29	68	11.79	161.4	1076	19.04	25.82
ICC 12495	80	120	23.42	1.00	60	12.42	175.8	1172	13.28	23.70
ICC 12968	35	81	17.57	1.14	25	4.02	52.8	352	18.47	25.39
ICC 4973	82	112	20.58	1.16	62	12.71	266.3	1776	16.34	21.37
ICC 4962	88	130	19.47	1.40	37	8.31	96.3	642	14.95	22.58
F_1s										
ICC 12491 x ICC 12492	69	115	17.49	1.17	96	16.56	214.3	1429	13.69	21.50
ICC 12491 x ICC 12493	73	108	16.23	1.26	70	12.06	207.4	1383	17.90	25.01
ICC 12491 x ICC 12494	77	121	18.28	1.26	56	10.48	153.4	1023	18.38	25.30
ICC 12491 x ICC 12495	77	120	18.49	1.21	71	13.55	172.5	1150	13.31	21.14
ICC 12491 x ICC 12968	51	85	21.57	1.11	83	17.27	224.6	1498	11.95	20.18
ICC 12491 x ICC 4973	70	117	19.49	1.25	77	15.02	191.0	1273	18.07	24.97
ICC 12491 x ICC 4962	76	120	19.87	1.32	54	11.75	150.2	1001	16.52	23.88
ICC 12492 x ICC 12493	80	125	15.59	1.29	69	12.23	169.6	1131	11.46	19.22
ICC 12492 x ICC 12494	79	124	17.61	1.27	71	14.40	143.6	957	10.26	18.64
ICC 12492 x ICC 12495	78	123	19.17	1.28	55	11.16	207.5	1383	17.28	24.46
ICC 12492 x ICC 12968	37	86	18.26	1.25	76	15.50	147.7	985	9.96	18.37
ICC 12492 x ICC 4973	80	119	18.87	1.25	74	15.33	129.8	866	10.34	18.63
ICC 12492 x ICC 4962	81	124	18.86	1.33	70	15.2	184.1	1227	15.57	23.21

Contd.

Conti..table 9.2

F_1 s	Days to 50% flow.	Days to maturity	100-Seed Wt. (g)	Seeds pod^{-1}	Pods $Plant^{-1}$	Yield $plant^{-1}$(g)	Yield $plot^{-1}$(g)	Yield kg ha^{-1}	Pod bore damage (%) Actual	Pod bore damage (%) Angular transformed
ICC 12493 x ICC 12494	82	121	16.50	1.32	73	14.5	119.0	793	8.86	17.26
ICC 12493 x ICC 12495	80	125	18.64	1.27	66	14.37	205.6	1370	8.03	16.25
ICC 12493 x ICC 12968	53	104	17.17	1.33	75	14.77	223.4	1489	12.78	20.86
ICC 12493 x ICC 4973	80	116	15.69	1.35	69	12.81	187.3	1249	15.35	22.79
ICC 12493 x ICC 4962	81	118	15.64	1.35	56	10.18	128	853	15.09	22.06
ICC 12495 x ICC 12494	80	109	19.90	1.24	64	14.46	159.5	1063	9.82	18.24
ICC 12968 x ICC 12494	51	90	19.44	1.19	74	14.35	201.8	1345	15.98	23.4
ICC 4973 x ICC 12494	80	112	19.50	1.19	76	15.07	178.9	1192	14.14	21.85
ICC 4962 x ICC 12494	80	123	21.55	1.42	60	15.10	180.6	1204	16.41	23.88
ICC 12495 x ICC 12968	68	108	21.00	1.16	120	25.71	128.5	857	9.22	17.59
ICC 12495 x ICC 4973	75	116	22.24	1.18	62	13.43	199.9	1333	15.87	23.46
ICC 12495 x ICC 4962	79	126	22.73	1.24	64	15.36	224.1	1494	15.03	22.80
ICC 12968 x ICC 4973	56	102	19.87	1.13	59	11.24	198.9	1326	13.42	21.40
ICC 12968 x ICC 4962	54	104	20.93	1.37	66	15.52	212.2	1415	18.00	25.10
ICC 4973 x ICC 4962	82	116	22.13	1.20	60	12.81	160	1066	19.32	25.97
Parents										
Mean	71.4	112	18.400	1.180	55.8	10.260	155	1094	14.870	22.430
F (prob at 5%)	<.001	<.001	<.001	<.001	<.001	<.001	<.001	<.001	0.0180	0.014
Fls										
Mean	71	113	19.03	1.24	70	14.29	178	1991	14.2	21.69
F (prob at 5%)	<.001	<.001	<.001	<.001	<.001	<.001	<.001	<.001	0.152	0.151
SED	3.95	6.66	1.05	0.06	10.9	2.3	30.6	203.8	3.38	2.83
LSD	7.9	13.28	2.09	0.13	21.8	4.5	60.1	406.5	6.7	5.64
CV(%)	6.8	7.2	6.8	6.2	20.0	2.7	21.6	21.6	29.2	15.8

Table 9.3: Characteristics of entires in F_2 desi 10 x 10 diallel for *H. armigera* resistance, ICRISAT, Patancheru, 2001-02.

Parents	Days to 50% flow.	Days to maturity	100-seed Wt. (g)	Seeds Pod^{-1}	Pods $plant^{-1}$	Yield $plant^{-1}$(g)	Yield $plot^{-1}$(g)	Pod borer damage (%) Ac tual	Pod borer damage (%) Angular transformed
ICC 12475	46	101	15.77	1.10	86	13.70	874.5	6.98	13.37
ICC 12476	77	116	13.08	1.32	81	12.44	655.8	10.65	17.22
ICC 12477	61	105	11.80	1.17	105	13.31	807.0	7.24	14.45
ICC 12478	53	105	14.76	1.08	92	13.46	889.1	9.76	17.15
ICC 12479	54	98	13.65	1.12	94	13.23	914.1	7.85	14.79
ICC 12490	76	110	12.61	1.41	87	13.46	782.1	10.84	18.09
ICC 14876	54	109	14.34	1.13	106	15.45	747.4	9.14	16.81
ICC 4918	43	89	18.98	1.19	72	12.76	668.8	21.30	26.60
ICC 12426	52	101	18.33	1.45	65	14.52	746.8	15.41	21.86
ICC 3137	77	115	24.73	1.06	34	8.72	706.9	28.47	31.64
F_2 s									
ICC 12475 x ICC 12476	62	110	14.33	1.27	84	13.60	809.9	9.44	16.26
ICC 12475 x ICC 12477	59	106	14.20	1.16	107	15.77	725.5	9.76	16.93
ICC 12475 x ICC 12478	61	107	15.01	1.07	103	15.31	758.1	8.04	15.33
ICC 12475 x ICC 12479	61	101	13.95	1.16	99	14.39	930.2	8.77	15.49
ICC 12475 x ICC 12490	67	105	13.94	1.30	112	18.36	781.1	8.22	15.51
ICC 12475 x ICC 14876	64	108	14.73	1.15	94	14.58	916.6	7.90	14.85
ICC 12475 x ICC 4918	59	102	17.68	1.26	100	19.07	634.4	12.78	20.04
ICC 12475 x ICC 12426	61	105	16.33	1.16	106	18.16	786.3	9.79	17.05
ICC 12475 x ICC 3137	62	110	19.35	1.17	79	14.70	668.7	15.34	22.01
ICC 12476 x ICC 12477	76	114	13.40	1.14	102	14.24	791.7	8.90	15.86
ICC 12476 x ICC 12478	78	115	11.85	1.40	93	13.39	852.4	11.58	18.84
ICC 12476 x ICC 12479	77	115	13.44	1.27	93	13.97	726.8	11.41	18.39
ICC 12476 x ICC 12490	78	114	13.77	1.27	91	13.82	868.5	10.97	18.29
ICC 12476 x ICC 14876	77	112	13.90	1.28	94	14.23	860.0	12.47	20.36
ICC 12476 x ICC 4918	70	107	14.17	1.27	90	13.7	771.6	14.95	21.88
ICC 12476 x ICC 12426	72	112	16.13	1.28	86	15.04	709.7	13.05	20.06
ICC 12476 x ICC 3137	78	117	13.44	1.27	77	11.43	767.0	11.94	18.16

Contd.

Conti ...table 9.3

F_2s	Days to 50% flow.	Days to maturity	100-seed Wt. (g)	Seeds pod^{-1}	Pods $plant^{-1}$	Yield $plant^{-1}$(g)	Yield $plot^{-1}$(g)	Pod borer damage Actual	Pod borer damage Angular transformed
ICC 12477 x ICC 12478	70	108	12.74	1.14	105	14.02	979.9	8.90	16.24
ICC 12477 x ICC 12479	68	106	11.91	1.16	111	13.66	841.3	9.01	15.88
ICC 12477 x ICC 12490	70	107	11.83	1.35	112	15.77	708.5	11.03	18.51
ICC 12477 x ICC 14876	72	110	12.20	1.17	123	15.86	766.9	9.91	16.89
ICC 12477xICC 4918	65	107	14.33	1.19	140	20.96	671.4	13.63	20.59
ICC 12477 x ICC 12426	60	102	14.83	1.26	122	19.40	639.5	14.06	21.05
ICC 12477 x ICC 3137	67	108	15.93	1.19	96	15.12	664.4	14.19	21.22
ICC 12478 x ICC 12479	73	111	14.05	1.12	114	16.65	785.6	7.09	14.24
ICC 12478 x ICC 12490	76	113	12.88	1.34	99	15.06	771.4	10.40	17.79
ICC 12478 x ICC 14876	69	110	13.75	1.14	130	18.28	675.8	7.96	15.02
ICC 12478 x ICC 4918	57	101	16.69	1.16	114	19.04	748.6	13.2	20.82
ICC 12478 x ICC 12426	61	104	16.42	1.25	107	18.98	675.4	13.40	20.50
ICC 12478 x ICC 3137	66	104	17.92	1.12	94	15.79	727.4	14.29	21.55
ICC 12479 x ICC 12490	71	110	12.59	1.39	95	14.58	726.9	9.66	16.66
ICC 12479 x ICC 14876	65	109	13.56	1.13	114	16.38	737.8	6.68	13.50
ICC 12479 x ICC 4918	66	108	16.93	1.19	124	21.33	734.4	15.15	21.85
ICC 12479 x ICC 12426	61	104	15.58	1.25	108	18.13	711.7	14.62	21.88
ICC 12479xICC 3137	71	113	18.35	1.16	102	17.82	617.9	16.78	23.39
ICC 12490 x ICC 14876	72	107	13.86	1.31	101	15.92	672.7	12.00	19.44
ICC 12490 x ICC 4918	66	108	15.91	1.33	124	22.27	582.3	14.66	21.81
ICC 12490 x ICC 12426	66	109	15.81	1.46	93	17.30	676.1	16.93	23.47
ICC 12490 x ICC 3137	73	118	18.52	1.28	80	15.20	736.3	16.90	23.35
ICC 14876 x ICC 4918	71	111	13.62	1.11	112	15.23	690.9	9.88	17.05
ICC 14876 x ICC 12426	61	103	14.23	1.14	109	16.05	657.7	9.36	16.25
ICC 14876 x ICC 3137	71	116	18.18	1.07	89	14.51	668.4	15.65	22.08
ICC 4918 x ICC 12426	60	106	18.60	1.34	102	20.67	645.9	17.75	24.19
ICC 4918 x ICC 3137	69	106	22.44	1.19	93	19.71	612.5	18.90	24.82
ICC 12426 x ICC 3137	67	109	21.83	1.28	77	16.21	714.7	23.70	28.41
Mean	66.2	109	15.150	1.220	98.8	15.720	745.3	12.340	19.200
F(prob at 5%)	<.001	<.001	<.001	<.001	<.001	<.001	0.004	<.001	<.001
SED	4.18	5.65	2.03	0.034	9.1	1.600	92.50	2.314	2.201
LSD	8.29	11.2	4.10	0.068	18.0	3.701	183.41	4.591	4.301
CV(%)	7.7	5.3	15.3	3.5	11.3	12.5	15.2	23.0	14.0

Table 9.4 : Characteristics of entries in F_2 kabuli 8 x 8 diallel for *H. armigera* resistance, ICRISAT, Patancheru, 2001-02.

Parents	Days to 50% flow.	Days to maturity	100-seed Wt. (g)	Seed Pod^{-1}	Pods $Plant^{-1}$	Yield $plant^{-1}$(g)	Yield $plot^{-1}$(g)	Pod borer damage (%) Actual	Pod borer damage (%) Angular transformed
ICC 12491	50	98	18.6	1.16	74.6	13.3	656.4	17.2	24.4
ICC 12492	81	113	17.3	1.19	72.6	13.0	718.1	11.3	19.6
ICC 12493	79	117	14.5	1.27	82.6	13.7	676.8	9.0	17.4
ICC 12494	79	113	16.7	1.35	73.1	13.6	627.9	16.0	23.6
ICC 12495	79	123	22.8	1.14	64.1	15.2	674.0	8.2	16.6
ICC 12968	35	84	21.8	1.12	47.8	9.6	421.9	17.2	24.5
ICC 4973	78	111	19.9	1.23	68.6	14.1	753.3	15.0	22.7
ICC 4962	84	122	20.9	1.39	45.2	11.2	514.0	13.4	21.4
F_2s									
ICC 12491 x ICC 12492	72	112	17.5	1.25	80.4	14.9	634.0	14.4	22.3
ICC 12491 x ICC 12493	74	114	17.2	1.25	91.4	16.8	578.2	12.5	20.7
ICC 12491 x ICC 12494	80	116	17.9	1.24	72.5	13.9	568.1	13.0	21.1
ICC 12491 x ICC 12495	81	120	19.6	1.21	90.1	18.7	605.4	10.6	18.9
ICC 12491 x ICC 12968	39	92	20.0	1.17	89.5	16.3	693.9	18.1	25.2
ICC 12491 x ICC 4973	76	117	19.3	1.21	78.9	15.4	572.4	15.6	23.1
ICC 12491 x ICC 4962	82	120	19.6	1.31	67.8	14.5	554.6	15.4	23.0
ICC 12492 x ICC 12493	82	125	14.7	1.31	131.2	24.6	384.1	6.7	15.0
ICC 12492 x ICC 12494	83	124	16.5	1.31	162.8	31.9	620.8	6.5	14.7
ICC 12492 x ICC 12495	72	119	20.2	1.21	101.7	22.1	594.3	10.3	18.6
ICC 12492 x ICC 12968	44	94	18.3	1.21	83.4	15.6	681.1	12.4	20.5
ICC 12492 x ICC 4973	76	119	19.0	1.21	77.7	15.0	717.5	15.6	23.2

Contd.

Conti.....table 9.4

F_2 s	Days to 50% flow.	Days to maturity	100-seed Wt. (g)	Seeds Pod^{-1}	Pods $Plant^{-1}$	Yield $plant^{-1}$(g)	Yield $plot^{-1}$ (g)	Pod borer damage (%) Actual	Pod borer damage (%) Angular transformed
ICC 12492 x ICC 4962	82	124	19.0	1.32	71.9	15.7	599.5	12.3	20.5
ICC 12493 x ICC 12494	82	121	16.0	1.33	90.7	16.5	623.2	12.6	20.8
ICC 12493 x ICC 12495	75	118	18.7	1.31	82.9	18.2	639.0	10.3	18.7
ICC 12493 x ICC 12968	39	90	19.1	1.18	96.4	18.1	709.9	13.8	21.7
ICC 12493 x ICC 4973	81	116	16.8	1.27	91.3	17.4	684.2	11.9	20.2
ICC 12493 x ICC 4962	82	118	16.7	1.40	77.5	15.4	564.1	13.8	21.8
ICC 12495 x ICC 12494	82	114	20.5	1.23	84.9	18.9	639.5	11.5	19.8
ICC 12968 x ICC 12494	46	109	21.1	1.16	66.6	12.4	666.3	24.2	29.4
ICC 4973 x ICC 12494	73	112	19.9	1.19	69.2	13.4	664.2	17.3	24.6
ICC 4962 x ICC 12494	84	123	21.4	1.33	60.3	14.4	572.9	14.2	22.1
ICC 12495 x ICC 12968	37	92	23.6	1.13	76.5	16.9	750.5	15.4	23.1
ICC 12495 x ICC 4973	80	118	21.0	1.22	89.1	20.4	525.7	8.0	16.4
ICC 12495 x ICC 4962	83	126	22.5	1.28	124.5	31.0	686.8	9.0	17.4
ICC 12968 x ICC 4973	38	89	21.2	1.10	88.8	16.3	773.8	18.8	25.6
ICC 12968 x ICC 4962	43	99	22.4	1.22	86.5	19.1	729.3	17.7	24.7
ICC 4973 x ICC 4962	80	112	21.9	1.20	113.6	26.2	785.9	11.5	19.8
Mean	69.9	7.13	19.27	1.240	84.10	17.00	668.00	13.35	21.19
F(prob at 5%)	<.001	<.001	<.001	<.001	<.001	<.001	<.001	<.001	<.001
SED	4.8	14.3	0.77	0.04	10.02	2.18	73.01	2.15	1.75
LSD	9.6	7.80	1.50	0.07	20.00	4.34	146.08	4.30	3.50
CV(%)	8.5	8.1	15.4	3.6	14.6	15.6	13.4	19.7	10.1

4.2.1 PERFORMANCE OF PARENTS AND CROSSES

4.2.1.1 Days to 50% flowering

In desi type trial, among the parents involved in the study, ICC 4918 (49) was the early flowering variety, while ICC 12479 (53), ICC 12475 (55), ICC 12426 (61) and ICC 14876 and ICC 12477 (65) were medium duration varieties. ICC 12490, ICC 3137 (76), ICC 12476 (77) were medium-long duration varieties. For the crosses it ranged from 51 days (ICC 12479 x ICC 4918) to 79 days (ICC 12476 x ICC 14876).

In kabuli type trial ICC 12968 was extra-short duration variety (35 days to 50% flowering). The crosses with ICC 12968 were early flowering. The F_2s with ICC 12968, ICC 4918, ICC 12475 and ICC 12479 were early flowering.

4.2.1.2 Days to maturity

ICC 4918 (94), ICC 12426 (101), ICC 12479 (102) were the earliest of all desi type parents with respect to number of days required for maturity. The overall mean of the parents for days to maturity was 106 days and it was 109 days for the F_1 crosses.

ICC 12479 x ICC 4918, ICC 4918 x ICC 12476 and ICC 12479 x ICC 12426 were early maturing crosses. In kabuli type trial, ICC 12968 was early maturing and the F_1s of crosses with ICC 12968 were also early maturing.

4.2.1.3 100-seed weight

Among desi type parents ICC 3137 was bold seeded type with 23.74 g /100 seed. ICC 4918 (18.48g) and ICC 12426 (17.13g) were also bold seeded. Among the F_1 crosses, ICC 4918 x ICC 3137 (21.78g), ICC 12426 x ICC 3137 (21.1g), ICC 4918 x ICC 12426 (19.92g) recorded significantly high seed mass. Among F_2s the highest and lowest values were exhibited by Annegiri x ICC 3137 (22.44 g) and ICC 12477 x ICC 12490 (11.83 g), respectively.

Among kabuli type parents ICC 12495 (23.42 g), ICC 4973 (20.58 g) and ICC 4962 (19.47 g) were bold seeded and the crosses ICC 12495 x ICC 4973, ICC 12495 x ICC 4962, and ICC 4973 x ICC 4962 recorded significantly high seed mass.

4.2.1.4 Number of pods per plant

Significantly highest number of pods per plant was recorded in ICC 12477, but its 100-seed weight was lowest among all the parents. Even then it's per plant yield was significantly high. Among F_1s ICC 12477 x ICC 12478, ICC 12475 x ICC 12478 and ICC 12475 x ICC 4918 recorded highest number of pods per plant. In desi F_2 trial ICC 14876 and ICC 12477 had highest number 106 and 105 pods per plant respectively. The lowest number of pods 34 per plant was recorded in ICC 3137. F_2s of ICC 12477 x ICC 4918 (140) and ICC 12426 x ICC 3137 (77) recorded highest and lowest number of pods per plant respectively.

Among kabuli type parents ICC 12492 and ICC 12494 had highest, while ICC 12968 and ICC 4962 had lowest number of pods per plant. The F_1s ICC 12495 x ICC 12968, ICC 12491 x ICC 12492 and ICC 12491 x ICC 12968 had significantly high number of pods. In kabuli F_2 trial the range of pods per plant was narrow compared to desi trial and it was from 45 (ICC 4962) to 82 (ICC 12493) pods per plant. Among the F_2s ICC 12492 x ICC 12494 (163) and ICC 12492 x ICC 12493 (131) recorded highest number of pods $plant^{-1}$.

4.2.1.5 Seeds per pod

The range of number of seeds per pod in desi type parents was from 1.07 (ICC 14876) to 1.43 (ICC 12490). The F_1s of ICC 12490 x ICC 14876, ICC 12490 x ICC 12426, and ICC 12476 x ICC 12426 were with highest seeds per pod. In desi F_2 trial the range of number of seeds per pod was from 1.06 (ICC 3137) to 1.45 (ICC 12426). In F_2s the variation was from 1.07 (ICC 14876 x ICC 3137 and ICC 12475 x ICC 12478) to 1.46 9ICC 12490 x ICC 12426). The mean seed pot^{-1} ratio was 1.22.

The range in kabuli type parents was from 1.00 (ICC 12495) to 1.4 (ICC 4962). Most of the F_1 crosses with ICC 4962 recorded high seeds per pod. In kabuli F_2 trial the range of seeds per pod was narrow in parents 1.39 (ICC 4962) to 1.12 (ICC 12968). In crosses there was slight variation ranging from 1.40 (ICC 12493 x ICC 4962) to 1.1 (ICC 12968 x ICC 4973). The average number of seeds per pod was 1.24.

4.2.1.6 Seed yield per plant

Significantly high yield (17.97 g plant^{-1}) was recorded for ICC 12477 among desi type parents, and among the F_1s ICC 12475 x ICC 4918, ICC 12475 x ICC 12478 and ICC 12477 x ICC 12478 recorded high yield plant^{-1}. In desi F_2 trial among the parents ICC 14876 (15.45 g) recorded highest yield plant^{-1} followed by ICC 12426 (14.52 g). Among the F_2s many crosses recorded higher yields than ICC 14876. The F_2s of ICC 12490 x ICC 4918 (22.77 g), ICC 12479 x ICC 4918 (21.33 g), ICC 12477 x ICC 4918 (20.96 g), ICC 4918 x ICC 12426(20.69 g) and ICC 12475 x ICC 4918(19.07 g) recorded high yield plant^{-1}.

Among kabuli parents in F_1 trail, ICC 12492 and ICC 12495 recorded high yield per plant and ICC 12968 lowest yield per plant. In kabuli F_2 trial among the parents ICC 4973 (14.18) recorded highest yield plant^{-1} and ICC 12968 (9.6 g) was the lowest. The F_2s with less plant stand ICC 12492 x ICC 12494 and ICC 12492 x ICC 12493 recorded high yield plant^{-1}.

4.2.1.7 Plot yield

ICC 12479 and ICC 12478 among desi type parents and F_1s of ICC 12479 x ICC 12478, ICC 12479 x ICC 12490, ICC 12475 x ICC 4918 and ICC 12475 x ICC 12478 recorded highest yields per plot. In F_2 trial highest yield was recorded in ICC 12479 (914 g) followed by ICC 12478 (889 g). Among F_2 s high yields were recorded in ICC 12477 x ICC 12478 (980 g), ICC 12475 x ICC 12479 (930 g) and ICC 12475 x ICC 14876 (917 g).

Among kabuli parents ICC 4973 and ICC 12495 were high yielding and among the F_1s ICC 12491 x ICC 12968, ICC 12495 x ICC 4962, ICC 12493 x ICC 12968 and ICC 12491 x ICC 12497 recorded significantly high yields. In Kabuli F_2 trial among the parents ICC 4973 (753 g) and ICC 12492 (718 g) recorded the highest yield and the F_2s of ICC 4973 x ICC 4962 (786 g), ICC 12968 x ICC 4973 (774 g) and ICC 12495 x ICC 12968 (750 g) recorded high yields.

4.2.1.8 Pod border damage

Among desi type parents ICC 12479 (6.43%), ICC 12476 (7.89%) and ICC 12478 (9.47%) were with less damage than the resistant check ICC 12475 (9.75%), but statistically on par with each other. Among the F_1s ICC 12478 x ICC 12479 (7.05%), ICC 12475 x ICC 12479 (7.11%), ICC 12490 x ICC 14876 (7.30%) and ICC 12476 x ICC 12478 (8.19%) recorded lowest damage which indicates the crosses between less susceptible parents were also less susceptible. In desi F_2 trial among the parents lowest damage was recorded in ICC 12475 (6.98%) followed by ICC 12477 (7.24%) and ICC 12479 (7.85%). The susceptible parents ICC 12426 (15.40%), ICC 4918 (21.30%) and ICC 3137 (28.50%) recorded highest damage.

Among the F_2s with ICC 12475 as parent, except ICC 12475 x ICC 4918 and ICC 12475 x ICC 3137 the remaining F_2s recorded less than 10% damage. The F_2s of ICC 12476 x ICC 12477 (8.90%), ICC 12477 x ICC 12478 (8.9%), ICC 12477 x ICC 12479 (9.01%) and ICC 72477 x ICC 14876 (9.91%) recorded lowest damage. Among the F_2s the crosses with ICC 12479, ICC 12490 and ICC 14876 were less susceptible. The F_2s of ICC 12479 x ICC 12490 (9.68%) and ICC 12479 x ICC 14876 (6.68%) were less susceptible. F_2s with ICC 14876 i.e. ICC 14876 x ICC 12426 (9.36%) and ICC 14876 x ICC 4918 (9.88%) were less susceptible. Among all the F_2s ICC 12479 x ICC 14876 (6.681) was least susceptible to *H. armigera*.

Among the kabuli parents ICC 12492 (10.11%), ICC 12491 (12.84%), and ICC 12495 (13.28%) were less susceptible, and the F_1 crosses ICC 12493 x ICC 12495, ICC 12493 x ICC 12494, ICC 12495 x ICC 12968, and ICC 12495 x ICC 12494 recorded significantly less damage percentage. In F_2 kabuli trial among the parents ICC 12495 (8.2%) and ICC 12493 (9.0%) were less susceptible. F_1s of ICC 12492 x ICC 12493 (6.7), ICC 12492 x ICC 12494 (6.5%), ICC 12495 x ICC 4973 (8.0) and ICC 12495 x ICC 4962 (9%) were less susceptible.

4.2.2 ANALYSIS OF VARIANCE FOR COMBINING ABILITY

ANOVA was conducted for method -2 of Griffing (1956) and Gardner and Eberhart (1966). In 10 x 10 F_1 desi diallel general combining ability (GCA) variances were highly significant (1% level) for all characters under study, except days to maturity. For this character variance for entries was significant only at 5% level of significance. The specific combining ability (SCA) variances were highly significant for total number of pods per plant, yield per plant and yield kg per ha^{-1} at 1% level and for pod borer damage percentage, variance for entries was significant only at 5% level of significance (Tables 10.1 and 11.1).

In 8 x 8 F_1 kabuli chickpea diallel general combining ability, variances were highly significant for all the characters studied. For specific combining ability, the variances were highly significant at 1% level for all characters except for pod borer damage percentage and days to maturity (Tables 14.1 and 15.1).

For F_2s ANOVA was conducted for method 2 of Griffings (1956) and the values were presented for F_2 desi and F_2 kabuli (Tables 12.1 and 16.1). In the both the F_2 trials general combining ability (GCA) variances were highly significant for all characters. In desi chickpea specific combining ability (SCA) variances were significant for all the characters except days to maturity, pod borer damage (%) and plot yield. In kabuli chickpea SCA variances for days to maturity and damage (%) were not significant.

Table 10.1: Estimates of GCA and SCA mean squares and variances from F_1 desi chickpea 10 x 10 diallel, Giffing (1956).

	d.f	Days to 50% flow.	Days to maturity	100-seed Wt. (g)	Seeds pod^{-1}	Pods plant^{-1}	Yield plant^{-1} (g)	Yield kg ha^{-1}	Pod borer damage (%) Actual	Angular transformed
Mean squares										
GCA	9	181.650**	30.382*	32.685**	0.047**	2030.92**	14.87**	143457**	63.288**	45.815**
SCA	45	22.736	9.401	0.972*	0.0050*	667.388**	21.661**	53173.3**	7.100*	5.044*
Error	108	19.292	12.093	0.280	0.003	159.745	5.707	26114.6	4.577	3.494
Variances										
$\sigma^2 g$		13.533**	1.524*	2.710**	0.004**	89.265**	0.764**	9778.5**	4.682**	3.527**
$\sigma^2 s$		3.444	2.692	0.692*	0.002*	507.644**	15.954**	27058.8**	2.522*	1.55*
$\sigma^2 A$		27.066	3.048	5.400	0.008	178.53	1.528	19557	9.364	7.054
$\sigma^2 D$		3.444	2.692	0.692	0.002	507.644	15.954	27058.8	2.522	1.551
Predictability Ratio		0.941	0.866	0.985	0.949	0.858	0.578/	0.843	0.946	0.947

Table 10.2: Estimates of combining ability effects of parents in F_1 desi chickpea 10 x 10 diallel, Giffing (1956).

Parents	Days to 50% flow.	Days to maturity	100-seed Wt. (g)	Pods plant^{-1}	Seeds pod^{-1}	Yield Kg ha^{-1}	Pod borer damage (%) Actual	Anguular transformed
ICC 12475 (R)	-3.572**	-1.589	0.569**	4.709	0.044**	201.909**	0.933	-0.701
ICC 12476	7.567**	2.856**	-1.359**	12.92**	0.04**	-133.7**	2.566**	-2.267**
ICC 12477	0.483	-0.006	-1.477*	15.942**	0.02	41.406	0.931	0.936
ICC12478	-0.239	0.189	-0.637**	4.32	-0.051**	55.484	-1.47*	-1.3*
ICC 12479	-3.239**	-1.672	-0.875**	0.042	-0.06**	100.217*	-2.226**	-1.988**
ICC 12490	4.594**	0.383	-1.471**	-3.341	0.131**	23.489	-0.844	-0.694
ICC 14876	-1.933	0.022	-1.225**	-0.713	-0.051**	-81.522	-1.764**	-0.437**
ICC 4918 (S)	-4.072**	-1.783	1.997**	-6.88*	0.024	-24.461	3.368**	2.778**
ICC 12426 (S)	-2.433**	-0.728	1.427**	-9.152**	0.063**	-22.111	1.828**	1.623**
ICC 3137 (S)	2.844**	2.328*	3.051*	-17.850*	-0.033*	-160.71**	3.676**	3.052**
S.E ±	1.203	0.952	0.145	3.461	0.014	44.256	0.586	0.512

Significant at 5% probability; ** Significant at 1% probability; R – Resistant check; S – Susceptible check.

Table 10.3: Estimates of SCA effects of F_1s in desi chickpea 10 x 10 diallel, Giffing (1956).

F_1s	Days to 50% flow.	Days to maturity	100-seed Wt (g)	Pods plant^{-1}	Seeds pod^{-1}	Yield plant^{-1}(g)	Yield kg ha^{-1}	Pod borer damage (%) Actual	Pod borer damage (%) Angular transformed
ICC 12475 x ICC 12476	-7.831*	-3.182	0.731	-10.201	-0.046	-2.709	105.831	3.155	2.845
ICC 12475 x ICC 12477	-0.747	3.679	-0.015	-13.957	0.054	-1.951	43.692	1.021	0.901
ICC 12475 x ICC 12478	-6.025	-3.848	0.295	11.199	-0.039	0.841	-6.919	0.519	0.231
ICC 12475 x ICC 12479	3.308	3.013	-0.281	17.477	0.011	2.975	-196.111	-2.426	-2.428
ICC 12475 x ICC 12490	6.141	4.624	0.743	-5.407	-0.050	-1.622	118.642	3.036	2.366
ICC 12475 x ICC 14876	-1.664	-4.348	0.540	-2.768	-0.009	-0.668	-30.147	2.799	2.376
ICC 12475 x ICC 4918	7.475*	2.790	0.924*	17.132	-0.009	5.226**	325.492*	-2.487	-1.811
ICC 12475 x ICC 12426	-8.164*	-4.265	-1.063*	41.871**	0.081	8.843**	257.808	-2.561	-2.048
ICC 12475 x ICC 3137	2.225	4.346	-0.189	17.032	0.075	4.782*	246.544	-0.905	-0.551
ICC 12476 x ICC 12477	-2.221	0.902	1.233**	-26.768*	-0.038	-2.801	269.533	-2.786	-2.570
ICC 12476 x ICC 12478	3.169	-0.626	-1.050*	24.388*	0.063	2.966	-380.841	-0.461	-0.327
ICC 12476 x ICC 12479	2.169	-1.432	0.907*	4.599	0.001	1.027	193.921	1.917	1.943
ICC 12476 x ICC 12490	1.003	1.179	-0.169	84.449*	-0.045	12.253**	-145.210	0.942	1.069
ICC 12476 x ICC 14876	8.531*	2.874	0.288	4.955	0.098*	1.818	-165.030	0.332	0.139
ICC 12476 x ICC 4918	5.003	-2.987	-0.688	7.721	0.002	1.658	-40.033	-3.810*	-2.941*
ICC 12476 x ICC 12426	5.697	1.624	-1.224**	-12.740	0.103*	-2.182	113.883	2.436	2.245
ICC 12476 x ICC 3137	3.086	2.902	-1.477**	39.221*	0.076	7.804**	-31.914	-2.388	-1.942
ICC 12477 x ICC 12478	1.253	0.235	0.057	11.766	-0.012	0.431	202.083	4.532*	3.875*
ICC 12477 x ICC 12479	3.586	2.096	-0.802	30.31*	0.009	2.213	-257.450	2.690	2.581
ICC 12477 x ICC 12490	-1.581	-0.293	0.322	-8.373	-0.028	-1.428	150.678	3.265	2.825
ICC 12477 x ICC 14876	-1.386	0.735	0.069	-3.268	-0.042	-0.897	-120.84	-1.102	-0.861
ICC 12477x ICC 4918	1.086	2.874	0.301	32.232**	-0.033	4.68*	144.761	1.981	1.498
ICC 12477 x ICC 12426	-4.221	-1.515	0.541	-20.362	-0.025	-1.763	17.711	-0.907	-0.718
ICC 12477 x ICC 3137	5.169	0.429	-0.892*	-3.468	0.056	0.266	-45.153	-0.402	-0.321
ICC 12478 x ICC 12479	-0.025	3.235	0.582	-14.868	-0.01	-1.841	-293.401	-1.942	-1.908

Contd.

Conti....table 10.3

F_1s	Days to 50% flow.	Days to maturity	100-seed wt. (g)	Pods plant^{-1}	Seeds Pod^{-1}	Yield plant^{-1}(g)	Yield kg ha^{-1}	Pod borer damage (%)	
								Actual	Angular transformed
ICC 12478 x ICC 12490	4.141	3.179	-1.198**	-10.218	0.069	-1.921	71.933	-0.957	-1.242
ICC 12478 x ICC 14876	-1.331	1.207	1.089*	2.421	0.009	0.664	222.841	5.566**	4.903**
ICC 12478 x ICC 4918	2.475	0.346	-0.371	25.321*	0.016	5.434**	77.017	-3.483*	-2.553*
ICC 12478 x ICC 12426	0.503	0.957	0.913*	30.393**	-0.004	6.491**	306.010	0.481	0.369
ICC 12478 x ICC 3137	-3.442	-0.098	0.921*	7.621	-0.031	2.004	257.203	-2.054	-1.278
ICC 12479 x ICC 12490	-5.525	-1.626	-0.764	-21.807*	0.033	-3.696	216.361	-0.415	-0.409
ICC 12479 x ICC 14876	-4.331	-1.265	0.217	-2.501	-0.011	-0.402	4.273	2.691	2.446
ICC 12479 x ICC 4918	-4.525	-6.793*	0.565	-0.868	-0.024	0.119	82.017	2.163	2.262
ICC 12479 x ICC 12426	1.836	3.152	1.105*	19.071	-0.066	4.702*	136.233	0.043	0.392
ICC 12479xICC 3137	-1.109	-3.904	-0.788	-13.168	0.003	-2.462	30.603	-1.095	-0.437
ICC 12490 x ICC 14876	3.503	-0.654	-0.201	0.016	0.168**	2.128	69.200	-2.784	-2.751
ICC 12490 x ICC 4918	3.975	3.485	0.568	-13.351	-0.101*	-3.152	-271.280	0.461	0.491
ICC 12490 x ICC 12426	4.003	-2.237	1.851**	-14.545	0.041	-1.038	-59.372	0.941	0.878
ICC 12490 x ICC 3137	-5.609	1.041	-0.368	24.216*	0.026	5.621**	327.397*	-1.437	-0.831
ICC 14876 x ICC 4918	4.503	5.513	-0.245	-14.179	0.163**	-0.427	168.189	-4.006*	-3.345*
ICC 14876 x ICC 12426	-1.471	0.790	-0.535	19.493	0.192**	0.939	-127.090	-1.836	-1.953
ICC 14876 x ICC 3137	-5.747	-4.265	-2.591**	-1.479	-0.068	-1.965	147.175	-3.914*	-3.078*
ICC 4918 x ICC 12426	2.669	-1.737	0.683	9.327	-0.039	1.101	101.211	3.508*	2.520*
ICC 4918 x ICC 3137	-2.609	0.541	0.917*	-14.779	0.002	-2.777	-104.351	4.244*	2.907*
ICC 12426 x ICC 3137	-2.914	3.485	0.810	-7.841	0.063	-1.604	210.160	2.671	1.967
SE OF S(I,J)±	3.627	2.871	0.437	10.436	0.042	1.973	133.437	1.767	1.544
SE OF S(I,J)-S(I,K)±	5.947	4.709	0.716	17.113	0.069	3.235	218.807	2.897	2.531
SE OF S(I,J)-S(K,L)±	5.670	4.489	0.683	16.317	0.066	3.084	208.625	2.762	2.413

Significant at 5% probability; ** Significant at 1% probability

4.2.3 GENERAL AND SPECIFIC COMBINING ABILITY EFFECTS AND GENETIC CONSTANTS

The estimates of GCA and SCA effects along with other genetic constants were presented (Tables 10.2, 10.3, 11.2 and 11.3 for desi F_1s and 14.2, 14.3, 15.2 and 15.3 for kabuli F_1s). The estimates of GCA and SCA effects, along with other genetic constants for F_2s of desi 10 x 10 diallel (Tables 12.2, 12.3, 13.1 and 13.2) and kabuli 8 x 8 diallels (Tables 16.2, 16.3, 17.1 and 17.2) were presented. Parameters were computed based on method 2 of Griffings (1956) and Eberhart and Gardner (1966).

4.2.3.1 Days to 50% flowering

The GCA effects were significant for ICC 12475, ICC 12476, ICC 12479 and ICC 4918 at 1% level and for ICC 12426 and ICC 3137 at 5% level in desi F_1 diallel. Among these lines, ICC 12475, ICC 12479, ICC 4918 and ICC 12426 showed significant negative GCA effects (Table 10.2). The SCA effects were significant in four of the 45 crosses. Two crosses showed significant negative SCA effects and two crosses showed significant positive SCA effects (Table 10.3). From Gardner and Eberhart analysis, it was shown that average heterosis was not significant for days to 50% flowering. The varietal effects were significant for ICC 4918 and ICC 3137. The heterosis due to varieties was significant for ICC 4918. Eight parents recorded significant GCA value and one cross ICC 12475 x ICC 12476 showed significant SCA value (Tables 11.2 and 11.3).

In F_2 trial ICC 12476 and ICC 3137 showed significant positive GCA effects and ICC 12475, ICC 4918 and ICC 12426 showed significant negative GCA effects (Table 12.2). Among the F_2s eight showed significant positive SCA effects and one negative SCA effect (Table 12.3). According to Gardner and Eberhart analysis the average heterosis was significant and positive. The varietal effects were significant for ICC 12475, ICC 12476, ICC 12490, ICC 4918 and ICC 3137. The heterosis effects, due to varieties was significant for ICC 3137. Significant negative GCA effects were recorded in ICC 12475, ICC 4918 and ICC 12426 (Table 13.1).

Table 11.1: ANOVA for different characters in F_1 desi chickpea 10 x 10 diallel, Gardner and Eberharts (1966).

Source	d.f	Days to 50% flow.	Days to maturity	100-seed Wt. (g)	Pods plant^{-1}	Seeds pod^{-1}	Yield plant^{-1}(g)	Yield kg ha^{-1}	Pod borer damage (%) Actual	Pod borer damage (%) Angular transformed
Entries	54	147**	38.69	18.77**	2283**	.036**	61**	204662**	40.3**	35.52**
Varieties (vi)	9	185*	33.44	36.27**	2086**	105**	23.8**	247071*	86.78**	62.5**
Heterosis (hij)	44	141**	38.47	15.57**	1874**	.03**	50.1**	153980*	42.43**	30.31**
Average (h)	1	72.18	95.65	1.87	22066**	103*	904**	2052989**	19.21	21.89
Variety (vi)	9	185.6**	24.84	22.18**	1062**	.03**	26**	118631**	40.11**	62.5**
Specific (sij)	17	141.6**	20.08	1.697**	1055**	.01**	29**	70041**	15.37**	28.86**
Error	108	23.67	14.84	.3434	196	.003	7	32049	63.3	10.85
GCA	9	181**	30.38	32.68**	1230**	.047**	14.8*	143556**	3.55**	4.2886**
SCA	45	11	4.70	.4860	933.69	.024	10.7*	26586	11.00	45.8**
GCA var.	9	7.6**	2.04	95**	6.28**	14.58**	2.12*	4.47**	.6319**	2.52**
SCA var.	45	.4801	.3167	1.41	1.7	.75	1.54*	.82	5881	10.68**

Significant at 5%; ** Significant at 1%

Table11.2: **Estimates of combining ability effects of parents in F_1 desi chickpea 10 x10 diallel, Gardner and Eberhart (1966).**

Desi Parents	Days to 50% flow.	Days to maturity	100-seed wt. (g)	Pods plant^{-1}	Seed pod^{-1}	Yield plant^{-1}g	Yield kg ha^{-1}	Pod borer damage(%)	
								Actual	Angular transformed
μ_v	63.430	107.6	15.59	75.51	1.197	11.610	1184.1	11.971	19.74
μ_c	65.150	109.6	0.276	105.5	1.233	17.670	1473.1	12.851	20.48
H	1.715	1.974	0.523*	29.98**	0.0358	6.072**	289.2**	0.884	0.94
SEof ħ	1.701	1.347	0.230	4.895	0.020	0.925	62.5	0.828	0.72
				Varietal effect (v_i)					
ICC 12475	-3.101	-2.967	0.523	-2.24	-0.092	-0.049	208.0	-2.218	-1.570
ICC 12476	7.233	6.701	-1.767**	-7.44	0.002	-1.439	9.2	-4.078	-3.994
ICC 12477	1.901	-2.967	-3.133**	57.36**	0.019	6.364**	116.9	-1.561	-0.958
ICC12478	0.567	-0.300	-1.667**	-10.84	-0.102	-2.562	119.7	-3.318	-2.863
ICC 12479	-2.767	0.033	-1.893**	15.49	-0.062	1.484	467.3**	-5.541*	-5.424**
ICC 12490	5.567	-1.967	-3.110**	0.36	0.233**	0.584	44.4	-2.491	-1.814
ICC 14876	-2.767	1.367	-1.540*	21.76	-0.130	1.414	-22.2	-1.678	-1.041
ICC 4918	-16.767**	-3.967	2.893**	-13.51	0.088	-0.062	-53.8	8.176**	6.813**
ICC 12426	-2.433	0.033	1.540*	-26.11*	0.178**	-2.016	-285.9	1.992	2.192
ICC 3137	12.567**	4.033	8.153**	-34.84**	-0.133**	-3.719	-603.6**	10.716**	8.658**
SE of v_i ±	4.616	3.655	0.623	13.28	0.054	2.511	169.8	2.248	1.965
				Average heterosis contributed by variety (h_i)					
ICC 12475	-2.696	-0.140	0.410	7.77	0.0030	1.927	130.5	0.234	0.111
ICC 12476	5.267	-0.659	-0.634	22.18**	0.0521	3.299*	-184.3	-0.703	-0.360
ICC 12477	-0.622	1.970	0.119	-16.98*	-0.0393	-3.728*	-22.7	2.281	1.887
ICC12478	-0.696	0.451	0.262	12.98	0.0009	1.711	-5.8	0.251	0.174
ICC 12479	-2.474	-2.251	0.096	-10.27	-0.0377	-2.433	-177.9	0.726	0.965
ICC 12490	2.415	1.822	0.111	-4.69	0.0183	-0.93	1.7	0.535	0.283
ICC 14876	-0.733	-0.881	-0.606	-5.45	0.0193	-2.916	-93.8	-1.233	-1.222
ICC 4918	5.748*	0.266	0.734	-0.16	-0.0271	0.641	3.2	-0.959	-0.838
ICC 12426	-1.622	-0.992	0.876*	5.20	-0.0349	1.850	161.1	1.11	0.702
ICC 3137	-4.585	0.414	-1.369**	-0.56	0.0453	0.578	188.1	-2.242	-1.702
SE of h_i ±	2.827	2.238	0.381	8.13	0.0330	1.537	104.0	1.377	1.203

Contd...

Conti...table 11.2

Desi parents	Days to 50% flow.	Days to Maturity	100-seed wt (g)	Pods plant^{-1}	Seed pod^{-1}	Yield plant^{-1}(g)	Yield kg ha^{-1}	Pod borer damage (%) Actual	Pod borer damage (%) Angular transformed
General combining ability (g_i)									
ICC 12475	-4.246**	-1.624**	0.672**	6.652**	-0.043**	1.90**	234.54**	-0.874*	-0.673*
ICC 12476	8.883**	2.691**	-1.517**	18.467**	0.053**	2.58**	-179.79**	-2.742**	-2.357**
ICC 12477	0.328	0.487	-1.447**	11.696**	-0.029**	-0.54**	35.72	1.501**	1.408**
ICC 12478	-0.413	0.302	-0.571**	7.567**	-0.050**	0.43**	54.03*	-1.408**	-1.257**
ICC 12479	-3.857**	-2.235**	-0.85**	-2.526**	-0.069**	-1.69**	55.73*	-2.044**	-1.747**
ICC 12490	5.198**	0.839	-1.444**	-4.515**	0.135**	-0.63**	23.91	-0.710*	-0.624*
ICC 14876	-2.117*	-0.198	-1.377**	-4.578**	-0.046**	-2.20**	-104.99**	-2.072**	-1.743**
ICC 4918	-2.635**	-1.717**	2.181**	-6.922**	0.017*	0.61**	-23.65	3.129**	2.568**
ICC 12426	-2.839**	-0.976	1.646**	-7.852**	0.054**	0.84**	18.16	2.106**	1.798**
ICC 3137	1.698*	2.431**	2.707**	-17.989**	-0.021**	-1.28**	-113.68	3.116**	2.626**
SE of g_i ±	0.656	0.519	0.089	1.888	0.008	0.35	24.14	0.320	0.279

Significant at 5% probability; ** Significant at 1% probability

Table11.3: Estimates of SCA effects of F_1s in desi chickpea 10x10 diallel, Gardner and Eberhart (1966).

Desi F_1s	Days to 50% flow.	Days to maturity	100-seed Wt (g)	Pods plant^{-1}	Seeds pod^{-1}	Yield plant^{-1}(g)	Yield kg ha^{-1}	Pod borer damage (%) Actual	Pod borer damage (%) Angular transformed
ICC 12475 x ICC 12476	-8.785*	-3.341	0.7358	-23.14*	-0.0663	-5.12*	66.7	3.111*	2.736*
ICC 12475 x ICC 12477	-0.230	2.863	-0.1983	-17.11	0.0568	-2.604	-35.8	0.231	0.228
ICC 12475 x ICC 12478	-5.489	-4.285	0.0762	0.56	-0.0464	-1.173	-90.7	0.236	-0.012
ICC 12475 x ICC 12479	4.289	3.252	-0.4579	12.65	0.0129	1.998	-236.9*	-2.827	-2.869
ICC 12475 x ICC 12490	5.901	3.844	0.5619	-11.63	-0.0648	-2.975	33.0	2.682	2.096
ICC 12475 x ICC 14876	-1.119	-4.452	0.5384	-6.31	-0.0289	-1.525	-91.9	2.888	2.482*
ICC 12475 x ICC 4918	6.401	2.401	0.5877	9.78	-0.0097	3.481	239.5*	-2.466	-1.801
ICC 12475 x ICC 12426	-7.396*	-4.341	-1.4346*	33.18**	0.0824	6.794	132.3	-3.057	-2.423
ICC 12475 x ICC 3137	3.733	3.919	0.001	9.78	0.0544	3.052	114.3	-0.564	-0.325
ICC 12476 x ICC 12477	-3.693	0.215	1.3112*	-33.52**	-0.0473	-3.798	268.7**	-3.341*	-3.123*
ICC 12476 x ICC 12478	1.715	-0.933	-1.0077	10.14	0.0474	0.609	-385.9**	-0.509	-0.452
ICC 12476 x ICC 12479	1.159	-1.063	0.9916	-3.83	-0.0087	-0.293	231.9*	1.751	1.62
ICC 12476 x ICC 12490	-1.231	0.531	-0.0886	74.62**	-0.0689	10.557**	-152.1	0.824	0.917
ICC 12476 x ICC 14876	7.085	2.901	0.5479	-2.18	0.0739	0.618	-148.1	0.655	0.363
ICC 12476 x ICC 4918	1.937	-3.248	-0.7629	-3.23	-0.0102	-0.431	-47.3	-3.555*	-2.811
ICC 12476 x ICC 12426	4.474	1.678	-1.3351**	-25.04*	0.0929	-4.573*	67.1	2.174	1.988
ICC 12476 x ICC 3137	2.604	2.604	-1.0262	28.37**	0.045	5.731*	-85.4	-1.812	-1.598
ICC 12477 x ICC 12478	1.270	-0.73	-0.0884	7.31	-0.0093	-0.168	156.6	3.738*	3.188
ICC 12477 x ICC 12479	4.048	1.807	-0.9059	31.67**	0.0218	2.649	-259.9*	1.778	1.695
ICC 12477 x ICC 12490	-2.341	-1.611	0.2141	-8.41	-0.0294	-1.367	103.4	2.401	2.110
ICC 12477 x ICC 14876	-1.359	0.104	0.1404	-0.61	-0.0434	-0.341	-144.3	-1.524	-1.199
ICC 12477xICC 4918	-0.507	1.956	0.0364	31.07**	-0.0226	4.348*	97.1	1.488	1.064
ICC 12477 x ICC 12426	-3.970	-2.119	0.2408	-22.87*	-0.0133	-2.398	-69.5	-1.916	-1.537
ICC 12477 x ICC 3137	6.159	-0.526	-0.6303	-4.53	0.0475	-0.05	-139.1	-0.572	-0.539

Contd.

Conti ......table 11.3

Desi F_1s	Days to 50% flow.	Days to maturity	100-seed Wt. (g)	Pods $plant^{-1}$	Seeds Pod^{-1}	Yield $plant^{-1}$(g)	Yield kg ha^{-1}	Pod borer damage (%)	
								Actual	Angular transformed
ICC 12478 x ICC 12479	0.456	3.326	0.4419	-21.01	-0.0071	-2.764	-300.1**	-2.347	-2.365
ICC 12478 x ICC 12490	3.401	2.252	-1.3416*	-17.74	0.0573	-3.221	20.4	-1.314	-1.528
ICC 12478 x ICC 14876	-1.285	0.956	1.1249	-2.41	-0.0027	-0.139	195.2	5.651**	4.993**
ICC 12478 x ICC 4918	0.901	-0.193	-0.6692	16.67	0.0164	3.742	25.1	-3.466*	-2.559*
ICC 12478 x ICC 12426	0.77	0.733	0.5786	20.39	-0.0016	4.496*	214.6*	-0.020	-0.022
ICC 12478 x ICC 3137	-2.433	-0.674	1.1475*	-0.93	-0.0481	0.327	159.0	-1.717	-1.068
ICC 12479 x ICC 12490	-5.822	-1.878	-0.8657	-23.52*	0.0311	-3.959	207.8	-0.891	-0.893
ICC 12479 x ICC 14876	-3.841	-0.841	0.2941	-1.52	-0.0128	-0.169	42.7	2.657	2.339
ICC 12479 x ICC 4918	-5.656	-6.656	0.3067	-3.71	-0.0147	-0.537	73.1	2.061	2.059
ICC 12479 x ICC 12426	2.548	3.604	0.8112	14.89	-0.0548	3.744	87.9	-0.577	-0.197
ICC 12479xICC 3137	0.344	-3.804	-0.5199	-15.91	-0.0052	-3.102	-24.5	-0.877	-0.424
ICC 12490 x ICC 14876	2.771	-1.248	-0.1261	-0.41	0.1518**	1.985	39.7	-2.771	-2.687*
ICC 12490 x ICC 4918	1.622	2.604	0.3066	-17.59	-0.1049*	-4.184*	-325.1*	0.406	0.457
ICC 12490 x ICC 12426	3.493	-2.804	1.5543**	-20.12	0.0389	-2.372	-152.7	0.369	0.461
ICC 12490 x ICC 3137	-5.378	0.122	-0.1034	20.08	0.0038	4.605*	227.4	-1.171	-0.648
ICC 14876 x ICC 4918	2.937	5.307	-0.3271	-15.72	0.1579**	-0.963	138.3	-3.619*	-3.001
ICC 14876 x ICC 12426	-1.193	0.901	-0.6525	16.61	-0.1944**	0.101	-196.5	-1.966	-1.995
ICC 14876 x ICC 3137	-4.730	-4.507	-2.147**	-2.92	-0.0905	-2.484	71.0	-3.206*	-2.518*
ICC 4918 x ICC 12426	1.326	-1.915	0.2301	2.62	-0.0295	-0.627	7.5	3.310	2.382
ICC 4918 x ICC 3137	-3.211	0.011	1.0256	-20.05	-0.0093	-4.186*	-204.8	4.884**	3.371**
ICC 12426 x ICC 3137	-1.674	3.270	0.8834	-14.45	0.0452	-3.315	70.3	2.793	2.046
SE of Sij	3.2911	3.3970	0.57898	10.341	0.04989	2.0340	107.88	1.61	1.23

* Significant at 5%; ** Significant at 1%

In kabuli F_1 diallel, all the parents showed significant GCA effects, except ICC 12492. Of these, ICC 12968 and ICC 12491 showed negetive and the remaining had positive effects. Among 28 crosses ICC 12495 x ICC 12968, ICC 12492 x ICC 4973 and ICC 12492 x ICC 12494 showed significant positive SCA effect while ICC 12492 x ICC 12968 and ICC 12495 x ICC 4973 showed significant negative effects (Tables 14.2 and 14.3). From Gardner and Eberhart analysis the average heterosis was not significant. The varietal effects were significant for all varieties except ICC 12492. The heterosis due to varieties was not significant. Except ICC 12492 all the parents recorded significant GCA values and two crosses showed significant SCA values (Tables 15.2 and 15.3).

In kabuli F_2 trial all parents showed significant GCA effects. ICC 12491 and ICC 12968 showed significant negative GCA effects and the remaining six parents showed significant positive GCA effects. Among the F_2s four showed significant positive SCA effects and four negative effects (Tables 16.2 and 16.3). According to a Gardner and Eberhart analysis average heterosis effect was not significant. Varietal effects were significant for ICC 12491, ICC 12968 and ICC 4962. Heterosis effect due to varieties was significant for ICC 12491 and ICC 12968. Except ICC 12491 and ICC 12494 all the varieties showed significant GCA effects of which, GCA effect for ICC 12968 was negative. ICC 12495 x ICC 12968 and ICC 12492 x ICC 12495 showed significant negative SCA effects (Tables 17.1 and 17.2).

4.2.3.2 Days to maturity

In desi F_1 trial two parents (ICC 12476 and ICC 3137) showed significant positive GCA values (Table 10.2). Among the 45 crosses ICC 12479 x ICC 4918 showed significantly negative SCA effect (Table 10.3). According to Gardner and Eberhart analysis ICC 12479, ICC 12475 and ICC 4918 were with significantly negative GCA effects. The cross ICC 12479 x ICC 4918 was with significantly negative SCA effect (Tables 11.2 and 11.3). In desi F_2 trial the parents ICC 12476, ICC 12490, ICC 4918, ICC 12426 and ICC 3137 showed significant positive GCA effects while ICC 12475 showed significant negative GCA effect. The F_2 of ICC 14876 x ICC 4918 showed significant positive SCA effect.

Table 12.1: Estimates of GCA and SCA mean squares and variances from F_2 desi chickpea 10 x 10 diallel, Griffing (1956).

Mean squares	d.f	Days to 50% flow.	Days to Maturity	100-seed Wt. (g)	Seeds pod^{-1}	Pods plant^{-1}	Yield plant^{-1}(g)	Yield plot^{-1}(g)	Pod borer damage (%) Actual	Angular transformed
GCA	9	264.948**	108.788**	39.934**	0.044**	910.531**	15.79**	19875.41**	93.353**	71.418**
SCA	45	28.299	12.462	1.162**	0.003**	148.607**	5.247**	5396.103	3.762	3.143
Error	108	8.737	10.45	0.133	0.001	41.484	1.28	4280.671	2.685	2.409
Variance										
$\sigma^2 g$	9	21.351**	8.195**	3.317**	0.004**	72.421**	1.209**	1299.562**	7.556**	5.751**
$\sigma^2 s$	45	19.562	2.012	1.029**	0.003**	107.123**	3.966**	1115.432	1.077	0.734
$\sigma^2 A$		42.702	16.39	6.634	0.008	144.842	2.418	2599.124	15.112	11.502
$\sigma^2 D$		19.562	2.012	1.029	0.003	107.123	3.966	1115.432	1.077	0.734
Predictability ratio		0.983	0.954	0.998	0.988	0.977	0.961	0.902	0.985	0.983

Table12.2 : Estimates of combining ability effects of parents in F_2 desi chickpea 10 x 10 diallel, Griffing (1956).

Parents	Days to 50% flow.	Days to Maturity	100-seed Wt. (g)	Seeds Pod^{-1}	Pods Plant^{-1}	Yield plant^{-1} (g)	Yield plot^{-1}(g)	Pod damage (%) Actual	Angular transformed
ICC 12475	-6.717**	-2.667**	0.202*	-0.044*	-2.514	-0.134	46.751**	-2.643**	-2.579**
ICC 12476	7.811**	5.111**	-1.505**	0.056**	-9.473**	-2.053	22.549	-0.809	-0.717
ICC 12477	0.033	-0.833	-1.971**	-0.027**	11.802**	-0.126	17.038	-1.821**	-1.591**
ICC12478	-0.828	-0.389	-0.648**	-0.044**	4.713**	0.04	46.181**	-1.779**	-1.377**
ICC 12479	-0.467	-1.083	-0.914**	-0.029**	5.179**	0.036	36.846*	-1.738**	-1.692**
ICC 12490	5.256	1.944*	-1.193**	0.118**	-0.621	0.187	-9.221	-0.274	-0.011
ICC 14876	0.283	1.389	-0.994**	-0.055**	7.599**	-0.083	-4.76	-2.138**	-1.84**
ICC 4918	-4.911**	-4.389**	1.642**	0	4.649**	2.047**	-64.08**	3.148**	2.927**
ICC 12426	-4.689**	-2.778**	1.482**	0.074*	-3.913*	1.338*	-40.663*	2.312**	2.119**
ICC 3137	4.228**	3.694**	3.899**	-0.048**	-17.42**	-1.252**	-50.641**	5.742**	4.761**
S.E.±	0.809	0.885	0.1	0.007	1.764	0.31	17.918	0.449	0.425

Significant at 5% probability, ** Significant at 1% probability.

Table 12.3: Estimates of SCA effects of F_2s in desi chickpea 10 x 10 diallel, Griffing (1956).

F_2s	Days to 50% flow.	Days to Maturity	100-seed Wt. (g)	Pods plant^{-1}	Seeds pod^{-1}	Yield plant^{-1}(g)	Yield plot^{-1}(g)	Pod borer damage (%) Actual	Pod borer damage (%) Angular transformed
ICC 12475 x ICC 12476	-5.27*	-0.687	0.299	-3.188	0.036	0.069	-4.696	0.551	0.358
ICC 12475 x ICC 12477	-0.492	1.258	0.642*	-1.03	0.014	0.312	-83.628	1.889	1.905
ICC 12475 x ICC 12478	2.702	2.48	0.126	2.104	-0.066**	-0.321	-80.187	0.12	0.087
ICC 12475 x ICC 12479	2.008	-3.159	-0.664*	-2.751	0.015	-1.234	101.307	0.809	0.562
ICC 12475 x ICC 12490	1.952	-2.187	-0.403	16.582**	0.007	2.582**	-1.805	-1.201	-1.095
ICC 12475 x ICC 14876	3.924	1.035	0.196	-9.815	0.032	-0.922	129.243*	0.345	0.074
ICC 12475 x ICC 4918	4.119	0.813	0.51	-1.01	0.081**	1.435	-93.644	-0.06	0.501
ICC 12475 x ICC 12426	5.896*	2.869	-0.688*	14.108**	-0.091**	1.231	34.923	-2.215	-1.685
ICC 12475 x ICC 3137	-1.354	1.396	-0.084	0.559	0.041*	0.364	-72.792	-0.094	0.636
ICC 12476 x ICC 12477	2.313	1.48	1.549**	0.74	-0.113**	0.694	6.827	-0.805	-1.027
ICC 12476 x ICC 12478	4.841*	2.369	-1.327**	-1.081	0.172**	-0.322	38.331	1.83	1.739
ICC 12476 x ICC 12479	3.813	3.063	0.529	-1.125	0.021	0.262	-77.917	1.619	1.604
ICC 12476 x ICC 12490	-1.576	-1.298	1.134**	2.63	-0.12**	-0.039	109.837*	-0.289	-0.18
ICC 12476 x ICC 14876	3.063	-2.076	1.069**	-3.388	0.057**	0.644	96.849	3.081*	3.723**
ICC 12476 x ICC 4918	0.924	-1.298	-1.3**	-3.762	-0.003	-2.012*	67.842	0.276	0.473
ICC 12476 x ICC 12426	2.369	1.424	0.822**	0.967	-0.074**	0.033	-17.552	-0.792	-0.533
ICC 12476 x ICC 3137	-0.215	0.619	-4.288**	5.04	0.042*	-0.987	49.76	-5.331**	-5.076**
ICC 12477 x ICC 12478	4.952*	1.313	0.033	-10.068	-0.013	-1.615	171.332**	0.161	0.009
ICC 12477 x ICC 12479	1.924	0.341	-0.535	-4.601	-0.001	-1.968*	42.104	0.227	-0.036
ICC 12477 x ICC 12490	-1.131	-2.02	-0.336	1.677	0.04*	-0.016	-44.689	0.783	0.914
ICC 12477 x ICC 14876	5.174*	1.535	-0.168	5.201	0.033	0.347	9.266	1.533	1.123
ICC 12477xICC 4918	3.369	4.313	-0.674*	24.585**	-0.003	3.314**	-26.874	-0.036	0.063
ICC 12477 x ICC 12426	-1.854	-2.631	-0.014	15.325**	-0.006	2.47**	-82.224	1.233	1.33
ICC 12477 x ICC 3137	-3.104	-3.104	-1.328**	2.731	0.043*	0.773	-47.292	-2.07	-1.149
ICC 12478 x ICC 12479	8.119**	4.563	0.282	4.811	-0.031	0.849	-42.792	-1.728	-1.887
ICC 12478 x ICC 12490	5.396*	3.535	-0.609*	-3.956	0.04*	-0.885	-10.845	0.115	-0.021
ICC 12478 x ICC 14876	3.702	0.758	0.066	19.058**	0.02	2.601**	-111.003*	-0.462	-0.955

Contd.

Conti.....12.3

F_2s	Days to 50% flow.	Days to Maturity	100-seed wt. (g)	Pods plant^{-1}	Seeds pod^{-1}	Yield plant^{-1}(g)	Yield plot^{-1}(g)	Pod borer damage (%) Actual	Pod borer damage (%) Angular transformed
ICC 12478 x ICC 4918	-3.104	-2.465	0.37	5.742	-0.013	1.228	21.167	-0.511	0.078
ICC 12478 x ICC 12426	0.341	-1.076	0.259	7.759	-0.005	1.877*	-75.404	0.531	0.559
ICC 12478 x ICC 3137	-3.242	-7.215	-0.661	7.965	-0.004	1.277	-13.438	-2.008	-1.026
ICC 12479 x ICC 12490	0.035	1.563	-0.636	-7.934	0.085**	-1.368	-46.06	-0.67	-0.829
ICC 12479 x ICC 14876	-0.659	0.785	0.138	2.88	-0.005	0.705	-39.658	-1.787	-2.16
ICC 12479 x ICC 4918	5.202*	5.563	0.876**	15.242*8	0.004	3.525**	16.328	1.404	1.42
ICC 12479 x ICC 12426	-0.02	-0.381	-0.321	7.426	-0.016	1.038	-29.802	1.703	2.254
ICC 12479xICC 3137	1.396	2.48	0.035	15.721**	0.015	3.311**	-113.66	0.441	1.122
ICC 12490 x ICC 14876	0.285	-4.576	0.714*	-5.264	0.023	0.094	-58.604	2.07	2.096
ICC 12490 x ICC 4918	-0.854	2.869	0.131	20.73**	-0.008	4.311**	-89.681	-0.553	-0.297
ICC 12490 x ICC 12426	-0.409	1.591	0.187	-1.519	0.047*	0.057	-19.378	2.55	2.164
ICC 12490 x ICC 3137	-2.992	4.785	0.481	-1.19	-0.013	0.54	50.797	-0.91	-0.592
ICC 14876 x ICC 4918	9.785**	6.424*	-2.354**	1.189	-0.051*	-2.453**	14.41	-3.473*	-3.234*
ICC 14876 x ICC 12426	-0.77	-3.854	-1.591**	6.55	-0.097**	-0.924	-42.18	-3.157*	-3.224*
ICC 14876 x ICC 3137	0.313	3.341	-0.058	-0.154	-0.043*	0.119	-21.545	-0.296	-0.036
ICC 4918 x ICC 12426	3.758	4.924	0.146	2.123	0.042*	1.563	5.28	-0.05	-0.051
ICC 4918 x ICC 3137	3.508	-1.548	1.569**	6.507	0.015	3.193**	-18.121	-2.325	-2.063
ICC 12426 x ICC 3137	0.952	-0.159	1.122**	-0.598	0.038	0.405	60.67	3.304*	2.331*
SE OF S(I,J) ±	2.441	2.669	0.301	5.318	0.02	0.934	54.024	1.353	1.282
SE OF S(I,J)-S(I,K) ±	4.002	4.377	0.493	8.721	0.033	1.532	88.588	2.219	2.102
SE OF S(I,J)-S(K,L) ±	3.816	4.173	0.47	8.315	0.032	1.461	84.466	2.115	2.004

Significant at 5% probability; ** Significant at 1% probability.

According to Gardner and Eberhart analysis ICC 12475, ICC 4918 and ICC 12426 recorded significant negative GCA effects and the F_2s of ICC 12478 x ICC 3137 recorded significant negative SCA effect.

In kabuli F_1diallel ICC 12968 and ICC 12491showed significant negative GCA effects. Among the F_1s ICC 12495 x ICC 12494, ICC 12492 x ICC 12968, ICC 12491 x ICC 12968 and ICC 12968 x ICC 12494 were with significant negative SCA effects. In kabuli F_2 trial ICC 12492, ICC 12495 and ICC 4962 showed significant positive GCA effects and ICC 12968 showed significant negative GCA effect. The F_2 of ICC 12968 x ICC 12494 showed significant positive SCA effect according to both the methods of analysis.

4.2.3.3 100-seed weight

In F_1 desi diallel seeds of ICC 3137 were bold (23.74 g per 100 seed). ICC 12474 and ICC 12490 showed the lowest hundred seed weight (12.5 g). The GCA effects were significant at 1% level for all the parents. Six parents showed negative GCA effects and four parents positive GCA effects (Table 10.2). Fifteen crosses recorded significant SCA effects, of which eight showed significant and positive SCA effects and for others SCA effects were negative, (Table 10.3). According to Gardner and Eberhart, except ICC 12475 all the varieties showed significant varietal effects of which ICC 3137, ICC 12426 and ICC 4918 showed both positive varietal effects and GCA effects. The heterotic effect attributable to ICC 3137 was significantly negative and it was significantly positive in ICC 12426 (Table 11.2). Seven crosses showed significant SCA effects of which four were positive and the remaining three were negative (Table 11.3).

In desi F_2 trial all the parents showed significant GCA effects, with four being positive and six negative. Among the F_2s eight showed significant positive SCA effects and nine showed significant negative SCA effects (Tables 12.2 and 12.3). According to Garnder and Eberheart analysis average heterosis effect was significant and negative. ICC 3137, ICC 4918, ICC 12426 and ICC 14876 recorded significant positive varietal effects. Heterosis due to ICC 3137 was significant and negative. GCA effects were significant for all the

Table13.1 : **Estimates of combining ability effects of parents in F_2 desi chickpea 10 x10 diallel, Gardner and Eberhart (1966).**

Parents	Days to50% flow.	Days to maturity	100-seed Wt. (g)	Pods plant^{-1}	Seeds pod^{-1}	Yield lant^{-1} (g)	Plot yield (g)	Pod borer damage (%)	
								Actual	Angular transformed
μ v	59.27	104.9	15.81	83.46	1.202	13.11	779.3	12.76	19.2
μ c	67.71	108.6	15.22	102.2	1.224	16.3	737.8	12.24	19.19
H	8.444**	3.637	-0.581*	18.76**	0.023	3.197	-41.46	-0.5193	-0.363
SE of ĥ	1.790	1.957	0.221	3.901	0.015	0.685**	39.618	0.992	0.940
				Varietal effect (v_i)					
ICC 12475	-13.27**	-4.267	-0.039	2.54	-0.105**	0.591	95.22	-5.784*	-5.831*
ICC 12476	17.4**	11.4*	-2.729**	-2.01	0.122**	-0.662	-123.46	-2.114	-1.978
ICC 12477	1.4	0.067	-4.002**	21.68*	-0.033	0.208	27.74	-5.524*	-4.751
ICC12478	-6.6	0.067	-1.042*	8.61	-0.118**	0.351	109.86	-3.007	-2.048
ICC 12479	-4.93	-6.6	-2.155**	10.88	-0.084	0.128	134.85	-4.91	-4.411
ICC 12490	17.07**	4.733	-3.192**	3.23	0.204**	0.351	2.85	-1.92	-1.105
ICC 14876	-4.93	4.067	-1.469*	22.42*	-0.076	2.344	-31.83	-3.627	-2.388
ICC 4918	-16.27**	-15.6**	3.171**	-11.02	-0.013	-0.342	-110.43	8.536**	7.405**
ICC 12426	-7.6	-3.933	2.528**	-18.55*	0.247**	1.418	-32.41	2.646	2.662
ICC 3137	17.73**	10.067*	8.928**	-37.78**	-0.145**	-4.386*	-72.39	15.703**	12.445**
SE of v_i ±	4.857	5.312	0.598	10.585	0.040	1.859	107.507	2.693	2.550
			Average heterosis contributed by variety (h_i)						
ICC 12475	-0.111	-0.711	0.2951	-5.048	0.011	-0.572	-1.15	0.331	0.449
ICC 12476	-1.185	-0.785	-0.1871	-11.29	-0.007	-2.296*	112.37	0.33	0.362
ICC 12477	-0.889	-1.156	0.0399	1.285	-50.014**	-0.307	4.22	1.255	1.046
ICC12478	3.296	-0.563	-0.1697	0.543	0.021	-0.181	-11.67	-0.368	-0.470
ICC 12479	2.667	2.956	0.2181	-0.346	0.017	-0.037	-40.77	0.956	0.686

Contd.

Conti....table 13.1

Parents	Days to50% Flow.	Days to maturity	100-seed Wt. (g)	Pods plant^{-1}	Seeds pod^{-1}	Yield plant^{-1}(g)	Plot Yield (g)	Pod borer damage (%)	
								Actual	Angular transformed
ICC 12490	-4.37	-0.563	0.5377	-2.983	0.021	0.015	-14.2	0.915	0.722
ICC 14876	3.667	-0.859	-0.3464	-4.816	-0.023	-1.673	14.87	-0.432	-0.862
ICC 4918	4.296	4.548	0.0747	13.547*	0.009	2.958*	-11.82	-1.493	-1.035
ICC 12426	-1.185	-1.081	0.291	7.146	-0.067**	0.839	-32.61	1.319	1.051
ICC 3137	-6.185*	-1.785	-0.7534*	1.959	0.032	1.255	-19.26	-2.813	-1.949
SE of h_i ±	2.974	3.253	0.367	6.482	0.025	1.139	65.834	1.649	1.562
				General combining ability (g_i)					
ICC 12475	-6.744*	-2.844**	0.276**	-3.776*	-0.042*	-0.2769	46.46**	-2.561**	-2.466**
ICC 12476	7.515**	4.915**	-1.551**	-12.296**	0.054**	-2.6272**	50.64**	-0.727	-0.627
ICC 12477	-0.189	-1.122	-1.961**	12.124**	-0.031**	-0.203	18.09	-1.507**	-1.329**
ICC12478	-0.004	-0.53	-0.691**	4.848**	-0.038**	-0.0054	43.26**	-1.871**	-1.494**
ICC 12479	0.2	-0.344	-0.86**	5.093**	-0.025**	0.0266	26.65	-1.499**	-1.520**
ICC 12490	4.163**	1.804*	-1.058**	-1.366	0.123**	0.1905	-12.77	-0.046	0.169
ICC 14876	1.2	1.174	-1.081**	6.395**	-0.061**	-0.5009	-1.04	-2.246**	-2.056**
ICC 4918	-3.837**	-3.252**	1.66**	8.036	0.002	2.7865**	-67.03	2.775**	2.668**
ICC 12426	-4.985**	-3.048**	1.555**	-2.127	0.057**	1.5479**	-48.81**	2.642**	2.382**
ICC 3137	2.681**	3.248**	3.711**	-16.93**	-0.040**	-0.9382**	-55.46**	5.038**	4.274**
SE of g_i ±	0.690	0.755	0.085	1.505	0.006	0.264	15.280	0.383	0.362

Significant at 5% probability; ** Significant at 1% probability.

Table 13.2 : Estimates of SCA effects of F_2s in desi chickpea 10x10 diallel, Gardner and Eberhart (1966).

Desi F_2s	Days to 50% flow.	Days to maturity	100-seed Wt (g)	Pods $plant^{-1}$	Seeds pod^{-1}	Yield $Plant^{-1}$ (g)	Yield $plot^{-1}$(g)	Pod borer damage (%) Actual	Pod borer damage (%) Angular transformed
ICC 12475 x ICC 12476	-6.481**	-0.974	0.378	-2.515	0.031	0.204	-24.96	0.48	0.156
ICC 12475 x ICC 12477	-1.778	1.063	0.6643	-3.501	0.011	-0.05	-76.86	1.587	1.532
ICC 12475 x ICC 12478	0.370	2.137	0.2006	-0.181	-0.078**	-0.714	-69.45	0.224	0.093
ICC 12475 x ICC 12479	-0.167	-4.381	-0.6871	-4.814	0.004	-1.663	119.32*	0.582	0.279
ICC 12475 x ICC 12490	1.537	-2.53	-0.5051	15.178**	-0.005	2.14	9.57	-1.418	-1.387
ICC 12475 x ICC 14876	1.500	0.767	0.314	-10.761**	0.031	-0.942	133.35**	0.465	0.178
ICC 12475 x ICC 4918	1.537	-0.807	0.5229	-6.546*	0.072*	0.257	-82.86	0.324	0.648
ICC 12475 x ICC 12426	4.685*	2.656	-0.7284	10.172**	-0.081**	0.583	50.9	-2.533	-2.06
ICC 12475 x ICC 3137	-1.315	1.359	0.136	-2.08	0.027	-0.388	-60.15	0.621	1.011
ICC 12476 x ICC 12477	1.296	1.304	1.6916*	-0.17	-0.112**	0.764	-14.78	-1.107	-1.378
ICC 12476 x ICC 12478	2.778	2.044	-1.1321	-1.806	0.164**	-0.284	20.69	1.934	1.767
ICC 12476 x ICC 12479	1.907	1.859	0.6267	-1.628	0.014	0.264	-88.28	1.392	1.343
ICC 12476 x ICC 12490	-1.722	-1.622	1.1521	2.787	-0.128**	-0.05	92.83	-0.505	-0.450
ICC 12476 x ICC 14876	0.907	-2.326	1.3079*	-2.773	0.061*	1.055	72.57	3.201*	3.848*
ICC 12476 x ICC 4918	-1.389	-2.9	-1.1666*	-7.738*	-0.007	-2.759*	50.24	0.661	0.641
ICC 12476 x ICC 12426	1.426	1.23	0.9021	-1.408	-0.060*	-0.184	-29.96	-1.11	-0.886
ICC 12476 x ICC 3137	0.093	0.6	-3.9468**	3.961	0.032	-1.308	34.02	-4.616**	-4.678**
ICC 12477 x ICC 12478	2.815	1.081	0.1708	-13.937**	-0.019	-2.075	180.73**	0.034	-0.134
ICC 12477 x ICC 12479	-0.056	-0.77	-0.4936	-8.248**	-0.005	-2.463	58.78	-0.232	-0.468
ICC 12477 x ICC 12490	-1.352	-2.252	-0.3749	-1.311	0.034	-0.524	-34.66	0.335	0.472
ICC 12477 x ICC 14876	2.944	1.378	0.0141	2.672	0.038	0.261	12.03	1.422	1.078
ICC 12477xICC 4918	0.981	2.804	-0.597	17.465**	-0.006	2.07	-17.44	0.118	0.061
ICC 12477 x ICC 12426	-2.87	-2.733	0.0084	9.805**	0.010	1.755	-67.59	0.684	0.807
ICC 12477 x ICC 3137	-2.87	-3.03	-1.0438	-1.491	0.034	-0.045	-35.99	-1.586	-0.922
ICC 12478 x ICC 12479	5.093	3.304	0.376	1.35	-0.045	0.322	-22.15	-1.781	-1.940
ICC 12478 x ICC 12490	4.13	3.156	-0.5953	-6.758*	0.026	-1.425	3.16	0.072	-0.083

Contd.

Conti...table 13.2

Desi F_2s	Days to 50% flow.	Days to maturity	100-seed wt. (g)	Pods plant^{-1}	Seeds pod^{-1}	Yield plant^{-1}(g)	Yield plot (g)	Pod borer damage (%) Actual	Pod borer damage (%) Angular transformed
ICC 12478 x ICC 14876	0.426	0.452	0.3004	16.715**	0.016	2.483	-104.27*	-0.168	-0.621
ICC 12478 x ICC 4918	-6.537	-4.122	0.4993	-1.193	-0.025	-0.047	34.58	0.048	0.455
ICC 12478 x ICC 12426	-1.722	-1.326	0.3347	2.425	0.003	1.131	-56.8	0.388	0.415
ICC 12478 x ICC 3137	-4.056	-7.289**	-0.3242	3.928	-0.021	0.427	1.83	-1.118	-0.421
ICC 12479 x ICC 12490	-1.074	0.304	-0.7197	-10.513**	0.072*	-1.944	-24.78	-1.043	-1.18
ICC 12479 x ICC 14876	-3.778	-0.4	0.276	0.759	-0.008	0.551	-25.65	-1.823	-2.115
ICC 12479 x ICC 4918	1.926	3.026	0.9082	8.53*	-0.007	2.214	37.01	1.633	1.508
ICC 12479 x ICC 12426	-1.926	-1.511	-0.3431	2.314	-0.008	0.256	-3.92	1.229	1.821
ICC 12479xICC 3137	0.741	1.526	0.2747	11.906**	-0.001	2.425	-91.11	1	1.438
ICC 12490 x ICC 14876	-1.074	-4.881	0.7714	-6.726	0.020	-0.073	-51.24	2.043	2.132
ICC 12490 x ICC 4918	-2.37	1.211	0.0836	14.677**	-0.020	2.987*	-75.64	-0.314	-0.218
ICC 12490 x ICC 12426	-0.556	1.341	0.0856	-5.971	0.054	-0.738	-0.14	2.086	1.721
ICC 12490 x ICC 3137	-1.889	4.711*	0.6401	-4.346	-0.031	-0.359	66.7	-0.341	-0.285
ICC 14876 x ICC 4918	6.259**	4.841*	-2.1807**	-4.406	-0.052**	-3.355**	21.18	-2.897	-2.76
ICC 14876 x ICC 12426	-2.926	-4.03	-1.472*	2.556	-0.079**	-1.297	-30.21	-3.284*	-3.27*
ICC 14876 x ICC 3137	-0.593	3.341	0.3225	-2.852	-0.049	-0.357	-12.91	0.609	0.667
ICC 4918 x ICC 12426	1.444	3.396	0.1603	-6.462*	0.052	0.033	23.92	0.088	-0.054
ICC 4918 x ICC 3137	2.444	-2.9	1.8447	-0.781	0.001	1.559	-2.81	-1.154	-1.316
ICC 12426 x ICC 3137	1.259	-0.104	1.3434*	-6.285*	0.042	-0.699	81.18	3.772*	2.557
SE ±	2.148	2.22	0.556	3.13	.028	1.315	49.45	1.58	1.53

Significant at 5% probability; ** Significant at 1% probability

varieties and positive for ICC 3137, ICC 12426, ICC 4918 and ICC 12475. The SCA effects were significantly positive for ICC 12476 x ICC 12477 and ICC 12426 x ICC 3137 (Tables 13.1 and 13.2).

In kabuli F_1 diallel the GCA effects were significant for five parents. ICC 12495, ICC 12968 and ICC 4962 showed significant positive GCA effects where as ICC 12493 and ICC 12492 showed significant negative SCA effects. Six crosses showed significant SCA effects, of which four were positive and other two were negative (Tables 14.2 and14.3). According to Gardner and Eberhart the average heterosis was positive but not significant. ICC 12495 and ICC 12968 were with significant positive varietal effects. ICC 12495, ICC 4973 and ICC 4962 were good general combiners with positive GCA effects. ICC 12491 x ICC 12968 and ICC 4962 x ICC 12495 were with significant positive SCA effects (Tables 15.2 and 15.3).

In kabuli F_2 trial ICC 12492, ICC 12495 and ICC 4962 showed significant positive GCA effects and ICC 12491, ICC 12494 and ICC 12968 showed significant negative SCA effects. Among the F_2s, 13 showed significant positive SCA effects and nine showed significant negative SCA effects (Tables 16.2 and 16.3). According to Gardner and Eberhart analysis three varieties ICC 12495, ICC 12968 and ICC 4962 showed significantly positive varietal effects and along with these ICC 4973 also recorded significant positive GCA effect. Six F_2s showed significant positive SCA effects and five were negative (Tables 17.1 and 17.2).

4.2.3.4 Number of pods per plant

In desi F_1 diallel ICC 12477 and ICC 12476 recorded significantly positive GCA effects and ICC 3137, ICC 12426 and ICC 4918 significantly negative GCA effects (Table 10.2). Eleven crosses recorded significant SCA effect, of which nine showed significant positive SCA effects and the two were negative SCA effects (Table 10.3). Average heterosis was positive and significant. Varietal effect was significant and positive for ICC 12477. The parents ICC 12476, ICC 12477, ICC 12478 and ICC 12475 recorded significantly positive

Table14.1: Estimates of GCA and SCA mean squares and variances from F_1 kabuli chickpea 8 x 8 diallel, Giffing (1956).

	d.f	Days to 50% flow.	Days to maturity	100-seed Wt. (g)	Seeds pod^{-1}	Pods $plant^{-1}$	Yield $plant^{-1}$ (g)	Yield kg ha^{-1}	Pod borer damage (%) Actual	Pod borer damage (%) Angular transformed
Mean squares										
GCA	7	784.593**	597.949**	19.868**	0.026**	14.892**	373.158**	112569.5**	12.804**	18.005**
SCA	28	21.509**	33.618	1.224**	0.004**	10.22**	197.006**	65206.97**	6.02**	8.312**
Error	70	7.802	22.177	0.549	0.002	2.561	59.874	20771.34	3.994	5.711
Variances										
$\sigma^2 g$		77.679**	57.577**	1.932**	0.002**	1.233**	31.328**	9179.818**	0.881**	1.229**
$\sigma^2 s$		13.707**	11.441	0.676**	0.002**	7.66**	137.132**	44435.64**	2.028**	2.601**
$\sigma^2 A$		155.358	115.154	3.864	0.004	2.466	62.656	18359.64	1.762	2.458
$\sigma^2 D$		13.707	11.441	0.676	0.002	7.66	137.132	44435.64	2.028	2.601
Predictability Ratio		0.986	0.973	0.970	0.929	0.745	0.791	0.775	0.810	0.812

Table 14.2: Estimates of combining ability effects of parents in F_1 kabuli chickpea 8 x 8 diallel, Giffing (1956)

Genotype	Days to 50% flow.	Days to maturity	100-seed Wt. (g)	Seeds pod^{-1}	Pods $plant^{-1}$	Yield $plant^{-1}$(g)	Yield kg ha^{-1}	Pod borer damage (%) Actual	Pod borer damage (%) Angular transformed
ICC 12491	-2.742*	-2.283	-0.263	-0.031*	3.4801	-0.076	34.636	0.777	0.637
ICC 12492	-0.508	2.083	-0.883	-0.013	5.5800*	0.492	-12.521	-1.894**	-1.626**
ICC 12493	4.792**	3.250*	-2.681	0.054**	-1.3471	-1.219*	6.569	-1.047	-0.960
ICC 12494	3.858**	1.983	-0.382	0.031*	0.6471	0.138	-67.548	0.419	0.348
ICC 12495	5.292**	5.050**	1.902	-0.059**	1.9131	1.231**	58.794	-0.650	-0.539
ICC 12968	-20.542**	-17.783**	0.943	-0.031*	7.3670**	1.919**	205.988**	-0.986	-0.709
ICC 4973 (S)	3.325**	0.451	0.295	-0.361**	-7.767**	-1.683**	-139.688**	1.570*	1.314*
ICC 4962 (S)	6.525**	7.251**	1.068	0.085**	-9.873	-0.803	-86.232*	1.811*	1.534**
S.E±	0.826	1.393	0.219	0.013	2.289	0.473	42.632	0.707	0.591

* Significant at 5% probability; ** Significant at 1% probability; S – Susceptible.

Table14.3: **Estimates of SCA effects of F_1s in kabuli chickpea 8 x 8 diallel, (Griffing 1956)**

F_1s	Days to 50% Flow.	Days to maturity	100-seed Wt.(g)	Pods $Plant^{-1}$	Seeds Pod^{-1}	Yield $plant^{-1}$(g)	Yield Kg ha^{-1}	Pod borer damage (%)	
								Actual	Angular transformed
ICC 12491 x ICC 12492	0.648	1.663	-0.248	19.577*	-0.028	2.743*	250.226*	0.618	0.628
ICC 12491 x ICC 12493	-0.652	-6.504	0.282	1.037*	-0.004	-0.046	185.266	3.978*	3.476*
ICC 12491 x ICC 12494	3.948	8.096*	0.037	-14.690*	0.022	-2.975*	-100.436	2.995	2.455
ICC 12491 x ICC 12495	2.848	4.363	-2.036**	-1.356	0.061	-1.002	-99.845	-1.009	-0.816
ICC 12491 x ICC 12968	2.681	-7.804*	2.003**	5.524	-0.068	2.031	100.675	-2.030	-1.603
ICC 12491 x ICC 4973	-1.852	5.296	0.574	14.391*	0.071*	3.378**	222.061	1.527	1.164
ICC 12491 x ICC 4962	0.615	2.163	0.178	-6.236	0.025	-0.765	-103.639	-0.263	-0.146
ICC 12492 x ICC 12493	3.781	6.130	0.265	-2.196	0.010	-0.441	-19.550	0.206	-0.051
ICC 12492 x ICC 12494	4.381*	6.396	-0.009	-2.523	0.012	0.369	-118.789	-2.461	-1.942
ICC 12492 x ICC 12495	1.281	2.996	-0.733	-19.191	0.111*	-3.957**	180.488	5.636**	4.761**
ICC 12492 x ICC 12968	-13.552**	-11.170**	-0.684	-4.376	0.055	-0.305	-364.835**	-1.349	-1.157
ICC 12492 x ICC 4973	5.581*	3.596	0.567	9.624	0.054	3.123*	-138.449	-3.528	-2.916
ICC 12492 x ICC 4962	3.715	1.796	-0.209	7.464	0.012	2.113	169.608	1.458	1.440
ICC 12493 x ICC 12494	1.415	2.231	0.671	6.537	-0.009	2.181	-302.101**	-4.708*	-3.99*
ICC 12493 x ICC 12495	-1.685	3.830	0.527	-1.931	0.034	0.964	48.778	-4.468*	-4.111*
ICC 12493 x ICC 12968	-2.852	4.996	0.021	2.084	0.066	0.669	120.672	0.621	0.672
ICC 12493 x ICC 4973	0.281	-0.570	-0.812	10.817	0.086*	2.317	225.794*	0.631	0.581
ICC 12493 x ICC 4962	-1.919	-6.037	-1.632**	-0.076	-0.033	-1.196	-223.441*	0.138	-0.368
ICC 12495 x ICC 12494	-0.419	-10.904**	-0.504	-5.79	0.026	-0.303	-84.171	-4.145*	-3.432*
ICC 12968 x ICC 12494	-4.252	-7.404*	-0.005	-0.843	-0.052	-1.104	50.746	2.351	1.904
ICC 4973 x ICC 12494	1.548	-3.97	0.696	15.624*	-0.043	3.221*	243.335*	-2.045	-1.669
ICC 4962 x ICC 12494	-1.985	0.563	1.98**	2.464	0.061	2.371	201.291	-0.012	0.141
ICC 12495 x ICC 12968	11.648**	7.863*	-0.735	43.957**	0.011	9.160*	-564.150*	-3.340	-3.021
ICC 12495 x ICC 4973	-5.219*	-2.37	1.159*	0.357	0.037	0.481	257.436*	0.758	0.827
ICC 12495 x ICC 4962	-4.085	0.163	0.87	5.397	-0.029	1.538	365.461*	-0.319	-0.053
ICC 12968 x ICC 4973	1.615	6.463	-0.255	-7.963	-0.051	-2.390	103.529	-1.353	-1.059
ICC 12968 x ICC 4962	-3.585	0.996	0.033	1.410	0.078*	1.003	138.810	2.983	2.412
ICC 4973 x ICC 4962	0.548	-4.904	1.884**	10.544	-0.08*9	1.901	136.105	1.744	1.266
SE OF S(I, J) ±	2.203	3.715	0.584	6.104	0.035	1.262	113.685	1.885	1.576
SE OF (I, I)-(I, K) ±	3.747	6.318	0.994	10.381	0.06	2.147	193.361	3.206	2.681
SE OF (I, J)-(K, L) ±	3.533	5.957	0.937	9.788	0.057	2.024	182.302	3.023	2.528

Significant at 5% probability; ** Significant at 1% probability

GCA effect (Table 11.2). ICC 12476 x ICC 12490, ICC 12475 x ICC 12426, ICC 12477 x ICC 12479, ICC 12476 x ICC 3137, ICC 12477 x ICC 4918 were with significant positive SCA effects according both the methods of analysis for increased pod number. But there were slight differences between the results obtained by two methods of analysis (Table 11.3).

In F_2 desi trial ICC 12477, ICC 12478, ICC 12479, ICC 14876 and ICC 4918 showed significant positive GCA effects and ICC 12476, ICC 12426 and ICC 3137 showed significant negative GCA effects. Among the F_2s, eight crosses showed significant positive SCA effects and none of the crosses showed significant negative SCA effects according to Griffings analysis (Tables 12.2 and 12.3). According to Gardner and Eberhart analysis average heterosis effect was positive and significant. Varietal effects were positively significant for ICC 12477 and ICC 14876. ICC 4918 showed significant positive GCA effect. Except IC 12490 and ICC 12426 all the varieties showed significant GCA effects. Nine F_2s showed significant positive SCA effects and eight were negative (Tables 13.1 and 13.2).

In kabuli F_1 diallel ICC 12968 and ICC 12492 showed significant positive GCA effects where as ICC 4973 and ICC 4962 with significant negative GCA effects. ICC 12968 was the best general combiner followed by ICC 12492 (Table 14.2). Five crosses recorded significant SCA effects (Table 14.3). According to Gardner and Eberhart the average heterosis was significant and positive. The varietal effect was positively significant with respect to ICC 12492 and heterotic effect was significant with respect to ICC 4973. ICC 12968, ICC 12492 and ICC 12491 showed significant positive GCA effects (Table 15.2).

In F_2 kabuli trial ICC 12492 and ICC 12493 showed significant positive GCA effects while ICC 12968 and ICC 4962 showed significant negative GCA effects. In F_2s eight were with significant positive SCA effects and three were with negative SCA effects (Tables 16.2 and 16.3). According to Gardner and Eberhart analysis average heterosis was positive and significant. GCA effects were significantly positive for ICC 12492 and ICC 12493. Four F_2s showed significant positive SCA effects and three were negative (Tables 17.1 and 17.2).

Table15.1: ANOVA for different characters in F_1 kabuli chickpea 8 x 8 diallel, Gardner and Eberhart (1966).

Source	d.f	Days to 50% flow.	Days to maturity	100-seed Wt. (g)	Pods plant^{-1}	Seeds pod^{-1}	Yield plant^{-1}(g)	Yield kg ha^{-1}	Pod borer damage (%) Actual	Pod borer damage (%) Angular transformed
Entries	35	522**	439**	14.85**	696.7**	.025**	33.46**	224038**	22.13*	30.75*
Varieties (vi)	7	846**	654**	23.9**	830**	.048**	2789**	518330**	19.1	26.88
Heterosis (hij)	27	457**	398**	12.7**	544**	.016**	24.92	138861*	23.3*	32.37
Average (h)	1	9.68	30.57	7.28	3873**	.085**	303**	463805*	10.25	14.1
Variety (vi)	7	51**	398	13.61**	214*	.01**	9.57*	31537	14.56*	20.1*
Specific (sij)	13	3.74**	61**	1.51**	261**	.004**	12.1*	79153	8.38*	11.5*
Error	108	10.11	28	.71	77	.0026	3.31	26925	5.17	7.4
GCA	7	784**	59**	19,8**	373**	.02**	14.89**	112569**	12.8*	18*
SCA	28	10	16.8	.61**	988*	.002	5.11*	32603**	3.0	14.1
GCA var.	7	28.8**	28.8**	27.9**	4.8**	9.93**	4.48**	4.1**	2.47*	2.4*
SCA var.	28	1.1	.58	.86**	1.26*	.76	1.53*	1.2**	.58	.56

* Significant at 5%; ** Significant at 1%.

Table15.2: Estimates of combining ability effects of parents in F_1 kabuli chickpea 8 x 8 diallel, Gardner and Eberhart (1966).

Kabuli Parents	Days to 50% flow.	Days to maturity	100-seed Wt. (g)	Pods Plant^{-1}	Seeds pod^{-1}	Yield plant^{-1}(g)	Yield kg ha^{-1}	Pod borer damage (%)	
								Actual	Angular transformed
μ v	71.04	112.201	18.401	55.83	1.189	10.26	1034	14.87	22.43
μ c	71.76	113.501	19.031	70.23	1.257	14.29	1191	14	21.69
Vi	0.720	1.280	0.614*	14.41**	0.06774**	4.03**	157.6**	-0.8665	-0.7409
SE of h ±	1.275	2.149	0.338	3.532	0.020	0.730	65.783	1.091	0.912
					Varietal effect (v_i)				
ICC 12491	-9.04**	-7.208	-0.435	9.04	-0.0458	1.301	-35.3	-2.026	-1.880
ICC 12492	-3.37	-0.542	-0.755	18.17*	-0.0858	2.297	118.2	-4.753*	-4.209*
ICC 12493	10.96**	5.458	-4.535**	0.37	0.0875	-1.526	68.1	-0.966	-0.599
ICC 12494	5.96*	7.458	-1.711*	12.11	0.1075*	1.531	42.6	4.177	3.385
ICC 12495	8.96**	8.125	5.015**	4.31	-0.1925**	2.157	138.2	1.471	1.269
ICC 12968	-36.38**	-31.542**	2.182**	6.04	-0.0292	2.441	741.9**	-1.586	-1.068
ICC 4973	5.96*	0.125	-0.831	-31.03**	-0.0525	-6.246**	-681.7**	3.6*	2.954*
ICC 4962	16.96**	18.125**	1.069	-19.03*	0.2108**	-1.953	-392*	0.084	0.147
SE of v_i ±	2.975	5.015	0.789	8.241	0.048	1.704	153.493	2.545	2.128
					Average heterosis contributed by variety (h_i)				
ICC 12491	2.542	1.887	-0.065	-1.487	0.01107	-1.0378	74.7	2.558	2.254
ICC 12492	1.685	3.363	-0.722	-5.011	0.04274	-0.9373	-102.3	0.689	0.684
ICC 12493	-0.982	0.744	-0.589	-2.192	0.01464	-0.6507	-39.2	-0.806	-0.943
ICC 12494	1.256	-2.494	0.677	-7.725	0.0325	-0.8964	-126.9	-2.385	-1.921
ICC 12495	1.161	1.411	-0.865	-0.344	0.05179	0.2179	-14.7	-1.979	-1.676
ICC 12968	-3.363	-2.875	-0.212	6.208	0.02393	0.9979	-235.6*	-0.275	-0.251
ICC 4973	0.494	0.554	1.0151*	11.065*	0.01345	2.0579	287.4*	-0.329	-0.234
ICC 4962	-2.792	-2.589	0.7617	-0.515	0.02821	0.2484	156.8	2.527	2.087
SE of h_i ±	1.92	2.327	0.509	5.319	0.031	1.1	99.079	1.643	1.374
					General combining ability (g_i)				
ICC 12491	-1.979**	-1.717*	-0.282*	3.034*	-0.03399**	-0.387	57.04*	1.545**	1.314
ICC 12492	-0.003*	3.092**	-1.099**	4.077**	-0.00018	0.211	-43.22	-1.688**	-1.421
ICC 12493	4.497**	3.473**	-2.857**	-2.004	0.05839**	-1.413**	-5.21	-1.289**	-1.242
ICC 12494	4.235**	1.235	-0.179	-1.671	0.02125**	-0.131	-105.63**	-0.296	-0.229
ICC 12495	5.640*	5.473**	1.642**	1.811	-0.04446**	1.296**	54.38*	-1.244**	-1.041
ICC 12968	-21.551**	-18.646**	0.879**	9.229**	-0.03851**	2.218**	135.3**	-1.068*	-0.784
ICC 4973	3.473**	0.616	0.599**	-4.447**	-0.0397**	-1.065**	-53.48	1.472**	1.244
ICC 4962	5.687**	6.473**	1.296**	-10.028**	0.0772**	-0.728*	-39.19	2.569**	2.161
SE of g_i ±	0.530	0.894	0.141	1.468	0.008	0.304	27.348	0.453	0.379

* Significant at 5% probability; ** Significant at 1% probability

Table 15.3: **Estimates of SCA effects of F_1s in kabuli chickpea 8 x 8 diallel, Gardner and Eberhart (1966).**

Kabuli F_1s	Days to 50% flow.	Days to maturity	100-seed Wt. (g)	Seeds pod^{-1}	Pods $plant^{-1}$	Yield $plant^{-1}$(g)	Yield kg ha^{-1}	Pod borer damage (%)	
								Actual	Angular transformed
ICC 12491 x ICC 12492	-0.781	-0.196	-0.151	-0.0527	18.325*	2.440	223.5*	-0.163	-0.089
ICC 12491 x ICC 12493	-1.280	-7.577	0.339	-0.0213	-1.061	-0.435	139.6	3.644**	3.248**
ICC 12491 x ICC 12494	2.649	7.994	-0.285	0.0158	-15.127*	-3.291*	-119.8	3.135*	2.52*
ICC 12491 x ICC 12495	1.577	3.089	-1.89**	0.0315	-4.008	-1.652	-152.9	-0.991	-0.825
ICC 12491 x ICC 12968	2.768	-7.792	1.947**	-0.0710	0.906	1.147	113.9	-2.523	-2.041
ICC 12491 x ICC 4973	-2.923	4.281	0.150	0.0634	8.315	2.177	78.4	1.051	0.723
ICC 12491 x ICC 4962	0.530	2.089	-0.169	0.02321	-8.837	-1.424	-208.1	-1.596	-1.284
ICC 12492 x ICC 12493	3.411	4.613	0.519	-0.0251	-3.237	-0.861	-12.1	0.434	0.191
ICC 12492 x ICC 12494	3.339	5.851	-0.134	-0.0046	-1.904	0.024	-85	-1.759	-1.406
ICC 12492 x ICC 12495	0.268	1.280	-0.395	0.0677	-20.785**	-4.637**	180.6	6.215**	5.223**
ICC 12492 x ICC 12968	-13.208**	-11.601*	-0.542	0.0351	-7.937	-1.219	-298.5**	-1.28	-1.123
ICC 12492 x ICC 4973	4.768	2.137	0.340	0.0296	4.606	1.891	-229.0	-3.444*	-2.886*
ICC 12492 x ICC 4962	3.887	1.281	-0.359	-0.0072	5.921	1.424	118.2	0.686	0.773
ICC 12493 x ICC 12494	1.173	2.470	0.505	-0.0165	6.311	1.749	-287.4*	-3.558**	-2.966**
ICC 12493 x ICC 12495	-1.899	2.899	0.824	-0.0008	-4.371	0.198	129.9	-3.441**	-3.161*
ICC 12493 x ICC 12968	-1.708	5.351	0.121	0.0532	-2.323	-0.331	168.1	1.137	1.194
ICC 12493 x ICC 4973	0.268	-1.244	-1.078	0.0710	4.954	0.999	116.3	1.164	1.098
ICC 12493 x ICC 4962	-0.946	-5.768	-1.822*	-0.0458	-2.465	-1.971	-293.7**	-0.186	-0.547
ICC 12495 x ICC 12494	-1.304	-10.863*	-0.586	0.0063	-6.57	-0.995	-76.7	-2.643*	-2.188*
ICC 12968 x ICC 12494	-3.78	-6.077	-0.282	-0.0529	-3.589	-2.031	124.5	3.341*	2.720
ICC 4973 x ICC 12494	0.863	-3.673	0.049*	-0.0451	11.42	1.977	160.2	-1.039	-0.858
ICC 4962 x ICC 12494	-1.685	1.804	1.409*	0.0646	1.735	1.67	157.3	0.138	0.256
ICC 12495 x ICC 12968	12.149**	8.018	-0.550	-0.0139	38.996**	7.899**	-524.1**	-2.471	-2.279*
ICC 12495 x ICC 4973	-5.875*	-3.244	0.975	0.0106	-6.061	-1.097	140.6	1.642	1.564
ICC 12495 x ICC 4962	-3.756	0.232	0.762	-0.0496	2.454	0.502	287.8**	-0.291	-0.012
ICC 12968 x ICC 4973	2.315	6.875	-0.634	-0.0520	-16.346*	-4.202**	53	-0.98	-0.749
ICC 12968 x ICC 4962	-1.899	2.351	-0.271	0.0777	-3.499	-0.266	127.4	2.501	2.026
ICC 4973 x ICC 4962	1.077	-4.577	1.211	-0.0910*	4.177	0.314	-32.2	1.277	0.874
SE of Sij ±	2.688	4.531	0.713	0.0430	7.446	1.540	108.1	1.301	1.110

* Significant at 5% probability; ** Significant at 1% probability

4.2.3.5 Seeds per pod

In all the trials both GCA and SCA variances were significant. In desi F_1 trial the GCA effects were significantly greater than zero for ICC 12490, ICC 12426, ICC 12475 and ICC 12476. SCA effects were significant and positive for ICC 12490 x ICC 14876 and ICC 14876 x ICC 4918. Average heterosis was positive but not significant. The Varietal effects were significant for ICC 12490 and ICC 12426 (Tables 10.2, 10.3, 11.2 and 11.3).

In F_2 desi trial among the parents ICC 12476, ICC 12490 and ICC 12426 showed significant positive GCA effects.Among F_2s, 11 showed significant positive SCA effects and eight showed significant negative SCA effects. According to Gardner and Eberhart analysis average heterosis effect was positive and significant. The varietal effects were significant for seven varieties. The heterotic effects attributable to varieties were negatively significant for ICC 12477 and ICC 12426. All the parents showed significant GCA effects except ICC 4918. Five F_2s showed significant positive SCA effects and five showed significant negative SCA effects (Tables 12.2, 12.3, 13.1 and 13.2).

In kabuli F_1 diallel for ICC 4962, ICC 12493 and ICC 12494 the GCA effects were significantly greater than zero. According to Griffing analysis four parents showed significant positive GCA effects and four parents showed significant negative GCA effects (Tables 14.2, 14.3, 15.2 and 15.3). Among the F_2s, 15 showed significant positive SCA effects and 11 showed significant negative SCA effects. According to Gardner and Eberhart analysis varietal effects were significant for four varieties. The GCA effects were significant for all the varieties except ICC 12491 and ICC 12492. Among the F_2s, 11 showed significant positive SCA effects and eight showed significant negative SCA effect (Tables 16.2, 16.3, 17.1 and 17.2).

4.2.3.6 Seed yield per plant

In F_1 desi type ICC 12476 and ICC 12475 recorded significantly positive GCA effects. ICC 14876 and ICC 3137 showed significantly negative GCA effects (Table 10.2). Ten crosses showed significant positive SCA values In F_2 desi trial ICC 4918 and ICC 12426 showed significant positive GCA effect and ICC 3137 showed significant negative GCA effect. Among F_2s nine were with significant positive SCA effects and three were with significant negative SCA effects. According to Gardner and Eberhart analysis average heterosis effect was significant and positive. Varietal effect was significant for ICC 3137.

In kabuli diallel Four parents recorded significant GCA effects of which ICC 12968 and ICC 12495 recorded positive GCA effects and ICC 4973 and ICC 12493 recorded negative GCA effects (Table 14.2). Seven crosses recorded significant SCA effects, of which five recorded significant positive SCA effects and two recorded significant negative SCA effects.

In F_2 kabuli diallel ICC 12492 and ICC 12495 showed significant positive GCA effects and ICC 12968 showed significant negative GCA effects. Among F_2s, six showed significant positive SCA effects and one was with significant negative SCA effect. According to Gardner and Eberhart analysis average heterosis effect was significant and positive. GCA effects were significantly positive for ICC 12492, ICC 12495 and ICC 4962. Four F_2s showed significant positive SCA effects and five were with negative effects. (Table 17.2).

4.2.3.7 Plot yield

In F_1 desi diallel among the parents ICC 12475 was the best general combiner followed by ICC 12479. The GCA effects for ICC 12477, ICC 12478 and ICC 12490 were positive but not significant. The GCA effect of ICC 3137 was significant but negative. ICC 12475 x ICC 4918, ICC 12476 x ICC 12477 and ICC 12490 x ICC 3137 recorded significantly positive SCA effects. ICC 12475 x ICC 4918 and ICC 12490 x ICC 3137

Table16.1: GCA and SCA mean squares and variances from F_2 kabuli chickpea 8 x 8 diallel, Griffing (1956).

Mean squares	d.f	Days to 50% flow.	Days to maturity	100-seed Wt. (g)	Pods plant^{-1}	·Seeds pod^{-1}	Yield plant^{-1}(g)	Yield Plot^{-1}(g)	Pod borer damage (%) Actual	Pod borer damage (%) Angular transformed
GCA	7	1299.701**	567.51**	23.523**	369.161**	0.021**	19.889**	9723.326**	32.662**	45.961**
SCA	28	46.197	28.811	0.619**	525.476**	0.001**	24.993**	11978.12**	4.482	6.105
Residual	70	11.662	25.722	0.303	50.165	0.001	2.368	2681.736	1.524	2.312
Variances										
$\sigma^2 g$	7	128.804**	54.179**	2.322**	31.9**	0.002**	1.752**	704.159**	3.114**	4.365**
$\sigma^2 s$	28	34.535	3.089	0.316**	475.311**	0.001**	22.625**	9296.379**	2.958	3.793
$\sigma^2 A$		257.608	108.358	4.644	63.8	0.004	3.504	1408.318	6.228	8.73
$\sigma^2 D$		34.535	3.089	0.316	475.311	0.001	22.625	9296.379	2.958	3.793
Predictability ratio		0.982	0.975	0.987	0.584	0.976	0.614	0.618	0.935	0.937

Table 16.2: Estimates of combining ability effects of parents in F_2 kabuli chickpea 8 x 8 diallel (Giffing 1956)

Parents	Days to 50% flow.	Days to maturity	100-seed Wt. (g)	Pods plant^{-1}	Seeds pod^{-1}	Yield plant^{-1}(g)	Yield plot^{-1}(g)	Pod borer damage (%) Actual	Pod borer damage (%) Angular transformed
ICC 12491	f2.342*	-2.158	-1.64**	-3.709	-0.53**	-1.64**	-49.072**	1.386**	1.225**
ICC 12492	4.425**	3.408*	1.258**	9.76**	-1.369**	1.258**	43.63**	-1.946**	-1.692**
ICC 12493	4.358**	2.708	0.104	6.993**	-2.523**	0.104**	-11.389**	-2.046**	-1.706**
ICC 12494	6.092**	3.675*	-0.483**	-0.351	-0.686**	-0.483**	-6.244**	1.123*	0.896*
ICC 12495	3.958**	4.508**	2.297**	2.12	1.826**	2.297**	26.109**	-2.873**	-2.476**
ICC 12968	-27.275**	-17.525**	-1.958**	-7.329**	1.571**	-1.958**	-16.167**	3.47**	2.836**
ICC 4973 (S)	3.058**	-0.325	-0.109	-1.082	0.531**	-0.109**	32.03**	0.849	0.767
ICC 4962 (S)	7.725**	5.708**	0.531**	-6.402**	1.179**	0.531**	-18.896**	0.037	0.15
SE ±	1.01	1.5	0.163	2.095	0.008	0.455	15.318	0.45	0.365

Significant at 5% probability; ** Significant at 1% probability.

Table 16.3: Estimates of SCA effects of F_2 s in 8 x 8 kabuli chickpea diallel, Griffing (1956).

F_2 s	Days to 50% flow.	Days to Maturity	100-seed wt. (g)	Pods plant^{-1}	Seeds pod^{-1}	Yield plant^{-1}(g)	Yield g plot^{-1}	Pod borer damage (%) Actual	Pod borer damage (%) Angular transformed
ICC 12491 x ICC 12492	0.389	-1.315	-1.779**	-9.738	0.074**	-1.779	-28.344	1.618	1.532
ICC 12491 x ICC 12493	1.789	1.052	1.292**	4.042	0.949**	1.292	-29.171	-0.161	0.013
ICC 12491 x ICC 12494	6.722*	2.752	-1.067*	-7.527	-0.198**	-1.067	-44.392	-2.898*	-2.216*
ICC 12491 x ICC 12495	9.856**	5.919	0.946*	7.579	-0.997**	0.946	-39.439	-1.258	-1.089
ICC 12491 x ICC 12968	-1.244	-0.715	2.888**	16.422**	-0.352**	2.888*	91.33*	-0.077	-0.098
ICC 12491 x ICC 4973	5.422*	7.085	0.059	-0.429	-0.008	0.059	-78.363	-0.013	-0.06
ICC 12491 x ICC 4962	6.756*	4.719	-1.395**	-6.173	-0.303**	-1.395	-45.191	0.602	0.478
ICC 12492 x ICC 12493	3.689	6.485	6.233**	30.363**	-0.682**	6.233**	44.000	-2.656*	-2.841*
ICC 12492 x ICC 12494	2.622	4.519	14.108**	69.341**	-0.743**	14.108**	252.622**	-6.065	-5.719
ICC 12492 x ICC 12495	-5.911*	-1.315	1.541**	5.737	0.515**	1.541	-61.247	1.741	1.57
ICC 12492 x ICC 12968	-3.344	-3.948	-0.714	-3.071	-1.133**	-0.714	-14.128	-2.512	-1.846
ICC 12492 x ICC 4973	-1.678	4.185	-3.203**	-15.018**	0.534**	-3.203**	-25.952	3.366**	2.941*
ICC 12492 x ICC 4962	0.322	3.152	-3.103**	-15.522**	-0.104**	-3.103*	-93.026	0.831	0.816
ICC 12493 x ICC 12494	2.022	2.219	-0.128	0.024	-0.088**	-0.128	-26.972	0.212	0.432
ICC 12493 x ICC 12495	-3.511	-0.948	-1.289**	-10.276*	0.083**	-1.289	-43.521	1.845	1.679
ICC 12493 x ICC 12968	-8.278**	-6.915	2.87*8	12.706	0.768**	2.87*	69.624	-0.941	-0.641
ICC 12493 x ICC 4973	4.056	1.885	0.371	1.286	-0.448**	0.371	-4.199	-0.274	-0.094
ICC 12493 x ICC 4962	0.056	-2.815	-2.316**	-7.141	-1.203**	-2.316	-73.38	2.432*	2.144*
ICC 12495 x ICC 12494	2.422	-6.248	0.036	-0.985	0.126**	0.036	-48.136	-0.115	0.192
ICC 12968 x ICC 12494	-3.011	11.119**	-2.256**	-9.84	0.971**	-2.256	20.873	6.239**	4.447**
ICC 4973 x ICC 12494	-6.011*	-3.748	-3.028**	-13.483*	0.768**	-3.028*	-29.367	2.003	1.715
ICC 4962 x ICC 12494	0.656	1.552	-2.695**	-17.007**	1.63**	-2.695*	-69.775	-0.268	-0.097
ICC 12495 x ICC 12968	-9.878**	-6.715	-0.529	-2.363	0.878**	-0.529	72.767	1.472	1.538
ICC 12495 x ICC 4973	2.789	2.085	1.165**	4.026	-0.668**	1.165	-100.18*	-3.284**	-3.047**
ICC 12495 x ICC 4962	1.789	3.385	11.088**	44.746**	0.244**	11.088**	311.756**	-1.538	-1.457
ICC 12968 x ICC 4973	-7.311**	-4.881	1.31**	13.152*	-0.133**	1.31	90.122*	1.117	0.829
ICC 12968 x ICC 4962	-6.978**	-1.248	3.46**	16.201**	0.336**	3.46**	96.575*	0.809	0.534
ICC 4973 x ICC 4962	-0.644	-5.781	8.731**	37.014**	0.906**	8.731**	104.975*	-2.773*	-2.318*
SE OF S(I,J) ±	2.694	4.001	0.434	5.587	0.02	1.214	40.849	1.199	0.974
SE OF S(I,J)-S(I,K) ±	4.582	6.804	0.739	9.502	0.035	2.065	69.478	2.04	1.656
SE OF S(I,J)-S(K,L) ±	4.32	6.415	0.697	8.959	0.033	1.947	65.504	1.923	1.562

Significant at 5% probability; ** Significant at 1% probability.

proved to be good specific combiners for per plant yield and yielding ha^{-1}. Average heterosis was significant and positive. The varietal effect was significantly positive for ICC 12479 and negative for ICC 3137. Heterosis due to varieties was not significant. ICC 12475, ICC 12479 and ICC 12478 recorded significant positive GCA effects according to Gardner and Eberhart (Tables 10.2, 10.3, 11.2 and 11.3).

In F_2 desi trial ICC 12475, ICC 12478, ICC 12479 showed significant positive GCA effects and ICC 4918, ICC 12426 and ICC 3137 showed significant negative GCA effects. Among F_2s three were with significant positive SCA effects and one was with significant negative SCA effect (Tables 12.2 and 12.3). According to Gardner and Eberhart analysis ICC 12475, ICC 12476 and ICC 12478 showed significant positive GCA effects and ICC 12426 and ICC 3137 showed significant negative GCA effects. Three F_2s showed significant positive SCA effects and one with negative effect (Tables 13.1 and 13.2).

In F_1 kabuli diallel three parents showed significant GCA values of which ICC 12968 was the best general combiner, followed by ICC 4973 and ICC 4962 recorded significant negative GCA effects. Eight crosses showed significant SCA effects (Tables 14.2 and 14.3). According to Gardner and Eberhart the average heterosis was significant and positive. Varietal effects were significantly positive for ICC 12968 and negative for ICC 4973 and ICC 4962. Heterosis due to varieties was positively significant for ICC 4973 and negatively significant for ICC 12968. Significantly positive GCA effects were recorded for ICC 12968, ICC 12491 and ICC 12495. Two crosses recorded significant positive SCA effects (Tables 15.2 and 15.3).

In F_2 kabuli trial ICC 12492 and ICC 4973 showed significant positive GCA effects and ICC 12491 and ICC 12968 showed significant negative GCA effect. Among F_2s eight were with significant positive SCA effects and three were with significant negative SCA effects (Tables 16.2 and 16.3). Vareital effect was significantly negative for ICC 12968 and heterosis effect due to ICC 12968 was significantly positive. ICC 12492 showed significantly positive GCA effect and ICC 12491 showed significantly negative GCA effect. Among the F_2s ICC 12492 x ICC 12494 and ICC 12495 x ICC 4962 showed significant positive SCA effects (Tables 17.1 and 17.2).

4.2.3.8 Pod borer damage

In F_1 desi diallel, ICC 12476, ICC 4918, ICC 12426 and ICC 3137 recorded significantly positive GCA effects. ICC 12479, ICC 12478 and ICC 14876 showed significant negative GCA effects (Table 10.2). ICC 14876 x ICC 4918, ICC 12476 x ICC 4918, ICC 12478 x ICC 4918 and ICC 14876 x ICC 3137 recorded significantly negative SCA effects while ICC 12478 x ICC 14876, ICC 12477 x ICC 12478, ICC 4918 x ICC 12426 and ICC 4918 x ICC 3137 showed significantly positive SCA effects (Table 10.3). According to Gardner and Eberhart analysis average heterosis effect was positive but not significant. Varietal effect was negatively significant for ICC 12479. GCA effects for all the genotypes were significant and for resistant parents (ICC 12475, ICC 12476, ICC 12478, ICC 12479, ICC 12490 and ICC 14876) the GCA effects were negative (Table 11.3), indicating that transfer of resistance to other lines will be effective.

In F_2 desi trial the susceptible genotypes ICC 4918, ICC 12426 and ICC 3137 were with significant positive GCA effects and the resistant genotypes ICC 12475, ICC 12477, ICC 12478, ICC 12479 and ICC 14876 showed significant negative GCA effects (Table 12.2). The F_2s of ICC 12476 x ICC 14876 and ICC 12426 x ICC 3137 showed significant positive SCA effects and ICC 12476 x ICC 3137, ICC 14876 x ICC 4918 and ICC 14876 x ICC 12426 showed significant negative SCA effects (Table 12.3). According to Gardner and Eberhart analysis the varietal effects were significantly positive for ICC 12475, ICC 4918 and ICC 3137 and negatively significant for ICC 12477. GCA effects were similar to Griffings' analysis. ICC 12476 x ICC 3137 and ICC 14876 x ICC 12426 showed significant negative SCA effects (Table 13.2).

Table 17.1: Estimates of combining ability effects of parents in F_2 kabuli chickpea 8 x 8 diallel, Eberharts and Gardner (1966).

Desi parents	Days to50% flow.	Days to maturity	100-seed wt. (g)	Pods plant^{-1}	Seeds pod^{-1}	Yield plant^{-1} (g)	Yield plant^{-1}((g)	Pod borer damage (%) Actual	Pod borer damage (%) Angular transformed
µ v	70.67	110.1	19.06	66.06	1.231	12.97	630.3	13.42	21.27
µ c	69.63	112.6	19.33	89.22	1.241	18.21	678.5	13.33	21.17
H	-1.036	2.494	0.276	23.15**	0.010	5.238**	48.19	-0.087	-0.106
SE of h	2.371	3.522	0.382	4.918	0.018	1.069	35.95	1.056	0.857
Varietal effect (v_i)									
ICC 12491	-20.33**	-12.13	-0.43	8.50	-0.067	0.32	26.12	3.80	3.09
ICC 12492	10	2.88	-1.75*	6.48	-0.042	0.05	87.78	-2.12	-1.69
ICC 12493	8	6.88	-4.52**	16.49	0.040	0.77	46.51	-4.39	-3.84
ICC 12494	8.67	3.21	-2.39**	7.05	0.117**	0.62	-2.43	2.63	2.33
ICC 12495	8.33	12.88	3.78**	-1.98	-0.087*	2.19	43.70	-5.25*	-4.73*
ICC 12968	-35.33**	-26.46	2.69**	-18.25	-0.113**	-3.36	-208.43*	3.82	3.21
ICC 4973 (S)	7	0.88	0.80	2.57	-0.004	1.15	123.02	1.56	1.47
ICC 4962 (S)	13.67*	11.88	1.82*	-20.85	0.155**	-1.75	-116.28	-0.04	0.17
SE of v_i ±	5.532	8.217	0.892	11.476	0.042	2.493	83.901	2.463	2.00
Heterosis due to varieties (h_i)									
ICC 12491	11.179**	5.58	-0.45	-11.37	0.021	-2.57	-88.76	-0.73	-0.46
ICC 12492	-0.821	2.82	-0.70	9.31	0.036	1.76	-0.37	-1.26	-1.21
ICC 12493	0.512	-1.04	-0.38	-1.79	0.033	-0.40	-49.49	0.21	0.31
ICC 12494	2.512	2.96	0.73	-5.53	-0.035	-1.14	-7.18	-0.27	-0.39
ICC 12495	-0.298	-2.76	-0.09	4.45	0.023	1.72	6.08	-0.36	-0.16
ICC 12968	-13.726**	-6.14	0.32	2.57	-0.024	-0.40	125.78*	2.23	1.76
ICC 4973 (S)	-0.631	-1.09	0.19	-3.38	-0.039	-0.98	-42.12	0.10	0.05
ICC 4962 (S)	1.274	-0.33	0.38	5.75	-0.014	2.01	56.06	0.08	0.10
SE of h_i ±	3.571	5.304	0.576	7.407	0.027	1.609	54.158	1,59	1.29
General combining ability effects (g_i)									
ICC 12491	1.012	-0.49	-0.67**	-7.12**	-0.01	-2.41*	-75.70**	1.17**	1.09**
ICC 12492	4.179**	4.25**	-1.58**	12.55**	0.01	1.79*	43.52**	-2.33**	-2.06**
ICC 12493	4.512**	2.40	-2.64**	6.46**	0.05**	-0.02	-26.24	-1.98**	-1.61**
ICC 12494	6.845	4.56**	-0.47**	-2.01	0.02**	-0.82	-8.40	1.04*	0.78*
ICC 12495	3.869**	3.68*	1.80**	3.45	-0.02**	2.81**	27.93	-2.98**	-2.52**
ICC 12968	-31.393**	-19.37**	1.67**	-6.56**	-0.08**	-2.08**	21.57	4.14**	3.36**
ICC 4973 (S)	2.869**	-0.65	0.59**	-2.10	-0.04	-0.40	19.39	0.88**	0.78*
ICC 4962 (S)	8.107**	5.61**	1.29**	-4.68*	0.06**	1.13*	-2.08	0.06	0.18
SE of g_i ±	0.986	1.464	0.159	2.045	0.007	0.444	14.949	0.439	0.356

S – Susceptible check, * Significant at 5% probability; ** Significant at 1% probability.

Table 17.2: Estimates of SCA effects of F_2s in kabuli chickpea 8x8 diallel, Gardner and Eberhart (1966).

F_2s	Days to 50% flow.	Days to maturity	100-seed wt. (g)	Pods plant^{-1}	Seeds pod^{-1}	Yield plant^{-1} (g)	Yield plot^{-1} (g)	Pod borer damage (%) Actual	Pod borer damage (%) Angular transformed
ICC 12491 x ICC 12492	-2.49	-4.39	0.36	-14.27	0.0047	-2.70	-12.31	2.24	2.06
ICC 12491 x ICC 12493	-1.49	-0.86	1.14**	2.85	-0.0336**	1.02	1.60	0.01	0.08
ICC 12491 x ICC 12494	2.85	-0.36	-0.34	-7.60	-0.0090**	-1.12	-26.32	-2.58	-1.94
ICC 12491 x ICC 12495	6.82	4.52	-0.90**	4.51	-0.0015	0.04	-25.34	-0.91	-0.88
ICC 12491 x ICC 12968	-0.25	-1.10	-0.37	13.92	0.0214**	2.62	69.51	-0.51	-0.47
ICC 12491 x ICC 4973	2.49	5.19	0.01	-1.15	0.0228**	-0.04	-49.81	0.20	0.09
ICC 12491 x ICC 4962	3.25	2.59	-0.34	-9.63	0.0159**	-2.39	-46.09	0.82	0.61
ICC 12492 x ICC 12493	4.01	5.40	-0.42	22.96*	0.0005	4.66*	48.25	-2.32	-2.55
ICC 12492 x ICC 12494	2.35	2.23	-0.81**	63.06**	0.0258**	12.76**	244.18**	-5.59**	-5.22**
ICC 12492 x ICC 12495	-5.35*	-1.89	0.69*	-3.54	-0.0268**	-0.67	-73.67	2.25	2.00
ICC 12492 x ICC 12968	1.25	-3.51	-1.08**	-11.78	0.0388**	-2.29	-62.46	-2.78	-1.99
ICC 12492 x ICC 4973	-1.01	3.11	0.63*	-21.94*	-0.0081*	-4.60	-23.91	3.74*	3.31*
ICC 12492 x ICC 4962	0.42	1.85	-0.07	-25.19*	0.0007	-5.40**	-120.44*	1.21	1.17
ICC 12493 x ICC 12494	1.35	1.09	-0.25	-2.92	0.0089*	-0.83	-20.68	0.25	0.48
ICC 12493 x ICC 12495	-3.35	-0.36	0.16	-16.22	0.0369	-2.85	-41.21	1.91	1.66
ICC 12493 x ICC 12968	-4.08	-5.32	0.72*	7.33	-0.0368**	1.95	36.03	-1.65	-1.24
ICC 12493 x ICC 4973	4.32	1.97	-0.45	-2.31	0.0199**	-0.38	12.58	-0.35	-0.18
ICC 12493 x ICC 4962	-0.25	-2.96	-1.27**	-13.47	0.0374**	-3.96*	-86.06	2.36	2.05
ICC 12495 x ICC 12494	1.99	-6.86	-0.13	-5.80	-0.0121**	-1.30	-58.52	0.09	0.38
ICC 12968 x ICC 12494	0.58	11.52**	0.59	-14.10	-0.0192**	-2.96	-25.42	5.67**	4.06**
ICC 4973 x ICC 12494	-6.35	-4.86	0.43	-15.95	-0.0298**	-3.56*	-25.29	2.07	1.84
ICC 4962 x ICC 12494	-0.25	0.21	1.24**	-22.22*	0.0001	-4.12*	-95.15	-0.19	0.01
ICC 12495 x ICC 12968	-5.44*	-4.60	0.75*	-9.61	-0.0118*	-2.09	22.50	0.93	1.08
ICC 12495 x ICC 4973	3.30	2.69	-0.76	-1.44	0.0390**	-0.22	-100.08*	-3.19*	-2.99*
ICC 12495 x ICC 4962	1.73	3.76	0.09	36.54**	-0.0009	8.81**	282.40**	-1.44	-1.41
ICC 12968 x ICC 4973	-2.77	-3.27	-0.35	8.25	-0.0161**	0.56	54.31	0.44	0.31
ICC 12968 x ICC 4962	-3.01	0.14	0.06	8.56	-0.0007	1.81	31.31	0.14	0.00
ICC 4973 x ICC 4962	-0.61	-5.91	0.67	31.16**	-0.0663	7.26**	90.08	-2.81	-2.34
SE of S_{ij} ±	2.23	3.1	.31	10.37	0.00379	1.75	50	1.49	1.36

Significant at 5% probability; ** Significant at 1% probability.

In kabuli F_1 diallel three parents showed significant GCA effects of which ICC 12492 showed significant negative GCA effect and ICC 4973 and ICC 4962 recorded significant positive GCA effects. Five crosses recorded significant SCA effects (14.2 and 14.3). According to Gardner and Eberhart analysis average heterosis was negative but not significant. Varietal effects and heterosis due to varieties was not significant for any of the varieties. ICC 12492, ICC 12493, ICC 12495 and ICC 12968 showed significantly negative GCA effects (Tables 15.2 and 15.3).

In F_2 kabuli trial ICC 12491, ICC 12494 and ICC 12968 showed significant positive GCA effects and ICC 12492 and ICC 12495 showed significant negative GCA effects. Among the F_2s ICC 12491 x ICC 12494, ICC 12492 x ICC 12493, ICC 12495 x ICC 4973 and ICC 4973 x ICC 4962 were with significant negative SCA effects (Tables 16.2 and 16.3). According to Gardner and Eberhart analysis analysis varietal effect was significantly negative for ICC 12495. All the varieties showed significant GCA effects except ICC 4962. The effects were significantly negative for ICC 12495 and ICC 12493 and positive for ICC 12968, ICC 12494, ICC 12496 and ICC 4973. Among the F_2s ICC 12492 x ICC 12494 and ICC 12495 x ICC 4973 recorded significant negative SCA effects (Tables 17.1 and 17.2).

4.3 MECHANISMS OF RESISTANCE TO *H. armigera* IN CHICKPEA

4.3.1 ANTIBIOSIS

4.3.1.1 Larval and pupal weights

The mean larval weight of the 10-day old larvae reared on leaves different genotypes differed significantly. The highest larval weight was recorded on ICC 4962 (339.0 mg), followed by those reared on ICC 4973 (319.0 mg), ICC 12968 (302.0 mg), ICC 3137(298.0 mg), ICC 12426 (259.0 mg) and ICC 4918 (221.0 mg). The lowest weight of the larvae was recorded on resistant check, ICC 12475 (145.0 mg), followed by ICC 12479(159.0 mg), and ICC 12490 (169.0 mg) (Table 18.1).

18.1: Growth and development of *H.armigera* on leaves of eighteen chickpea genotypes, ICRISAT, Patancheru, 2000-02.

Genotype	Unit larval Wt. 10^{th} Day (mg)	Larval period (days)	Pupal period (days)	Pupal Wt. (mg)	Larval Survival (%) 10^{th} day		Pupation (%)		Adult emergence (%	
					Actual	AT*	Actual	AT*	Actual	AT*
ICC 12476	189^{abc}	21.9^{def}	13.2^{bcd}	224^{ab}	64^{ab}	(53)	56^{ab}	(48)	56^{ab}	(48)
ICC 12477	178^{abc}	20.5^{bcd}	12.0^{abc}	215^{a}	68^{abc}	(55)	58^{abc}	(50)	58^{abc}	(50)
ICC12478	191^{abc}	23.0^{ef}	11.1^{a}	256^{bc}	66^{abc}	(54)	62^{abc}	(52)	62^{abc}	(52)
ICC 12479	159^{ab}	23.1^{ef}	15.6^{ef}	221^{ab}	68^{abc}	(55)	62^{abc}	(52)	60^{abc}	(51)
ICC 12490	169^{abc}	23.4^{f}	13.3^{cd}	215^{a}	64^{ab}	(53)	62^{abc}	(52)	60^{abc}	(51)
ICC 14876	189^{abc}	23.1^{ef}	14.2^{de}	219^{a}	64^{ab}	(53)	60^{abc}	(51)	60^{abc}	(51)
ICC 12426	259^{def}	19.2^{abc}	10.9^{a}	302^{e}	86^{de}	(68)	86^{d}	(68)	86^{d}	(68)
ICC 3137	298^{efg}	18.6^{ab}	11.2^{a}	321^{f}	88^{e}	(69)	88^{e}	(70)	86^{d}	(68)
ICC 12491	201^{abcd}	20.1^{abcd}	13.6^{cd}	256^{b}	70^{abcd}	(56)	66^{abcd}	(54)	62^{abc}	(52)
ICC 12492	212^{bcd}	19.6^{abc}	14.5^{d}	273^{cde}	74^{abcd}	(59)	62^{abc}	(52)	62^{abc}	(52)
ICC 12493	201^{abcd}	19.33^{abc}	13.5^{cd}	213^{a}	78^{bcde}	(62)	70^{bcde}	(57)	68^{abcd}	(56)
ICC 12494	198^{abc}	19.23^{abc}	15.6^{e}	215^{a}	76^{bcde}	(60)	72^{bcde}	(58)	68^{abcd}	(56)
ICC 12495	182^{abc}	21.22^{a}	14.9^{de}	265^{cd}	76^{bcde}	(60)	70^{bcde}	(57)	70^{bcd}	(57)
ICC 12968	302^{fg}	19.6^{cde}	12.5^{abc}	266^{cd}	82^{cde}	(64)	78^{cde}	(62)	78^{cd}	(62)
ICC 4973	319^{fg}	17.9^{a}	11.2^{a}	312^{f}	88^{e}	(69)	86^{de}	(68)	86^{d}	(68)
ICC 4962	339^{g}	18.3^{ab}	12.0^{ab}	306^{ef}	90^{e}	(71)	86^{de}	(68)	86^{d}	(68)
Controls										
ICC 12475 (R)	145^{a}	23.0^{ef}	17.0^{f}	215^{a}	58^{a}	(49)	48^{a}	(44)	48^{d}	(44)
ICC 4918 (S)	221^{c}	18.9^{abc}	11.2a	299^{def}	88^{e}	(69)	86^{de}	(68)	86^{d}	(68)
Mean	242	21.07	14.5	260.5	74	(60)	67	(56)	67	(56)
F(Prob. At 5%)	<0.001	0.015	0.012	<0.001	0.113	0.078	0.015	0.009	0.02	0.015
SED	29.1	1.11	0.926	19.0	8.85	5.5	10.23	6.4	10.3	6.4
LSD	61.0	2.23	1.82	37.3	17.6	10.9	20.4	12.7	20.4	12.7
CV%	12.9	19.5	18.3	9.8	15.9	9.8	22.6	14.0	22.6	14.0

Means followed by same letters do not differ significantly; Number of larvae=50 neonate larvae, AT* =Angular transformed values; R – Resistant, check; S – Susceptible check .

18.2: **Growth and development of *H.armigera* on pods of eighteen chickpea genotypes, ICRISAT, Patancheru, 200-02.**

Genotype	Unit larval Wt. 10th day (mg)	Larval period (days)	Pupal period (days)	Pupal Wt. (mg)	Larval Survival (%) (10th day)		Pupation (%)		Adult emergence (%)	
					Actual	AT*	Actual	AT*	Actual	AT*
ICC 12476	191.6ba	21.8bc	12.7b	264.1cd	72	(58)	68ab	(56)	66a	(54)
ICC 12477	188.1^{ba}	20.3^{cd}	13.1^{bc}	225.9^{a}	76	(61)	64^{a}	(53)	64^{a}	(53)
ICC12478	196.4^{ba}	22.6^{ab}	10.9^{ef}	293.1^{ef}	74	(59)	70^{ab}	(57)	70^{ab}	(57)
ICC 12479	160.9^{a}	22.9^{ab}	14.2^{a}	236.2^{ab}	70	(57)	56^{a}	(48)	56^{a}	(48)
ICC 12490	161.3^{a}	23.5^{ab}	11.7^{de}	245.75^{ab}	74	(59)	64^{ab}	(53)	64^{ab}	(53)
ICC 14876	151.2^{a}	24.5^{a}	12.1^{c}	248.5^{bc}	74	(59)	64^{ab}	(53)	62^{ab}	(52)
ICC 12426	291.9^{ed}	18.4^{defg}	10.5^{ef}	315.7^{gh}	88	(70)	88^{b}	(70)	88^{b}	(70)
ICC 3137	332.9^{e}	16.9^{ghi}	10.9^{ef}	331.2^{h}	90	(72)	88^{b}	(70)	88^{b}	(70)
ICC 12491	199.1^{ba}	19.2^{def}	13.0^{a}	269.8^{cd}	72	(58)	70a^{b}	(57)	68^{ab}	(56)
ICC 12492	227.0^{cb}	17.3^{fgh}	12.9^{bd}	244.8^{ab}	80	(63)	74^{ab}	(59)	74^{ab}	(59)
ICC 12493	215.3^{ba}	18.9^{defg}	10.4^{f}	226.3^{a}	76	(61)	72^{ab}	(58)	72^{ab}	(58)
ICC 12494	189.4^{ba}	18.7^{defg}	11.3^{ef}	233.1^{a}	80	(63)	76^{ab}	(61)	76^{ab}	(61)
ICC 12495	193.8^{ba}	19.9^{cde}	10.7^{ef}	254.1^{bcd}	80	(63)	70^{ab}	(57)	70^{ab}	(57)
ICC 12968	288.1^{edc}	18.1efg	11.5^{ef}	277.4^{de}	92	(74)	90^{b}	(72)	90^{b}	(72)
ICC 4973	332.4^{e}	15.1^{i}	10.8^{ef}	320.5^{g}	92	(74)	88^{b}	(70)	88^{b}	(70)
ICC 4962	333.2^{e}	15.5^{hi}	10.8^{ef}	333.9^{h}	94	(76)	88^{b}	(70)	88^{b}	(70)
Controls										
ICC 12475 (R)	156.8	23.3^{ab}	13.7^{ab}	225.8^{a}	68	(56)	54^{a}	(47)	54^{a}	(47)
ICC 4918 (S)	236.9^{dcb}	18.8^{defg}	11.0^{ef}	303.3^{fg}	90	(72)	88^{b}	(70)	88^{b}	(70)
Mean	245.0	19.4	13.24	279.85	81	65.5	71	58.5	71	58.5
F (Pro. at 5%))	<.001	<.001	<.001	<.001	0.106	0.078	0.025	0.008	0.023	0.006
SED	32.58	1.021	0.639	11.4	11.1	8.2	11.5	8.6	11.6	8.7
LSD	65.39	2.061	1.256	22.42	22.2	16.5	23.5	17.6	23.5	17.6
CV%	9.6	9.8	8.5	11.5	20.1	15.1	29.6	22.2	29.9	22.4

Means followed by same letters do not differ significantly; Number of larvae=50 neonate larvae; AT*=Angular transformed values;
R – Resistance check; S – Susceptible check

The larvae fed on the pods of ICC 14876 (151.0 mg), ICC 12475 (157.0 mg), ICC 12479 (161.0 mg) and ICC 12490 (215.0 mg)) weighed significantly lower than those that fed on ICC 3137 (333.0 mg), ICC 4962(333.0 mg), and ICC 4973 (332.0 mg) (Table 18.2).

Larvae reared on diet impregnated with lyophilized leaf powder of ICC 12475 (181.4 mg), ICC 12479 (185.5 mg) and ICC 14876 (191.9 mg) weighed significantly lower than the larvae reared on ICC 4962 (344.6 mg), ICC 4973 (375.0 mg), ICC 3137 (357.0 mg), ICC 12426 (316.0 mg) and ICC 4918 (291.0 mg) (Table 18.5). Larvae fed on diet with lyophilized pod powder of ICC 12475 (275.3 mg), ICC 12495 (278.9 mg), ICC 12476 (293.6 mg), ICC 12494 (298.7 mg) and ICC 12479 (298.8 mg) weighed significantly lower than those fed on ICC 4973 (298.8 mg), ICC 3137(298.7 mg), ICC 12426 (445.0 mg), ICC 4918 (404.6 mg), and ICC 4962 (401.2 mg). Larvae in the control diet (without lyophilized leaf powder) weighed significantly higher (451.2 mg) than those reared on diets with lyophilized leaf powder (Table 18.5).

Mean pupal weight of one-day old pupae on different genotypes differed significantly. When the larvae were reared on leaves, highest pupal weight was recorded on ICC 3137(321.0 mg) and ICC 4973 (312.0 mg), and lowest on ICC 12475 (215.0 mg), ICC 12490 (215.0 mg) and ICC 12477 (215.0 mg) (Table 18.1). Pupal weights were highest on ICC 4962 (226.0 mg) and ICC 3137 (331.0 mg) than on ICC 12475 (226.0 mg), ICC 12477 (226.0 mg), and ICC 12479 (236.0 mg) when larvae were reared on pods (Table 18.2).

The pupae that were formed from larvae reared on artificial diet with lyophilized leaf powder of genotypes ICC 12477 (219.2 mg), ICC 12478 (237.3 mg), ICC 12476 (243.6 mg), ICC 12491 (233.3 mg), ICC 12493 (265.0 mg) and ICC 12494 (256.8 mg), and the resistant check, ICC 12475 (260.1 mg) weighed significantly less than the other genotypes tested. Pupal weight of larvae reared on ICC 4973 (344.2 mg) was on par with those reared on standard diet (380.7 mg) (Table 18.5).

Table 18. 3 : **Growth of *H. armigera* on artificial diet impregnated with different concentrations of lyophilized chickpea leaf powder, ICRISAT, Patancheru, 2000-02.**

Genotype	Leaf Powder (g)	Uynit larval Wt. 10th day (mg)	Larval period (days)	Pupal period (days)	Pupal Wt. (mg)	Larval survival (%) (10th day)		Pupation (%)		Adult emergence (%)	
						Actual	AT*	Actual	AT*	Actual	AT*
ICC 4918	10	391.0[e]	16.9[e]	10.9[ef]	312.4[ef]	90[cd]	(72)	83[e]	(66)	83[f]	(66)
ICC 4918	15	398.0[e]	17.8[de]	11.2[def]	313.1[ef]	83[c]	(72)	73[cd]	(64)	73[de]	(64)
ICC 4918	20	291.9[d]	17.8[de]	11.7[cde]	286.0[de]	80[bc]	(64)	63[b]	(53)	63[c]	(53)
ICC 4918	25	204.3[fc]	19.3[c]	11.8[bcd]	266.0[cd]	80[bc]	(66)	67[bc]	(55)	67[cd]	(55)
ICC 4918	30	260.1[cd]	20.9[b]	11.8[bcd]	250.0[bc]	70[ab]	(57)	60[ab]	(51)	53[a]	(47)
ICC 12475	10	276.6[d]	18.2[cd]	12.1[abc]	295.0[de]	70[ab]	(69)	80[de]	(63)	77[ef]	(61)
ICC 12475	15	255.0[cd]	21.8[b]	12.5[abc]	288.0[de]	80[bc]	(64)	73[cd]	(59)	70[cd]	(57)
ICC 12475	20	153.9[ab]	24.1[a]	12.6[ab]	266.9[cd]	67[a]	(55)	63[b]	(53)	63[c]	(53)
ICC 12475	25	127.4[a]	25.1[a]	12.6[ab]	235.8[b]	63[a]	(53)	60[ab]	(51)	53[a]	(47)
ICC 12475	30	855.0[a]	24.8[a]	12.9[a]	204.9[a]	63[a]	(49)	53[a]	(47)	50[a]	(45)
Standard diet		544.5[f]	14.7[f]	10.7[f]	332.5[f]	100[d]	(90)	97[f]	(79)	97[g]	(79)
Mean		270.0	20.12	11.88	280.1	76.9	(64)	70	(58)	68	(57)
F (prob. at 5%)		<0.001	<0.001	0.028	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
SED		35.0	0.59	0.44	15.0	6.3	5.3	4.5	2.7	4.7	3.0
LSD		70.1	1.16	0.87	30.1	12.7	10.9	9.3	5.7	9.8	6.2
CV%		50.7	11.3	15.4	20.5	10.5	10.1	8.1	6.0	8.9	6.8

Means followed by same letters do not differ significantly; Number of larvae=30 neonate larvae; AT*=Angular transformed values.

Table 18. 4: **Growth of *H. armigera* on artificial diet impregnated with different concentrations of lyophilized chickpea pod powder, ICRISAT, Patancheru, 2000-02.**

Genotype	Pod powder (g)	Unit larval Wt. 10th day (mg)	Larval period (days)	Pupal period (days)	Pupal wt. (mg)	Larval survival (%) (10th day)		Pupation (%)		Adult emergence (%)	
						Actual	AT*	Actual	AT*	Actual	AT*
ICC 4918	10	415.9^{f}	16.4^{e}	11.2^{d}	321.4^{b}	93^{gh}	(75)	90^{fg}	(72)	90^{ef}	(72)
ICC 4918	15	382.6^{ef}	16.7^{e}	11.4^{cd}	318.9^{b}	90^{efgh}	(72)	83^{ef}	(66)	83de	(66)
ICC 4918	20	335.4^{de}	17.0^{d}	12.0^{abcd}	286.6^{ab}	83^{ef}	(66)	63^{bcd}	(53)	63^{bc}	(53)
ICC 4918	25	289.5^{cd}	18.0^{c}	12.0^{abcd}	278.9^{ab}	77^{cd}	(61)	69^{c}	(56)	69^{c}	(56)
ICC 4918	30	221.4^{bc}	19.0^{c}	11.2^{d}	269.8^{ab}	70^{cd}	(57)	60^{abc}	(51)	50^{ab}	(45)
ICC 12475	10	332.4^{de}	17.3^{de}	12.0^{abcd}	289.8^{ab}	87^{efg}	(69)	73de	(59)	73^{c}	(59)
ICC 12475	15	285.9^{cd}	18.2^{cd}	12.7^{ab}	284.1^{ab}	80de	(63)	73de	(59)	70^{cd}	(57)
ICC 12475	20	189.1^{ab}	21.2^{b}	11.7^{bcd}	211.8^{a}	67^{abc}	(55)	53^{ab}	(47)	53^{ab}	(47)
ICC 12475	25	169.8^{ab}	22.1^{a}	13.0^{a}	210.3^{a}	63^{ab}	(53)	53^{ab}	(47)	53^{ab}	(47)
ICC 12475	30	123.6^{a}	22.8^{ab}	12.6^{abc}	205.6^{a}	57^{a}	(49)	50^{a}	(45)	43^{a}	(41)
Standard diet		512.9^{g}	15.1^{f}	11.0^{d}	362.1^{b}	100^{h}	(90)	100^{g}	(90)	100^{f}	(90)
Mean		296.11	18.53	11.87	276.20	78.79	64.37	69.89	55.38	68.07	54.21
F (Prob. at 5%)		<0.001	<0.001	0.059	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
SED		41.51	0.69	0.60	56.23	5.69	3.11	5.69	4.26	6.12	4.36
LSD		83.10	1.25	1.27	101.20	11.79	6.22	12.1	8.52	13.2	8.72
CV%		36.8	13.9	16.8	19.2	14.4	10.1	16.3	12.3	18.2	14.5

Means followed by same letters do not differ significantly; Number of larvae=30 neonate larvae;
AT*=Angular transformed values.

Weights of pupae from lyophilized pod powder of ICC 12479 (241.8 mg), ICC 12478 (242.1 mg), ICC 12475 (253.3 mg) and ICC 12476 (263.6 mg) were significantly lower than the insect reared on ICC 12426 (312.0 mg), ICC 3137 (320.1 mg), ICC 4973 (314.0 mg), ICC 4918 (332.4 mg), and the standard diet (330.3 mg) (Table 18.6).

4.3.1.2 Post embryonic development larval and pupal periods

Differences in duration of larval and pupal development of insects reared on leaves, pods, and lyophilized leaf and pod powder of different genotypes were significant. When larvae were reared on leaves the larval period was longest on ICC 12475, ICC 12478, ICC 12479, ICC 12490 and ICC 14876 (23 days). Larval period was shorter on ICC 3137 (18.6 days), ICC 4918 (18.9 days), ICC 12494 (19.2 days), ICC 12426 (19.2 days), ICC 12493 (19.3 days), ICC 12492 (19.6 days) and ICC 12491 (20.1 days). Significantly longer larval period was recorded on ICC 12475 and ICC 12479 (15.6 days). Mean larval and pupal periods (19.4 and 13.2 days respectively) were shorter on pods than on leaves (21.0 and 14.5 days respectively).

Larvae reared on diets using lyophilized leaf powder of ICC 12478 (22.6 days), ICC 12479 (22.9 days), ICC 12490 (23.5 days) and ICC 12475 (23.3 days) had significantly longer larval periods than in diets having leaf powder of ICC 3137 (16.9 days), ICC 4973 (16.1 days) and ICC 4962 (16.1 days) and the standard diet (15.5 days) (Table 18.5).

When the larvae were reared on diets having lyophilized pod powder, significantly shorter larval periods were recorded on ICC 12476 (16.6 days) and ICC 4962 (16.4 days), which were on par with the standard diet (16.8 days). Significantly longer larval period was recorded in diets having ICC 14876 (19.2 days) pod powder. Longest pupal period was recorded in diets having pod powder of ICC 12475 (13.1 days), and shortest in diets with pod powder of ICC 4973 (9.9 days), which was on par with the standard diet (9.9 days) (Table 18.6).

Table 18.5: Growth and development of *H.armigera* on artificial diet impregnated with 20g of lyophilized leaf powder, of eighteen chickpea genotypes, ICRISAT, Patancheru, 2000-02.

Genotype	Unit larval Wt. 10th day (g)	Larval period (days)	Pupal period (days)	Unit Pupal Wt. (g)	Larval survival (%) (10th day)		Pupation (%)		Adult emergence (%)	
					Actual	AT*	Actual	AT*	Actual	AT*
ICC 12476	193.8^{a}	21.8^{bc}	10.7^{abcd}	243.6^{ab}	77^{abc}	(61)	57^{ab}	(49)	57^{ab}	(49)
ICC 12477	196.9^{a}	20.3^{ac}	11.1^{abc}	219.2^{a}	73^{ab}	(59)	63^{abc}	(53)	63^{abc}	(53)
ICC12478	221.0^{abc}	22.6^{ab}	11.0^{abcd}	237.3^{ab}	77^{abc}	(61)	67^{abcd}	(55)	67^{abcd}	(55)
ICC 12479	185.5^{a}	22.9^{ab}	12.0^{a}	259.9^{b}	77^{abc}	(61)	70^{bcd}	(57)	70^{bcd}	(57)
ICC 12490	195.9^{a}	23.5^{a}	9.0^{d}	269.4^{b}	70^{a}	(57)	57^{ab}	(49)	57^{ab}	(49)
ICC 14876	191.9^{a}	20.1^{cd}	11.5^{ab}	272.2^{bc}	73^{ab}	(59)	60^{ab}	(51)	60^{ab}	(51)
ICC 12426	316.5^{ef}	18.4^{de}	9.4^{cd}	339.4^{de}	90^{bcd}	(72)	83^{def}	(66)	83^{def}	(66)
ICC 3137	357.5^{fg}	16.9^{fg}	10.9^{abcd}	308.9^{cde}	93^{cd}	(75)	93^{ef}	(75)	90^{ef}	(72)
ICC 12491	201.4^{ab}	19.2^{d}	10.5^{abcd}	233.3^{ab}	77^{abc}	(61)	70^{bcd}	(57)	70^{bcd}	(57)
ICC 12492	251.6^{cd}	17.3^{ef}	10.8^{abcd}	268.5^{b}	83^{abcd}	(66)	80^{cde}	(63)	80^{cde}	(63)
ICC 12493	239.9^{bc}	18.9^{de}	10.4^{abcd}	250.0^{ab}	80^{abc}	(63)	73^{bcd}	(59)	73^{bcd}	(59)
ICC 12494	259.8^{cd}	18.7^{de}	11.3^{abc}	256.8^{ab}	80^{abc}	(63)	73^{bcd}	(59)	73^{bcd}	(59)
ICC 12495	195.6^{a}	19.9^{d}	10.7^{abcd}	315.3^{de}	73^{abc}	(59)	63^{abc}	(53)	63^{abc}	(53)
ICC 12968	241.0^{bc}	18.5^{de}	11.1^{abcd}	301.1^{cd}	80^{abc}	(63)	73^{bcd}	(59)	70^{bcd}	(57)
ICC 4973	357.0^{fg}	16.1^{fg}	9.8^{bcd}	344.2^{ef}	90^{bcd}	(72)	83^{def}	(66)	83^{def}	(66)
ICC 4962	394.6^{g}	16.1^{fg}	10.2^{abcd}	315.9^{de}	93^{cd}	(75)	83^{def}	(66)	83^{def}	(66)
Checks										
ICC 12475 (R)	181.4^{a}	23.3^{ab}	12.0^{a}	260.1^{b}	73^{ab}	(59)	50^{a}	(45)	50^{a}	(45)
ICC 4918 (S)	291.5^{de}	18.8^{de}	10.0^{abcd}	327.0^{de}	90^{bcd}	(72)	83^{def}	(66)	83^{def}	(66)
Standard diet	518.2^{h}	15.5^{g}	9.9^{bcd}	380.7^{f}	100^{d}	(90)	100^{f}	(90)	100^{f}	(90)
Mean	263.11	19.401	10.6	284.12	81.6	65.7	72.8	59.8	72.5	59.5
F(Prob)	<.001	<.001	<.001	<.001	0.102	0.069	0.012	0.006	0.025	0.009
SED	21.55	0.90	1.08	20.21	8.8	6.1	9.2	6.5	9.3	6.5
LSD	42.90	1.71	2.13	40.63	17.4	12.2	18.5	13.0	18.6	13.0
CV%	15.5	9.8	14.3	10.5	18.6	13.0	24.8	17.3	24.9	17.4

Means followed by same letters do not differ significantly; Number of larvae=30 neonate larvae;
AT*= Angular transformed values, R-Resistant check, S-susceptible check.

Table 18.6: Growth and development of *H.armigera* on artificial diet impregnated with 20g of lyophilized pod powder of eighteen chickpea genotypes, ICRISAT, Patancheru, 2000-02.

Genotype	Unit larval Wt.10th day (mg)	Larval period (days)	Pupal period (days)	Pupal Wt. (g)	Larval survival (%) 10^{h} day		Pupation (%)		Adult emergence (%)	
					Actual	AT*	Actual	AT*	Actual	AT*
ICC 12476	293.6^{a}	16.6^{e}	12.5^{ab}	263.6^{abc}	83^{ab}	(66)	67^{ab}	(55)	67^{ab}	(55)
ICC 12477	361.4^{bcd}	17.6^{abcde}	12.1^{abc}	268.2^{bc}	83^{ab}	(66)	70^{ab}	(57)	70^{ab}	(57)
ICC12478	339.1^{abc}	18.1^{abcde}	11.9^{abc}	252.1^{ab}	83^{ab}	(66)	70^{ab}	(57)	70^{ab}	(57)
ICC 12479	298.8^{ab}	17.5^{abcde}	12.2^{abc}	241.8^{ab}	80^{a}	(63)	73^{bc}	(59)	70^{bc}	(57)
ICC 12490	312.5^{ab}	19.2^{abc}	11.0^{cdefg}	256.4^{ab}	80^{a}	(63)	77^{bcd}	(61)	77^{bcd}	(61)
ICC 14876	301.1^{ab}	19.8^{a}	11.4^{bcd}	264.1^{bc}	83^{ab}	(66)	83^{cde}	(66)	83^{cde}	(66)
ICC 12426	445.0^{ef}	17.4	10.3^{efg}	312.0^{fgh}	97^{abc}	(79)	87^{def}	(69)	87^{def}	(69)
ICC 3137	480.1^{f}	18.0^{bcde}	10.5^{defg}	320.1^{gh}	97^{c}	(79)	93^{e}	(75)	93^{e}	(75)
ICC 12491	325.8^{ab}	19.2^{abcde}	11.2^{cdef}	296.6^{def}	83^{ab}	(66)	77^{bcd}	(61)	77^{bcd}	(61)
ICC 12492	301.2^{ab}	19.6^{abc}	10.3^{efg}	298.9^{def}	87^{abc}	(69)	87^{def}	(69)	87^{def}	(69)
ICC 12493	301.2^{ab}	18.2^{abc}	11.9^{bc}	280.9^{cd}	87^{abc}	(69)	73^{bc}	(59)	73^{bc}	(59)
ICC 12494	298.7^{ab}	18.2^{abcde}	11.7^{bcd}	274.1^{bc}	83^{ab}	(66)	77^{bcd}	(61)	77^{bcd}	(61)
ICC 12495	278.9^{a}	18.2^{abcde}	12.6^{ab}	279.4^{cd}	87^{abc}	(69)	70^{ab}	(57)	70^{ab}	(57)
ICC 12968	439.8^{ef}	18.8^{abcd}	10.0^{fg}	267.9^{bc}	90^{abc}	(72)	83^{cde}	(66)	83^{cde}	(66)
ICC 4973	451.2^{ef}	17.2^{cde}	9.9^{g}	314.0^{fgh}	93^{bc}	(75)	87^{def}	(69)	87^{def}	(69)
ICC 4962	401.2^{cde}	16.4^{e}	10.1^{fg}	301.1^{def}	97^{c}	(79)	87^{def}	(69)	87	(69)
Checks										
ICC 12475 (R)	275.3^{a}	18.0^{abcd}	13.1^{e}	253.3^{ab}	80^{a}	(63)	60^{a}	(51)	57.	(49)
ICC 4918 (S)	404.6^{de}	17.5b^{cde}	10.6^{defg}	332.4^{h}	97^{c}	(79)	87^{def}	(69)	87	(69)
Standard diet	550.4^{g}	16.84^{de}	9.98^{fg}	330.3^{h}	97^{c}	(79)	97^{f}	(79)	97	(79)
Mean	412.9	17.42	11.6	0.2918	88	71	78	65	77	64
F (Prob. at 5%)	<.001	<.001	<.001	<.001	0.010	0.007	0.003	<.001	0.003	<.001
SED	32.58	1.02	0.64	11.41	5.55	3.89	6.39	4.47	6.39	4.47
LSD	65.4	2.06	1.26	22.42	10.10	7.07	12.8	8.96	12.9	9.03
CV%	9.6	9.8	8.5	11.5	18.1	12.67	12.5	8.75	12.9	10.2

Means followed by same letters do not differ significantly; R-Resistant check: S-Susceptible check;
Number of larvae=90 neonate larvae, AT*=Angular transformed values.

When data from all the four experiments were compared, mean larval and pupal periods were longest (21.1 days and 14.5 days respectively) when the larvae reared on leaves, while shortest larval period was recorded on diet having on lyophilized pod powder (17.4 days). Shortest pupal period was recorded on diet with lyophilized leaf powder (10.6 days).

4.3.1.3 Larval and pupal survival

When the larvae were reared on lyophilized leaf powder, percent pupation and percent adult emergence differed significantly. Percent adult emergence was almost same as percent pupation. Average larval survival was higher on diets with lyophilized pod powder than on diets having lyophilized leaf powder. Lowest survival was recorded when the larvae were reared on leaves.

Significantly lower survival was recorded on resistant check ICC 12475. Larval survival was lower when the insects were reared on leaves of ICC 12476 (56%), ICC 12477 (63%), ICC 12478 (67%), ICC 12490 (57%), ICC 14876 (60%), ICC 12495 (63%) and ICC 12475 (50%). There were no significant differences in larval of pupal survival when the larval reared on pods of ICC 12476 (67%), ICC 12477 (70%), ICC 12478 (70%), ICC 12478 (70%) , ICC 12495 (70%), and ICC 12475 (60%).

Larval survival was lower when the insects were reared on diets with lyophilized leaf powder of ICC 12476 (56%), ICC 12477 (58%), ICC 12478 (62%), ICC 12479 (62%), ICC 14876 (60%), ICC 12490 (62%), ICC 12491 (66%), and ICC 12475 (48%). When the larvae were reared on diets with lyophilized pod powder, ICC 12476 (67%), ICC 12477 (70%), ICC 12478 (70%) and ICC 12494 (77%) and ICC 12495 (70%), were on par with the resistant check ICC 12475 (60%).

Fecundity and egg viability of insect reared on different genotypes did not differ significantly.

4.3.2 RELATIVE SUSCEPTIBILITY OF THE CHICKPEA GENOTYPES TO *H. armigera* UNDER NO-CHOICE CAGED CONDITION

Significantly lower leaf feeding was recorded on ICC 12478 (1.5), ICC 12479 (2.3), ICC 14876 (3.0) and ICC 12968 (3.2) which were on par with the resistant check, ICC 12475 (1.0) during the vegetative stage. In the same experiment, when the larvae were released during the flowering stage which were also infested at the vegetative stage, the genotypes ICC 12478 (0.8) and ICC 12479 (1.8) were on par with resistant check, ICC 12475 (1.0) (Table 19.1).

When the larvae were released during vegetative stage significantly lower leaf damage was recorded in ICC 12479 (2.3), ICC 14876 (3.0), ICC 12491 (2.8) and check ICC 12475 (1.5) than on ICC 37 (4.5). In another experiment the genotypes were infested only at the vegetative stage and ICC 12476 (3.0) and ICC 12479 (2.3) were on par with resistant check ICC 12475 (2.2). During flowering time ICC 12476 (2.5), ICC 12479 (1.8) and ICC 14876 (2.6) were on par with resistant check ICC 12475 (1.6). Mean damage rating during flowering stage (3.86) was less than that recorded at the vegetative stage (4.1) (Table 19.3).

During the vegetative stage statistically same number of larvae survived in all the genotypes except on ICC 12476 (85%), ICC 4973(85%), ICC 4962 (85%), ICC 12490 (75%) and ICC 4918 (90%). When the larvae were released on the same plants during the flowering stage, significantly lower number of larvae survived on ICC 12476 (50%), ICC 12477 (55%), ICC 12490 (55%), ICC 12491 (40%), ICC 12492 (45%), ICC 12493 (335%), ICC 12494 (50%), ICC 12495 (45%) and ICC 12475 (50%). than on ICC 14876 (60%), ICC 12426 (71%), ICC 3137 (75%), ICC 12478 (63%), ICC 12479 (71%), ICC 124968 (60%), ICC 1473 (65%), ICC 4962 (71%), and susceptible check ICC 4918 (76%) (Table 19.1).

When the larvae were released at the vegetative and flowering stages separately, significantly lower number of larvae survived on ICC 12476, ICC 12477, ICC 12478, ICC 12479, ICC 14876, ICC 12491, ICC 12495, and ICC 12475 (Table 19.2).

Table 19 . 1: **Relative susceptibility of eighteen chickpea genotypes to *H.armigera* (vegetative + flowering stage) under no-choice caged conditions, ICRISAT, Patancheru, 2000-02.**

	Vegetative stage			Flowering stage		
Genotype	Damage rating (0-9)	Larval survival (%)	Unit Larval Wt (mg)	Damage rating (0-9)	Larval survival (%)	Unit Larval Wt (mg)
ICC 12475	3.6^{bcd}	83^{bcd}	105^{abc}	2.5^{bcd}	50^{abcd}	367.1
ICC 12477	4.8^{d}	67^{ab}	988^{abc}	3.83^{de}	55^{abcde}	332.7
ICC12478	1.5^{ab}	80^{abcd}	787^{ab}	0.8^{a}	63^{cde}	472.3
ICC 12479	2.3^{abc}	58^{a}	641^{a}	1.8^{abc}	71de	379.7
ICC 12490	3.8^{cdef}	73^{cd}	665^{ab}	3.0^{cde}	55^{abcde}	372.7
ICC 14876	3.0^{abcde}	62^{abcd}	907^{abc}	2.6^{bcd}	60^{bcde}	399.0
ICC 12426	4.5^{cdef}	90^{a}	192^{efg}	5.1^{ef}	71de	572.9
ICC 3137	5.6^{f}	72^{abcd}	192^{efg}	6.0^{f}	75^{e}	742.3
ICC 12491	2.6^{abcd}	60^{a}	141^{cde}	1.5^{abc}	38^{ab}	682.3
ICC 12492	5.5^{f}	78^{abcd}	117^{abc}	4.3^{ef}	45^{abc}	355.3
ICC 12493	5.3^{f}	82^{abcd}	142^{cde}	4.8^{f}	35^{a}	401.7
ICC 12494	5.6^{f}	78^{abcd}	120^{bcd}	4.5^{ef}	50^{abcd}	623.7
ICC 12495	5.0^{ef}	75^{abcd}	138^{c}	3.8^{de}	45^{abc}	413.3
ICC 12968	3.1^{abcde}	77^{abcd}	114^{abc}	2.6^{bcd}	60^{bcd}	644.7
ICC 4973	5.0^{e}	85^{e}	212^{fg}	4.5^{ef}	65^{cde}	984.7
ICC 4962	5.6^{f}	93^{d}	229^{g}	5.6^{f}	71de	191.3
Checks						
ICC 12475 (R)	1.0^{a}	77^{abcd}	802^{ab}	1.0^{af}	50^{abcd}	284.2
ICC 4918 (S)	4.0^{bcde}	88^{e}	172^{def}	4.8^{f}	76^{e}	442.2
Mean	4.02	77	131.2	3.53	75	501.0
F (prob. at 5%)	<.001	0.036	<.001	<.001	0.002	0.114
SED ±	1.07	11.52	26.22	0.88	10.3	27.25
LSD ±	2.18	23.656	54.10	1.78	20.9	54.89
CV%	32.7	18.4	24.9	30.6	21.9	61.6

Number of larvae released =20, Replications =3; R-Resistant check, S-Susceptible check
Damage rating 0-9 scale (0= no damage, 1 = < 10% leaf area damaged, 2 = 11 to 20%, 3 = 21 to 30%, 4 = 31 to 40%, 5 = 41 to 50%, 6 = 51 to 60%, 7 = 61 to 70%, 8 = 71 to 80% and 9 = > 80% leaf area damaged).

4.3.2.1 Larval weight: g larva^{-1}

Significantly lower larval weights were recorded when the larvae were reared on ICC 12476, ICC 12477, ICC 12478, ICC 12479, ICC 12490, ICC 14876, ICC 12492, and ICC 12475,than on ICC 12426, ICC3137, ICC 12491, ICC 12493, ICC 12494, ICC 12495, ICC 4973, ICC 4962 and ICC 4918 during vegetative stage and during the flowering stage, no significant differences were observed between the genotypes tested. Mean larval weight during the flowering stage (50.0 mg) was less than that during the vegetative stage (131.0 mg) (Table 19.1).

When the larvae were released during vegetative stage; significantly lower larval weights were recorded in ICC 12475 (resistant check), ICC 12476, ICC 12477, ICC 12478, ICC 12479, ICC 12490, ICC 14876, and ICC12491 than on ICC 12426, ICC 3137, ICC 12492, ICC 12493, ICC 12494, ICC 12495, ICC 12968, ICC 4973, ICC 4962 and ICC 4918. During the flowering stage ICC 12492, ICC 12493, ICC 12495 and ICC 12968 were also on par with the resistant check, ICC 12475 (Table 19.2).

4.3.2.2 Survival of the plants and grain yield

When the plants were infested with *H.armigera* during vegetative and flowering stages; significantly more number of plants survived in ICC 12479, ICC 12490, ICC 14876 as compared to ICC 12475, grain yield was also higher on ICC 12479, ICC 12490, ICC 14876 than on ICC 12475.

Significantly less number of plants survived in ICC 12477, ICC 12478, ICC 12426, ICC 3137, ICC 12491, ICC 12494, ICC 12495, ICC 12968, ICC 4973, ICC 4962, and ICC 4918 when the plants were infested at the vegetative stage. There were, no significant differences in grain yield in damaged and undamaged plants. Significantly less grain yield was recorded under infested conditions in ICC 12476, ICC 12477, ICC 12478, ICC 12426, ICC 12495, and ICC 4918 (Table 19.3).

Table 19.2: **Relative recovery of eighteen chickpea genotypes from *H.armigera* damage (vegetative + flowering stage) under no-choice caged condition, ICRISAT, Patancheru, 2000-02.**

Genotype	Plants recovered			Total yield (g)			Yield plant^{-1} (g)		
	Damaged	Undamaged	Mean	Damaged	Undamaged	Mean .	Damaged	Undamaged	Mean
ICC 12476	2.33b	4.00	3.17	3.20^{bc}	7.70^{cd}	5.79	1.37	1.93	1.84
ICC 12477	2.33b	4.67	3.50	3.89^{ab}	8.20^{bc}	5.83	1.67	1.76	1.36
ICC12478	2.33b	4.67	3.50	3.98^{ab}	7.40^{de}	4.04	1.71	1.58	0.99
ICC 12479	3.67ab	5.00	4.34	4.23^{a}	4.80^{gh}	4.96	1.15	0.96	1.11
ICC 12490	4.00a	5.00	4.50	4.31^{a}	6.80^{c}	4.71	1.08	1.36	1.06
ICC 14876	4.00a	4.67	4.33	3.65^{a}	7.90^{cd}	4.15	0.91	1.69	1.00
ICC 12426	2.67b	4.33	3.00	2.11^{d}	8.90^{ab}	5.55	1.26	2.05	1.77
ICC 3137	2.00b	5.00	3.50	2.69^{cd}	5.90^{f}	4.07	1.35	1.18	0.95
ICC 12491	2.33b	5.00	3.67	2.11^{d}	7.80^{cd}	2.83	0.91	1.56	0.69
ICC 12492	2.33b	4.67	3.50	1.90^{c}	4.80^{gh}	3.03	0.82	1.03	0.81
ICC 12493	2.00b	4.33	3.17	1.70^{c}	5.50^{f}	3.55	0.85	1.27	1.55
ICC 12494	2.00b	4.33	3.17	1.60^{c}	4.60^{h}	3.87	0.80	1.06	0.98
ICC 12495	2.67b	4.67	3.17	2.20^{de}	6.90^{c}	5.17	1.32	1.48	1.26
ICC 12968	2.67b	4.33	3.00	0.80^{f}	2.20^{i}	3.87	0.48	0.51	0.95
ICC 4973	2.33b	5.00	3.17	2.30^{de}	6.80^{c}	4.85	1.73	1.36	1.11
ICC 4962	2.33b	4.33	2.83	2.10^{de}	4.80^{gh}	3.53	1.58	1.11	0.86
Checks ICC 12475 (R)	4.00a	5.00	4.50	4.12^{a}	7.90^{cd}	5.29	1.03	1.58	1.17
ICC 4918 (S)	2.00b	5.00	3.50	3.69^{a}	9.20^{a}	5.14	1.85	1.84	1.33
Mean	2.39	4.67		2.81	6.56		1.41	1.16	
	F (prob. at 5%)	SED ±	0.505	F (prob. at 5%))	SED±	0.389	F (prob. at 5%)	SED ±	0.412
Geno	<.001	LSD ±	1.002	<.001	LSD±	0.760	<.001	LSD ±	0.205
Treat	<.001	CV%	19.7	<.001	CV%	19.8	<.001	CV%	15.7
Geno.Treat	0.003			0.098			0.087		

20 neonate larvae released on 5 plants; replications-5; R- Resistant check, S – Susceptible check

Table 19. 3: **Relative susceptibility of eighteen chickpea genotypes to *H.armigera* under no-choice caged condition in glass house, ICRISAT, Patancheru, 2000-02.**

	Damage rating (0-9 scale)			Larval survival (%)			Weight of the larvae (mg)		
Genotype	Vegetative stage		Flow. stage	Vegetative stage		Flow. stage	Vegetative stage		Flow. stage
ICC 12476	3.17^{bcd}	3.00^{abc}	2.50^{abc}	75^{bcd}	75^{bc}	55^{ab}	938.0^{abc}	755.0^{ab}	123.5^{bcdef}
ICC 12477	3.17^{bcd}	3.67^{c}	3.17^{cd}	65^{abc}	75^{bc}	60^{abc}	114.5^{bc}	673.0^{ab}	837.0^{abc}
ICC12478	3.17^{bcd}	3.50^{cd}	3.00^{cd}	68^{abcd}	70^{ab}	67^{bcd}	818.0^{ab}	849.0^{abc}	835.0^{abc}
ICC 12479	2.33^{ab}	2.33^{ab}	1.83^{ab}	68^{abcd}	72^{ab}	62^{abc}	632.0^{a}	576.0^{a}	715.0^{ab}
ICC 12490	3.17^{bcd}	3.33^{c}	3.00^{cd}	75^{bcd}	80^{bcd}	70^{cde}	881.0^{ab}	894.0^{abcd}	105.7^{abcd}
ICC 14876	3.00^{abcd}	3.17^{bc}	2.67^{abc}	75^{bcd}	75^{bc}	60^{abc}	112.0^{bc}	124.8^{cdef}	111.8^{abcde}
ICC 12426	5.00^{eg}	4.83^{e}	5.00^{efg}	80^{cd}	90^{d}	62^{de}	176.4^{ef}	167.5^{gh}	147.7^{def}
ICC 3137	5.67^{gh}	5.83^{gh}	5.67^{g}	87^{d}	90^{d}	70^{cde}	210.4^{f}	164.0^{gh}	173.3^{f}
ICC 12491	2.83^{abc}	3.17^{bc}	3.17^{c}	57^{a}	75^{bc}	60^{abc}	110.5^{f}	103.7^{bcde}	102.6^{abcd}
ICC 12492	4.67^{efg}	4.33^{de}	4.00^{de}	75^{bcd}	75^{bc}	70^{cde}	119.5^{bc}	868.0^{abc}	885.0^{abcd}
ICC 12493	5.17^{efgh}	5.33^{fgh}	5.17^{efg}	60^{abc}	75^{bc}	65^{bcd}	131.5^{cd}	105.4^{bcde}	825.0^{abc}
ICC 12494	5.33^{efgh}	5.83^{gh}	5.33^{fg}	60^{ab}	80^{bcd}	65^{bcd}	132.5^{cd}	125.7^{def}	118.5^{bcdef}
ICC 12495	4.17^{cdef}	3.33^{c}	3.67^{cdd}	65^{abc}	75^{bc}	60^{abc}	122.3^{b}	118.7^{cdef}	83.0^{abc}
ICC 12968	4.00^{cde}	4.67^{ef}	4.17^{def}	80^{cd}	75^{bc}	70^{cde}	120.2^{b}	154.2^{fgh}	102.2^{abcd}
ICC 4973	5.50^{fg}	5.50^{fgh}	5.33^{f}	85^{d}	85^{cd}	75^{de}	211.0^{f}	191.5^{hi}	118.9^{bcdef}
ICC 4962	6.50^{h}	6.50^{h}	6.17^{g}	85^{d}	85^{cd}	80^{e}	216.0^{f}	986.0^{j}	170.7^{e}
Checks									
ICC 12475 (R)	1.51^{a}	2.17^{a}	1.67^{a}	65^{abc}	60^{a}	50^{a}	617.0^{a}	534.0^{a}	566.0^{a}
ICC 4918 (S)	4.33^{def}	4.50^{de}	4.00^{de}	80^{d}	80^{cd}	70^{cde}	169.0^{de}	133.9^{efg}	138.4^{cdef}
Mean	4.04	4.17	3.86	73	75	76	0.13	0.12	0.11
F (prob. at 5%)	<.001	<.001	<.001	<.001	<.001	<.001	<.001	<.001	0.016
SED ±	0.74	0.47	0.63	7.5	5.88	5.98	20.01	20.01	31.22
LSD ±	1.50	0.96	1.28	15.13	11.89	12.01	40.12	40.25	60.01
CV %	22.4	14.2	20	12.5	9.4	11.3	18.3	18.5	33.8

R- Resistant check; S – Susceptible check

Damage rating 0-9 scale (0= no damage, 1 = < 10% leaf area damaged, 2 = 11 to 20%, 3 = 21 to 30%, 4 = 31 to 40%, 5 = 41 to 50%, 6 = 51 to 60%, 7 = 61 to 70%, 8 = 71 to 80% and 9 = > 80% leaf area damaged).

Table 19.4: **Relative recovery of eighteen chickpea genotypes from *H.armigera* damage (vegetative stage) under no-choice condition in glass house, ICRISAT, Patancheru, 2000-02.**

Genotype	Number of plants recovered			Total yield (g)			Yield per plant (g)		
	Damaged	Un-damaged	Mean	Damaged	Un-damaged	mean	Damaged	Un-damaged	mean
ICC 12476	2.67^{cd}	4.00^{ab}	3.33	4.20^{ab}	7.37^{ab}	5.79	1.58	1.84	1.74
ICC 12477	2.67^{cd}	5.00^{a}	3.83	4.84^{a}	6.82^{abc}	5.83	1.81	1.36	1.52
ICC12478	2.33^{d}	5.00^{a}	3.67	3.13^{abcd}	4.95^{defg}	4.04	1.34	0.99	1.10
ICC 12479	4.00^{abc}	5.00^{a}	4.50	4.37^{ab}	5.55^{cdef}	4.96	1.09	1.11	1.10
ICC 12490	5.00^{a}	5.00^{a}	5.00	4.13^{ab}	5.29^{cdef}	4.71	0.83	1.06	0.94
ICC 14876	4.33^{abc}	4.67^{a}	4.50	3.62^{abcd}	4.69^{defg}	4.15	0.84	1.00	0.92
ICC 12426	1.00^{de}	4.33^{a}	2.67	3.43^{abcd}	7.67^{a}	5.55	3.43	1.77	2.08
ICC 3137	2.67^{cd}	5.00^{a}	3.83	3.40^{abcd}	4.74^{defg}	4.07	1.27	0.95	1.06
ICC 12491	3.33^{bcd}	5.00^{a}	4.17	2.20^{d}	3.47^{g}	2.83	0.66	0.69	0.68
ICC 12492	3.33^{bcd}	4.67^{a}	4.00	2.27^{cd}	3.80^{fg}	3.03	0.68	0.81	0.76
ICC 12493	1.67^{d}	2.67^{b}	2.17	2.97^{bcd}	4.13^{efg}	3.55	1.78	1.55	1.64
ICC 12494	0.67^{f}	4.33^{a}	2.50	3.50^{abcd}	4.23^{efg}	3.87	5.25	0.98	1.55
ICC 12495	1.33^{d}	5.00^{a}	3.17	4.03^{abc}	6.30^{abcd}	5.17	3.03	1.26	1.63
ICC 12968	1.67^{cd}	4.33^{a}	3.00	3.60^{abcd}	4.13^{g}	3.87	2.16	0.95	1.29
ICC 4973	2.67^{cd}	5.00^{a}	3.83	4.13^{ab}	5.57^{cdef}	4.85	1.55	1.11	1.27
ICC 4962	2.67^{cd}	4.67^{a}	3.67	3.07^{abcd}	4.00^{efg}	3.53	1.15	0.86	0.96
Checks									
ICC 12475 (R)	4.33^{ab}	5.00^{a}	4.67	4.73^{ab}	5.84^{bcde}	5.29	1.09	1.17	1.13
ICC 4918 (S)	2.00^{de}	5.00^{a}	3.50	3.62^{abcd}	6.66^{abc}	5.14	1.81	1.33	1.47
Mean	2.69	4.65		3.62	5.29		1.74	1.16	
Geno		<.001			<.001			<.001	
Treat		<.001			<.001			<.001	
Geno.Treat		0.004			0.341			0.213	
SED ±		0.707			0.903			0.220	
LSD ±		1.410			1.801			0.439	
CV%		23.6			24.8			21.5	

20 neonate larvae released on 5 plants; replications 5; R- Resistant check, S – Susceptible check

4.3.3 RELATIVE FEEDING PREFERENCES AND DEVELOPMENT OF *H. armigera* LARVAE TOWARDS WASHED AND UNWASHED CHICKPEA LEAVES

When the neonate *H.armigera* larvae were given a choice between washed and unwashed leaves of chickpea inserted in agar-agar significantly greater leaf feeding was recorded on washed leaves of ICC 12478, ICC 12479, ICC 14876, ICC 12494, ICC 12495 and check ICC 12475 compared to unwashed leaves of the same genotype. Mean damage rating on washed leaves were 4.33 as compared to 3.35 on-unwashed leaves (Table 20.1).

Significantly more number of larvae were recorded on washed leaves than on unwashed leaves of ICC 12476, ICC 12477, ICC 12478, ICC 12479, ICC 12490, ICC 14876, ICC 12492, ICC 12493, ICC 12494, ICC 12495, ICC 4973, and ICC 12475. Numbers of larvae present on washed and unwashed leaves after three days were significantly different except on ICC 12426, ICC 3137, ICC 12968, ICC 4962 and ICC 4918. There were more (4.22) larvae on washed leaves compared to the unwashed leaves (3.33) (Table 20.1).

There was no significant variation in larval weights when the larvae were reared on washed and unwashed leaves separately for three days. But the leaf feeding rating and number of larvae survived were significantly different for the genotypes tested. Leaf feeding of ICC 12477 on washed leaves was 4.8 compared to unwashed leaves 3.4. Mean damage rating on unwashed leaves 3.01 compared to 4.03 on washed leaves, but the differences were not significant. Significantly less damage was recorded on unwashed leaves of ICC 12476, ICC 12477, ICC 12478, ICC 12491, ICC 12492, ICC 12493 and ICC 12494, which were on par with the resistant check, ICC 12475. Damage ratings on un-washed twigs of all the genotypes were on par with resistant check, ICC 12475 (except ICC 14876, ICC 12426, ICC 3137, ICC 12495, ICC 12968, ICC 4973, ICC 4962, and ICC 4918.) No significant variation was observed between washed and unwashed leaves in larval survival, except on ICC 3137. Numbers of larvae survived after three days were significantly lower in washed leaves of ICC 3137 compared to unwashed leaves (Table 20.2).

Table 20.1: **Relative feeding preference of *H armigera* larvae towards washed and unwashed leaves of eighteen chickpea genotypes, ICRISAT, Patancheru, 2000-02.**

Genotypes	Damage rating (0-9) scale			Relative larval preference (%)		
	Unwashed	Washed	t (value)	Unwashed	Washed	t (value)
ICC 12476	2.8^{a}	3.7^{a}	-1.52	26^{a}	38^{b}	-2.55
ICC 12477	3.6^{a}	4.1^{a}	-.76	32^{a}	47^{b}	-5.23
ICC12478	2.6^{a}	3.7^{b}	-2.87	27^{a}	38^{b}	-2.82
ICC 12479	2.9^{a}	4.4^{b}	2.57	29^{a}	45^{b}	-4.95
ICC 12490	3.0^{a}	4.0^{a}	-1.17	30^{a}	39^{b}	-2.38
ICC 14876	2.8^{a}	4.2^{b}	-3.03	29^{a}	40^{b}	-3.16
ICC 12426	4.7^{a}	5.7^{a}	-1.01	45^{a}	45^{a}	0
ICC 3137	4.8^{a}	5.8^{a}	-1.02	34^{a}	38^{a}	-.95
ICC 12491	3.0^{a}	4.1^{a}	-1.14	34^{a}	38^{a}	-1.1
ICC 12492	3.2^{a}	3.5^{a}	-.47	37^{a}	41^{b}	-3.82
ICC 12493	3.5^{a}	4.6^{a}	-1.16	37^{a}	43^{b}	4.35
ICC 12494	2.9^{a}	3.3^{b}	-2.64	34^{a}	37^{b}	-3.49
ICC 12495	3.2^{a}	4.5^{b}	-2.42	33^{a}	39^{b}	-1.86
ICC 12968	3.5^{a}	3.8^{a}	-1.24	30^{a}	35^{a}	-1
ICC 4973	3.9^{a}	4.9^{a}	1.1	45^{a}	53^{b}	-3.09
ICC 4962	4.0^{a}	5.0^{a}	-1.16	40^{a}	46^{a}	-8.4
Checks ICC 12475 (R)	2.6^{a}	4.3^{b}	-3.91	22^{a}	38^{b}	-3.98
ICC 4918 (S)	3.3^{a}	4.4^{a}	-1.87	35^{a}	41^{a}	-1.86
Mean	3.35	4.33		33.33	41.2	

Means followed by same letters do not differ significantly; Number of larvae =100; Damage rating 0-9 scale (0= no damage, 1 = < 10%, 2 = 11 to 20%, 3 = 21 to 30%, 4 = 31 to 40%, 5 = 41 to 50%, 6 = 51 to 60%, 7 = 61 to 70%, 8 = 71 to 80% and 9 = > 80% leaf area damaged).

Table 20.2 **Relative feeding preference and development of *H armigera* larvae on washed and unwashed leaves of eighteen chickpea genotypes, ICRISAT, Patancheru, 2000-02.**

Genotypes	Damage rating (0-9 scale)			Larvae survival (%)			Unit larval weight (mg)		
	Unwashed	Washed	Mean	Unwashed	Washed	Mean	Un-washed	Washed	Mean
ICC 12476	A 3.6^{abc}	A3.7a	3.7	A40ab	A 54^{bcdef}	47	6.8	9.9	8.4
ICC 12477	A 6.2^{f}	A 4.4^{abc}	5.3	A 45^{ab}	A 55^{bcdefg}	50	8.8	12.3	10.6
ICC 12478	A 4.2^{abcd}	A 4.4^{abc}	4.3	A 40^{ab}	A 53^{bcde}	46	7.3	9.7	8.5
ICC 12479	A 3.4^{bcd}	A 4.4^{abc}	4.4	A 46^{abc}	A 50^{abcde}	48	4.1	5.4	4.8
ICC 12490	A 5.0^{def}	A 4.0^{ab}	4.5	A 44^{ab}	A 56^{bcdefg}	50	9.6	13.4	11.5
ICC 14876	A 6.2^{f}	A 5.7^{def}	6.0	A 60de	A 61de	61	9.0	12.1	10.6
ICC 12426	A 8.6^{g}	B 5.3^{cd}	7.0	A 82^{fh}	A 71^{g}	77	11.9	9.2	10.6
ICC 3137	A 8.6^{g}	B 6.1^{e}	7.4	A 88^{gh}	B 64^{ef}	76	13.3	12.1	12.7
ICC 12491	A 3.4^{ab}	A 3.8^{a}	3.6	A 44^{ab}	A 46^{abc}	45	7.2	9.2	8.2
ICC 12492	A 3.3^{ab}	A 4.0^{ab}	3.7	A 33^{a}	A 45^{ab}	39	4.4	5.9	5.2
ICC 12493	A 3.9^{abcd}	A 4.0^{ab}	4.0	A 39^{a}	A 49^{ab}	44	7.2	9.8	8.5
ICC 12494	A 4.1^{abcd}	A 4.7^{ab}	4.4	A 40^{ab}	A 50^{ab}	45	5.2	6.5	5.9
ICC 12495	A 4.6^{cd}	A 5.1^{bcde}	4.9	A 54^{bc}	A 60^{cdef}	57	7.6	9.1	8.4
ICC 12968	A 4.9^{de}	B 6.2^{fg}	5.6	A 55^{bc}	A 68^{c}	62	8.1	11.4	4.6
ICC 4973	A 6.0^{ef}	A 5.4^{cde}	5.7	A 70^{ef}	A 60^{cdef}	65	10.3	12.8	11.6
ICC 4962	A 7.0^{f}	A 6.8^{f}	6.9	A 79^{fh}	A 72^{g}	76	10.5	13.2	11.9
Checks									
ICC 12475 (R)	A 3.2^{a}	A 3.7^{a}	3.5	A 36^{a}	A 38^{a}	37	4.3	5.3	4.8
ICC 4918 (S)	A 6.8^{f}	B 5.0^{bcde}	5.9	A 62^{e}	A 68^{e}	63	11.5	10.1	10.8
Mean	A 5.013	A 4.836	4.93	A52.69	A 55.97	54.33	8.2	9.2	8.7
	F (prob. at 5%)	SED	LSD	F (prob. at 5%)	SED	LSD	F (prob. at 5%)	SED	LSD
Treat	0.066	0.121	0.243	0.066	1.771	3.50	0.399	0.0016	0.003
Ent	<.001	0.427	0.845	<.001	5.313	10.50	0.048	0.0050	0.009
Treat*Ent	<.001	0.601	1.200	0.018	7.514	14.85	0.054	0.0071	0.014
CV%	19.3			21.9			25.1		

Number of larvae=100; Means followed by same capital letters within the row do not differ significantly; Means followed by same lower case subscript within the column do not differ significantly, S – Susceptible check; R – Resistant check; Damage rating 0-9 scale (0= no damage, 1 = < 10% leaf area damaged, 2 = 11 to 20%, 3 = 21 to 30%, 4 = 31 to 40%, 5 = 41 to 50%, 6 = 51 to 60%, 7 = 61 to 70%, 8 = 71 to 80% and 9 – > 80% leaf area damaged).

4.3.4 ANTIXENOSIS FOR OVIPOSITION

Under no choice conditions, lowest number of eggs were laid on resistant check, ICC 12475 (543), followed by ICC 12476 (793), ICC 12477 (818), and ICC 12479 (867) under no choice conditions. Highest number of eggs were recorded on ICC 4973 (1569), which were approximately three times greater than the eggs laid on resistant check, ICC 12475. Under multi-choice conditions, lowest number of eggs were laid on resistant check, ICC 12475 (423), followed by ICC 12476 (632), ICC 12477 (828), ICC 12426 (854) and ICC 12479 (878). Highest number of eggs were recorded on ICC 4962 (1686). Under dual-choice conditions significantly lower number of eggs were laid on ICC 12475 and ICC 12476 compared to the susceptible check, ICC 4918 (Table 21.1).

ICC 12475, ICC 12476, ICC 12477, ICC 12478, ICC 12479, ICC 12490 and ICC 14876 were not preferred for oviposition compared to ICC 4918 (susceptible check) under no-choice, dual-choice and multi-choice conditions. ICC 12491 was less preferred under no-choice and multi-choice conditions and ICC 12492 under dual-choice conditions. ICC 12426, ICC 3137, ICC 12493, ICC 12494, ICC 12495, ICC 12968, ICC 4973 and ICC 4962 were preferred for oviposition as compared to the susceptible check ICC 4918 (Tables 21.1 and 21.2).

More number of eggs were recorded on ICC 12426, ICC 3137, ICC 12491, ICC 12493, ICC 12494, ICC 12495, ICC 12968, ICC 4973 and ICC 4962 as compared to the susceptible check ICC 4918, under dual-choice condition but the differences were not significant (Table 21.2).

Under field conditions there were no significant differences in the number of eggs laid per plant among the tested genotypes (Tables 22.3 and 22.4). The correlation between eggs laid and larval incidence was positive (r = 0.122) but not significant because of loss of larvae due to predation by birds and mortality due to different factors (Table 22.5).

Table 21.1: **Oviposition preference of *H.armigera* among chickpea genotypes in single choice and multi choice cage tests under laboratory conditions, ICRISAT, Patancheru, 2000-02.**

Genotype	Single choice			Multi choice		
	Mean No. of eggs	$\sqrt{\bar{x}+0.5}$ ±SE (3 rep)	ROP*	Mean No. of eggs	$\sqrt{\bar{x}+0.5}$ ±SE (3 rep)	ROP*
ICC 12476	793.5	(23.475 ±0.9584)	-21.5	632	(22.947±0.865)	-25.0
ICC 12477	818.0	(23.789 ±1.2505)	-20.0	828	(25.210±0.274)	-12.0
ICC12478	992.0	(25.555 ±1.8489)	-10.6	939	(26.053±0.015)	-5.7
ICC 12479	867.0	(24.318 ±1.4495)	-17.2	878	(25.686±0.328)	-9.1
ICC 12490	921.0	(24.348 ±2.0329)	-14.3	692	(23.753±1.687)	-20.7
ICC 14876	916.5	(25.579 ±0.4593)	-14.5	899	(25.942±0.347)	-7.9
ICC 12426	1412.5	(31.997 ±0.4062)	7.0	854	(28.108±3.220)	-10.4
ICC 3137	1369.5	(31.184 ±1.0020)	5.5	1189	(34.439±1.692)	6.1
ICC·12491	1143.0	(28.443 ±1.2217)	-3.6	909	(30.133±0.657)	-7.3
ICC 12492	1438.5	(31.049 ±1.8438)	7.9	1390	(33.903±0.037)	13.8
ICC 12493	1363.0	(31.044 ±0.8455)	5.2	1496	(33.709±1.223)	17.4
ICC 12494	1404.5	(31.146 ±1.3805)	6.7	1256	(32.290±0.637)	8.8
ICC 12495	1392.5	(30.270 ±1.6352)	6.3	1378	(31.847±0.557)	13.4
ICC 12968	1290.5	(29.943 ±0.9434)	2.5	1176	(29.854±0.410)	5.5
ICC 4973	1569.5	(33.631 ±0.6615)	12.2	1572	(35.086±0.434)	19.8
ICC 4962	1477.5	(32.962 ±0.0075)	9.2	1686	(35.906±1.940)	23.1
Checks						
ICC 12475 (R)	543.5	(20.137 ±0.0124)	-38.6	423	(18.680±0.867)	-42.7
ICC 4918 (S)	1227.5	(29.989 ±0.3751)	0.0	1053	(29.586±0.599)	0.0

R-Resistant check, S-Susceptible check.

ROP*- Relative oviposition preference with respect to ICC 4918

Table 21.2 : Relative oviposition preference of *H.armigera* towards chickpea genotypes under dual choice caged conditions, ICRISAT,Patancheru, 200-02.

Genotype	No. of eggs		t (value)	ROP*
	Test genotype	ICC 4918		
ICC 12476	103.0	174.3	1.81*	-25.7
ICC 12477	82.5	129.8	1.18	-22.3
ICC 12478	49.0	119.5	1.57	-41.8
ICC 12479	75.2	137.6	1.19	-29.3
ICC 12490	84.9	107.0	0.63	-11.5
ICC 14876	81.0	148.4	1.44	-29.3
ICC 12426	154.3	124.2	-0.82	10.8
ICC 3137	142.8	102.5	-1.00	16.4
ICC 12491	144.8	111.6	-0.86	12.9
ICC 12492	114.2	127.3	0.37	-5.4
ICC 12493	127.7	105.1	-0.79	9.7
ICC 12494	126.4	104.8	-0.73	9.3
ICC 12495	119.7	116.7	-0.10	1.3
ICC 12968	134.3	109.3	-0.71	10.3
ICC 4973	183.8	163.5	-0.54	5.8
ICC 4962	148.2	134.7	-0.44	4.8
ICC 12475 (R)	74.5	175.2	2.82*	-40.3

* Significant at 5% probability, R- Resistant check; Replications = 3; ROP * Relaive oviposition preference with respect to ICC 4918.

4.3.5 TOLERANCE

Tolerance to *H. armigera* damage in chickpea genotypes under protected and unprotected field conditions was studied and results were presented.

4.3.5.1 100-seed weight

Mean 100 seed weight was significantly high (17.18 g) under unprotected conditions compared to protected conditions (15.24 g). In ICC 3137, ICC 12491, ICC 12494, ICC 12495, ICC 12968, ICC 4973 and ICC 4962 (because of compensation) significantly high 100 seed weight was recorded under unprotected conditions (Table 22.1).

4.3.5.2 Seeds per pod

Significantly high number of seeds per pod were recorded under unprotected conditions in ICC 12426, ICC 3137, ICC 12493, ICC 12494, ICC 12495 and ICC 4918 whereas significantly high number of seeds per pod under protected conditions were recorded in ICC 4962. Mean number of seeds per pod were high under unprotected conditions (1.23) compared to protected conditions (1.18) but not significant (Table 22.1).

4.3.5.3 Yield per plant

In ICC 12476, ICC 12479, ICC 12490, ICC 12426, ICC 3137, ICC 12491, ICC 12492, ICC 12495, ICC 4973, ICC 4962 and ICC 4918 significantly high yield per plant was recorded under protected conditions. Mean yield per plant under protected conditions (15.56 g) was greater as compared to yield per plant under unprotected conditions (10.87 g) (Table 22.1).

4.3.5.4 Yield loss (%)

Tolerance index was recorded based on yield loss (%). ICC 12475 (3.3 %) was the most tolerant genotype followed by ICC 4918 (4.4%), ICC 12490 (18.1%), ICC 12493 (19.7%), and ICC 12476 (26.1%). Highest yield reduction was recorded in ICC 3137 (59.5%) and ICC 4962 (53.4%), which were highly susceptible to *H. armigera* damage. Mean loss in yield was 26.7 % under unprotected conditions and 2.8 % under protected conditions (22.2).

Table 22.1: **Yield components of eighteen chickpea genotypes under protected and unprotected conditions to *H. armigara*, ICRISAT, Patancheru, 2001-2002.**

Genotype	100 seed weight (g)			Seeds pod^{-1}			Yield plant^{-1} (g)		
	Protected	Unpro-tected	Mean	Protected	Unpro-tected	Mean	Protected	Unpro-tected	Mean
ICC 12476	11.61^{a}	12.63^{a}	12.12	1.354^{a}	1.343^{a}	1.349	16.72^{a}	10.15^{b}	13.72
ICC 12477	11.78^{a}	12.21^{a}	11.99	1.072^{a}	1.149^{a}	1.111	13.96^{a}	12.05^{a}	13.06
ICC12478	13.74^{a}	14.57^{a}	14.15	1.040^{a}	1.156^{a}	1.098	16.72^{a}	12.92^{a}	14.87
ICC 12479	12.84^{a}	13.81^{a}	13.32	1.126^{a}	1.115^{a}	1.120	17.04^{a}	10.11^{b}	14.03
ICC 12490	10.80^{a}	12.01^{a}	11.4	1.459^{a}	1.511^{a}	1.485	17.98^{a}	9.50^{b}	14.33
ICC 14876	14.35^{a}	14.64^{a}	14.50	1.202^{a}	1.32^{b}	1.261	18.78^{a}	10.85^{b}	14.95
ICC 12426	17.35^{a}	18.38^{a}	17.86	1.202^{a}	1.405^{b}	1.304	15.76^{a}	12.25^{a}	14.32
ICC 3137	20.94^{a}	26.43^{b}	23.68	1.078^{a}	1.099^{a}	1.088	13.04^{a}	7.45^{b}	11.15
ICC 12491	16.32^{a}	18.8^{b}	17.56	1a.098^{a}	1.253^{b}	1.175	15.08^{a}	9.40^{b}	12.45
ICC 12492	14.37^{a}	15.98^{a}	15.18	1.198^{a}	1.273^{a}	1.235	15.97^{a}	11.13^{b}	13.61
ICC 12493	12.83^{a}	14.20^{a}	13.51	1.189^{a}	1.228^{b}	1.208	12.92^{a}	10.18^{a}	11.64
ICC 12494	14.30^{a}	16.72^{b}	15.51	1.206^{a}	1.339^{b}	1.273	13.00^{a}	10.69^{a}	12.25
ICC 12495	20.81^{a}	22.77^{b}	21.79	1.063^{a}	1.085^{b}	1.074	17.82^{a}	9.62^{b}	13.99
ICC 12968	15.08^{a}	20.45^{b}	17.76	1.031^{a}	1.118^{a}	1.074	5.44^{a}	9.84^{a}	7.65
ICC 4973	16.78^{a}	19.17^{b}	17.98	1.182^{a}	1.209^{a}	1.195	20.16^{a}	13.41^{b}	17.06
ICC 4962	17.21^{a}	21.86^{b}	19.54	1.440^{a}	1.270^{b}	1.355	18.06^{a}	10.10^{b}	14.36
Checks									
ICC 12475 (R)	15.38^{a}	15.7^{a}	15.54	1.128^{a}	1.135^{a}	1.131	14.9^{a}	14.28^{a}	14.63
ICC 4918 (S)	17.84^{a}	18.85^{a}	18.34	1.109^{a}	1.210^{b}	1.155	16.73^{a}	11.74^{a}	14.48
Mean	15.24	17.18	16.21	1.18	1.23	1.21	15.56	10.87	13.48
	F (5%)	LSD		F (5%)	LSD		F (5%)	LSD	
Treat	0.033	1.5508		0.035	0.0471		0.001	0.777	
Genotype	<.001	1.1112		<.001	0.0672		<.001	2.906	
Treat.Geno	<.001	1.7126		<.001	0.0946		0.001	4.009	
CV%	6.0			4.8			18.7		

R-Resistant check, S-Susceptible check.

Table 22.2: Loss in yield due to *H armigera* damage in eighteen chickpea genotypes under protected and unprotected conditions, ICRISAT, Patancheru, 2001-02.

	Yield kg ha^{-1}				Pod borer damage (%)						Loss in grain weight (%)		
		Expected			Actual			Angular transformed					Avoid-able loss
Genotype	Actual in protected	in protected	Unpro-tected	Mean	Prote-cted	Unpro-tected	Mean	Prote-cted	Unpro-tected	Mean	Protected	Unpro-tected	(%)
ICC 12477	1677^{a}	1691	2162^{a}	1927	0.9^{ab}	15.7^{cd}	8.3	5.1	23.3	16.7	0.828	-27.85	-28.9
ICC 12478	2392^{a}	2405	1742^{b}	2073	0.6^{a}	14.4^{bcd}	7.5	4.4	22.2	15.5	0.541	27.57	27.1
ICC 12479	2189^{a}	2253	1792^{a}	2022	1.1^{ab}	12.3^{abc}	6.7	6.1	20.2	16.1	2.841	20.46	18.1
ICC 12490	2443^{a}	2549	1517^{b}	2033	2.8^{ab}	17.0^{de}	9.9	9.4	24.3	21.6	4.158	40.49	37.9
ICC 14876	2165^{a}	2194	1657^{a}	1926	1.4^{ab}	15.7^{cd}	8.5	6.6	23.3	18.2	1.322	24.48	23.4
ICC 12426	2341^{a}	2429	1681^{b}	2055	3.9^{ab}	21.2^{g}	12.5	11.3	27.3	25.0	3.623	30.79	28.1
ICC 3137	1976^{a}	2257	800^{b}	1528	13.5^{c}	33.7^{j}	23.6	20.2	35.5	38.0	12.45	64.55	59.5
ICC 12491	2123^{a}	2181	1226^{b}	1704	2.7^{ab}	27.1^{i}	14.9	9.1	31.3	24.8	2.659	43.79	42.2
ICC 12492	2623^{a}	2641	2107^{a}	2374	0.7^{a}	15.2^{bcd}	8.0	4.8	22.9	16.2	0.682	20.22	19.6
ICC 12493	1964^{a}	1992	1415^{a}	1703	1.3^{ab}	11.6^{ab}	6.4	6.2	19.8	16.0	1.406	28.97	27.9
ICC 12494	2242^{a}	2389	1343^{b}	1866	6.1^{bc}	23.8^{h}	15.0	12.9	29.2	27.5	6.153	43.78	40.1
ICC 12495	2303^{a}	2358	1115^{b}	1736	3.0^{ab}	12.4^{abc}	7.7	9.9	20.5	20.1	2.332	52.71	51.5
ICC 12968	859^{a}	863	1000^{a}	932	0.5^{a}	14.2^{b}	7.3	3.3	22.0	14.3	0.463	-15.87	-16.1
ICC 4973	2470^{a}	2535	1618^{b}	2077	2.9^{ab}	15.9^{bcd}	9.4	9.7	23.4	21.4	2.564	36.17	34.4
ICC 4962	2580^{a}	2659	1202^{b}	1930	3.1^{ab}	19.7^{efg}	11.4	10.0	26.1	23.1	2.971	54.80	53.4
Checks													
ICC 12475 (R)	2454^{a}	2465	2383^{a}	2424	0.4^{a}	9.4^{a}	4.9	3.5	17.8	12.4	0.446	3.33	2.89
ICC 4918 (S)	2295^{a}	2362	2258^{a}	2310	2.9^{ab}	20.9^{fgh}	11.9	9.7	27.1	23.2	2.836	4.40	2.60
Mean	2174	2240	1584	1912	2.8	17.6	10.2	8.5	24.5	20.7	2.864	26.738	27.4
	F(Prob.. at 5%)	LSD			F(Prob. at 5%)	LSD		F(Prob. at 5%)	LSD				
Treat	0.025	453.7			<.001	3.3		<.001	2.0				
Geno	<.001	428.4			<.001	3.8		<.001	2.0				
Treat.Geno	<.001	627.8			<.001	5.4		<.001	3.3				
CV %	19.4				31.9			19.7					

R – Resistant check; S – susceptible check.

Table 22.3: Population of *H. armigera* on different genotypes of chickpea under protected and unprotected conditions, ICRISAT, Patancheru,2001-2002.

Genotype	Eggs plant^{-1} ($\sqrt{x + 0.5}$) under protected conditions						Eggs plant^{-1} ($\sqrt{x + 0.5}$) under unprotected conditions					
	Veg. stage	Flow. stage	Flow- stage	Pod. stage	Pod. stage	Mean	Veg. stage	Flow. stage	Flow- stage	Pod. stage	Pod. stage	Mean
ICC 12476	1.14	0.92	0.83	0.84	0.71	0.89	1.28	1.63	1.61	1.68	1.57	1.55
ICC 12477	1.18	0.77	0.74	0.98	0.71	0.87	0.89	1.68	1.45	1.42	1.34	1.36
ICC 12478	1.13	0.82	0.82	0.83	0.79	0.88	1.46	1.64	1.49	1.45	1.67	1.54
ICC 12479	1.40	0.80	0.77	0.78	0.71	0.89	1.14	1.56	1.51	1.46	1.38	1.41
ICC 12490	1.21	0.83	0.78	0.84	0.71	0.87	1.03	1.51	1.53	1.46	1.33	1.37
ICC 14876	0.95	0.72	0.71	0.75	0.71	0.77	0.78	1.51	1.01	0.85	0.83	1.00
ICC 12426	0.79	0.73	0.71	0.78	0.71	0.74	1.00	1.33	1.18	1.26	1.28	1.21
ICC 3137	0.93	0.75	0.71	0.88	0.76	0.81	0.92	1.38	1.26	0.96	1.04	1.11
ICC 12491	0.97	0.73	0.76	0.75	0.71	0.78	0.79	1.68	1.24	1.24	1.01	1.19
ICC 12492	0.83	0.79	0.73	0.82	0.71	0.77	0.77	1.62	1.13	1.28	1.14	1.19
ICC 12493	0.98	0.74	0.71	0.79	0.71	0.79	1.06	1.38	1.14	1.28	1.29	1.23
ICC 12494	1.03	0.73	0.73	0.78	0.71	0.79	1.02	1.53	1.11	1.25	1.22	1.23
ICC 12495	1.08	0.72	0.75	0.83	0.71	0.82	1.03	1.62	1.17	1.41	1.31	1.31
ICC 12968	1.03	0.82	0.71	0.85	0.71	0.83	1.01	1.59	1.21	1.37	1.34	1.30
ICC 4973	1.09	0.81	0.91	0.80	0.71	0.86	1.15	1.49	1.31	1.29	1.47	1.34
ICC 4962	1.03	0.79	0.78	0.79	0.71	0.82	0.91	1.58	1.26	1.27	1.30	1.26
Checks												
ICC 12475 (R)	0.99	0.72	0.73	0.81	0.71	0.79	0.79	1.57	1.33	1.26	0.97	1.18
ICC 4918 (S)	0.98	0.74	0.74	0.86	0.71	0.81	0.95	1.45	1.21	1.08	1.27	1.19
Mean	1.04	0.77	0.76	0.82	0.71	0.82	1.00	1.54	1.29	1.29	1.27	1.28
F (prob. at 5%)	N.S	N.S	N.S	N.S	N.S	N.S	N.S	N.S	N.S	N.S	N.S	N.S

R-Resistant check, S-Susceptible check.

Table 22.4 Population of *H. armigera* on eighteen chickpea genotypes under protected and unprotected conditions, ICRISAT, Patancheru, 2001-02.

Genotype	Larvae plant^{-1} ($\sqrt{x + 0.5}$) under protected conditions						Larvae plant^{-1} ($\sqrt{x + 0.5}$) under unprotected conditions					
	Veg. stage	Flow. stage	Flow-stage	Pod. stage	Pod. stage	Mean	Veg. stage	Flow. stage	Flow-stage	Pod. stage	Pod. stage	Mean
ICC 12476	1.14	0.82	0.76	0.72	1.09	0.91	1.14	1.18	1.21	0.82	1.28	1.13
ICC 12477	1.19	0.78	0.75	0.71	0.78	0.84	0.92	1.11	0.88	0.85	0.89	0.93
ICC 12478	1.24	0.77	0.74	0.71	0.88	0.87	1.16	1.17	1.18	0.84	1.46	1.16
ICC 12479	1.18	0.79	0.75	0.73	0.81	0.85	1.09	1.25	1.07	0.74	1.14	1.06
ICC 12490	1.20	0.78	0.84	0.71	0.82	0.87	1.01	1.23	1.25	0.79	1.03	1.06
ICC 14876	1.09	0.71	0.71	0.71	0.72	0.79	0.82	0.73	0.73	0.71	0.78	0.75
ICC 12426	0.99	0.71	0.72	0.71	0.84	1.89	0.94	0.86	0.92	0.78	1.00	0.90
ICC 3137	1.05	0.72	0.75	0.71	1.21	1.59	0.90	0.88	0.75	0.75	0.92	0.84
ICC 12491	1.15	0.72	0.71	0.71	0.78	0.81	0.82	0.81	0.79	0.73	0.79	0.79
ICC 12492	1.14	0.72	0.72	0.71	0.79	0.82	0.81	0.93	1.12	0.71	0.77	0.87
ICC 12493	1.03	0.73	0.72	0.71	0.82	0.80	0.96	0.89	0.98	0.75	1.06	0.93
ICC 12494	1.10	0.74	0.71	0.72	0.84	0.82	0.95	0.72	0.85	0.72	1.02	0.85
ICC 12495	1.27	0.71	0.73	0.71	0.84	0.86	0.97	0.80	0.90	0.78	1.03	0.90
ICC 12968	1.16	0.73	0.71	0.75	0.96	0.86	0.90	0.85	0.92	0.76	1.01	0.89
ICC 4973	1.15	0.73	0.72	0.71	0.85	0.83	0.93	0.85	0.93	0.79	1.15	0.93
ICC 4962	1.19	0.74	0.75	0.71	0.87	0.85	0.84	1.22	0.77	0.78	0.91	0.84
Controls												
ICC 12475 (R)	1.39	0.76	0.74	0.74	0.74	0.87	0.81	0.86	0.97	0.76	0.79.	0.84
ICC 4918 (S)	1.10	0.72	0.72	0.71	0.72	0.79	0.85	1.12	0.84	0.86	0.95	0.86
Mean	1.15	0.74	0.74	0.72	0.83	0.84	0.93	0.94	0.95	0.77	1.00	0.92
F (Prob.)	N.S	N.S	N.S	N.S	N.S	N.S	N.S	N.S	N.S	N.S	N,S	N.S

R- Resistant check; S – Susceptible check.

Table 22.5 Correlations between pod borer damage and yield in chickpea genotypes, ICRISAT, Patancheru, 2001-02.

Yield and damage parameters	Correlation value
ORS and PDS	0.533 *
ORS and damage %	0.211
PDS and damage %	0.732 *
ORS and yield kg ha^{-1}	-0.220
PDS and yield kg ha^{-1}	-0.412 *
Damage % and yield	-0.201
Eggs and Larvae	0.112
Eggs and damage%	0.104
Eggs and yield kg ha^{-1}	-0.122
Larvae and Damage %	0.198
Larvae and yield kg ha^{-1}	-0.160

* Significantly different at 5% probability.

Discussion

CHAPTER-V

DISCUSSION

The results obtained in the investigation of **"Stability, Inheritance and Mechanisms of Resistance to *Helicoverpa armigera* (Hub.) in Chickpea (*Cicer arietinum* Linn)"** are discussed in this chapter with the probable reasons available in the literature.

5.1 STABILITY

5.1.1 GERMPLASM LINES

During 2000 season pod borer damage was significantly low in ICC 12488 (9.8 %) compared to resistant check ICC 12475 (14.4%). ICC 12478 (10.7%), ICC12495 (10.9%), ICC 12492 (12.8%), ICC 12493 (13.3%) and ICC 12490 (132.4%) were less susceptible to *H. armigera* and were on par with resistant check. The highest damage percentage (31.6%) was recorded in ICC 4958, which was more than susceptible check ICC 4918 (27.14). High damages were recorded in ICCC 4, ICC 12484, ICC 12496, ICC 12481 and ICC 12426. Pod damage scores were slightly higher than the damage scores at vegetative stage, indicating preference of *H. armigera* larvae to chickpea pods than the leaves.

In 2001 during the first and second plantings least damage (8.5% and 6.8%) was recorded in resistant check ICC 12475. ICC 12479 (11.8 and 5.1%), ICC 12477 (12.0) and 7.4%) and ICC 12478 (12.2 and 6.4% damage respectively in first and second plantings) were on par with resistant check. Significantly high damage was recorded in ICC 3137 (37.3 and 30.1%) when compared to the susceptible check ICC 4918 (29.9% and 17.3%) during first and second plantings.

During 2000 significantly high yield was recorded in ICCL 86111 (2625 kg ha^{-1}) followed by ICC 12480 (2595 kg ha^{-1}) and ICC 15996 (2534 kg ha^{-1}) compared to resistant check ICC 12475 (2385 Kg ha^{-1}). In some of the lines exhibiting low borer incidence, yields were also low. The susceptible lines such as ICC 12426, ICC 4918 and ICCC 4 also recorded high yields. ICC 12478 and ICC 12479 had low borer damage with high yields.

During 2001 first planting highest yields were recorded in check ICC 12475 followed by ICC 12480. During the first planting average damage percentage of all the genotypes was high but the yields were more during second planting.

5.1.2 BREEDING LINES

During 2000, yield kg ha^{-1} and pod borer damage percentage were not significant in both the plantings (at 5% probability). During the first planting highest damage was recorded in ICCV 93122 (15.9%) and ICC 4918 (15.4%) and lowest in ICC 12475 (5.3%) and ICCV 96752 (5.3%). During the second planting lowest and highest damages were recorded in resistant (ICC 12475) and susceptible (ICC 4918) checks respectively. In most of the breeding lines the yields were higher than the resistant checks.

During 2001 high damage percentage was recorded during first planting and yields were not much different between two plantings. ICC 12426, ICC 15996 and ICCV 93122 were susceptible during both the seasons. ICC 12483 recorded least borer damage (3.8%) and was comparable to the resistant check ICC 12475 (4.1%) during second planting. ICCL 86102 and ICCV 96752 were less susceptible during both the seasons. During first season pod damage scores (PDS) were more than the overall resistant scores (ORS). In ICC 15996 both the damage and yields were high in both the seasons indicating its tolerance to *H. armigera*. ICCL 87315, ICCL 87316, ICCL 87317 and ICCV 95992 showed less susceptible reaction and high yields during both the seasons.

Days to 50% flowering and days to maturity were less during second planting due to high temperatures. Number of eggs and larvae, pod borer damage, ORS and PDS were less during second planting, because the seasonal activity of *H. armigera* is highest during November and December but declines during January and February (Parikaya, 1992). For this reason, second planting appears to escape larval incidence.

Correlation studies indicated that there were positive correlations between ORS and PDS, PDS and pod borer damage percentage. The correlations were negetive for damage and yield in both germplasm and breeding lines.

Table 22.6: **Correlations between pod borer damage parameters and yield in chickpea.**

Correlations	Breeding lines	Germplasm lines
ORS and PDS	0.426 *	0.231
ORS and damage %	0.182	0.173
PDS and damage %	0.672 *	0.375
ORS and yield	-0.36	-0.16
PDS and yield	-0.215	-0.28
Damage % and yield	-0.235	-0.122

5.1.3 STABILITY OF YIELD AND ITS COMPONENTS IN CHICKPEA

5.1.3.1 Seed per pod and 100-seed weight

Singh and Choudhary (1980) reported that soybean varieties with bold seed were most suited for growing in favourable environment. Tomer *et al.* (1973) concluded that large seeded chickpea cultivars were unstable and were only suitable for high yielding environments. In present studies ICCL 86102 with highest 100-seed weight (19.3 g) was unstable in its yield and adapted to high yielding seasons and was unstable with respect to pod borer resistance. Bold seeded genotypes ICC 4958(33 g/100-seed), ICC 12968(24 g/100-seed), ICC 10817(23 g/100-seed), ICC 12495 (23 g/100-seed) and susceptible check ICC 4918 (21g/100-seed) were susceptible and unstable in their resistance to *H. armigera*..

In ICCL 87211 for seed per pod 'b' was significantly greater than 1, indicating that double seeded-ness will increase in this genotype under favourable conditions and was unstable in its resistane. In ICCL 87220 and susceptible check ICC 4918, seed per pod ratio was high (1.2 seeds pod) and were susceptible and not stable in their resistane to *H.*

armigera. Among germplasm lines ICC 15996(1.5), ICC 12426 (1.4), ICC 12486 (1.4), ICC 12488 (1.4), ICC 12489 (1.4), ICC 12490 (1.4) and ICC 12495 (1.4) had high seeds per pod ratio. ICC 15996 and ICC 12426 were high yielding and susceptible to *H. armigera.* ICC 12486, ICC 12488, ICC 12489, ICC 12490 and ICC 12495 were moderate yielding. Among these ICC 12486, ICC 12489, ICC 12490 and ICC 12495 were stable in their resistance.

5.1.3.2 Per Plant Yield

ICCV 95992 was high yielding and stable in per plant yield and pod borer resistance. ICCL 87211 recorded highest yield but it was not stable in yield and resistance to pod borer. The highest per plant yield in ICCL 87211 may be because of low plant stand. ICCL 86111 was not stable in yield and adaptable to high yielding environment. The results were in accordance with Singh and Singh (1991), and Singh *et al.* (1995a). ICC 12968(14.9 g), ICC 12484(14.8 g) and ICC 12493 (14.5 g) recorded high yields along with resistant check ICC 12475 (14.3 g) and were moderately resistant to *H. armigera* damage.

5.1.3.3 Yield kg ha^{-1}

The genotype x environment interaction was significant at 10% level for yield kg ha^{-1}. Singh and Singh (1991), and Baisakh and Nayak (1991) also reported significant differences for genotypes, environment and genotype x environment interaction for yield in chickpea.

Among the breeding lines highest mean yield kg ha^{-1} were recorded in ICCV 95992 (2291 kg ha^{-1}), ICCL 87316 (2284 kg ha^{-1}), ICCL 87317 (2223 kg ha^{-1}), ICCL 86102 (2206 kg ha^{-1}), ICCL 87314 (2197 kg ha^{-1}) and ICCL 87315 (2155 kg ha^{-1}). Yields of these genotypes were also more than resistant check ICC 12475(2137 kg ha^{-1}). Except ICCL 86102 all others were stable in their yields. In ICCL 86102 'b' value is significantly greater than 1 indicating its adaptability to high yielding environments (Eberhart and Russell, 1966). ICCV 95992, ICCL 87316 and ICCL 87317 were moderately resistant and stable in their resistance to *H. armigera* damage. ICCL 87314 and ICCL 87315 were susceptile to

Helicoverpa. ICCL 86102 was not stable in resistance. Singh *et al.* (1988) reported that none of the chickpea genotypes were adapted for low yielding environments. ICCL 93122 was low yielding, unstable in its yield and highly susceptible as well.

Among the germplasm lines highest and stable yield was recorded in ICC 15996 followed by resistant check ICC 12475. Though ICC 15996 was high yielding but was susceptible to *H. armigera* damage. Yields were high and stable in ICC 12484, ICC 12482 and ICC 12480 and were moderately resistant and unstable. ICC 12426 was adapted to high yielding environments and susceptible. Moderate and stable yields were recorded in ICC 12479, ICC 12478 and ICC 12477. ICC 12479 and ICC 12478 were stable in resistance to *Helicoverpa*. ICC 12477 was moderately resistant and unstable.

5.1.4 STABILITY OF RESISTANCE TO *H. armigera*

5.1.4.1 Pod borer damage (%)

Among the breeding lines the G x E interaction for pod borer damage was not significant indicating the stability of resistance to different planting seasons. These genotypes were selected from ICRISAT's breeding program over 5-6 years of screening and in the present investigations these proved to be stable. Among germplasm lines the G x E interaction was significant at $P < 0.05$ indicating that resistance in some lines varies with seasonal fluctuations.

Among the breeding lines least damages were recorded in ICCV 96752 (7%) ICCL 87316 (8%), ICCL 87317 (9%) and ICCV 95992 (10%) (compared to 5% in ICC 12475) which were stable with unit 'b' and minimum 'δi^2' values. The resistant check ICC 12475 also had unit slope. ICCL 87316 and ICCL 87317 were less susceptible while ICCV 95992 showed moderate susceptible reaction (10% damage) and were highly stable with unit slope. In ICCL 86102 (7% damage) 'δi^2' = 12 but 't' value was not significant, showing slight unstability in its reaction to pod borer resistance. ICCL 87220 (10% damage) had $\delta i^2=0$ but 'b' was significantly <1 indicating its susceptibility for high infestation conditions. In ICCL

87211 and ICCV 93122 `b' values were more than 1 indicating these may be more susceptible under favorable climatic conditions to *H. armigera.*

Among the germplasm lines least damage was recorded in resistant check ICC 12475 (9%) followed by ICC 12478 (10%), ICC 12479 (11%), ICC 14876 (11%), ICC 12495 (12%). All were stable in their resistance. ICC 12490 showed 'b' value significantly <1 and may be suitable for high infestation condition (Sharma and Lopez, 1991).

5.1.4.2 ORS and PDS

In ICC 12476 "b" value was significantly greater than 1 for ORS indicating its resistance may be unstable over seasons and susceptible at higher infestation conditions. In ICC 12495 "b" was significantly less indicating its suitability for high infestation conditions (Sharma and Lopez, 1991). In ICC 14876 'b' was < 1 for PDS and its δ^2=0 which indicates its resistance is highly stable.

5.2 INHERITANCE OF RESISTANCE TO *H. armigera* IN CHICKPEA

5.2.1 ANALYSIS OF VARIANCE

Among the desi parents performance of ICC 12479 was better than resistant check ICC 12475 with respect to per plant yield, plot yield and reduced pod damage. ICC 12478, ICC 12476 were less susceptible and high yielding. ICC 4918 was susceptible but high yielding. Among the crosses, ICC 12479 x ICC 12490, ICC 12476 x ICC 12479, ICC 12475 x ICC 12478, ICC 12478 x ICC 12490 and ICC 12475 x ICC 12479 were high yielding and less susceptible.

Among the kabuli parents ICC 4973 was high yielding but susceptible. ICC 12492, ICC 12495 and ICC 12491 were moderate in yield and less susceptible. The crosses ICC

12491 x ICC 12968, ICC 12493 x ICC 12495 and ICC 12491 x ICC 12492 and ICC 12495 x ICC 12968 and ICC 12492 x ICC 12968 were high yielding and less susceptible.

5.2.2 GENETIC INTERPRETATION OF DIFFERENT CHARACTERS

Ever since Fisher (1918) partitioned the heritable variations into additive, dominance and epistatic components there have been consistent efforts to devise biometrical methods to estimate and use them in breeding programme. Diallel crossing is one of the most important mating designs, permitting the separation of total genetic variance into additive and dominance components (assuming the absence of epistasis).

Diallel analysis has many advantages compared to other methods. It has been extensively used in almost all the sexually propagating crops to derive the information on the combining ability of parents and crosses and the nature of gene action. By this method, an overall genetic evaluation is possible, which is useful in identifying promising parents and crosses. Being unaffected by segregation and linkage it requires relatively few individuals to estimate certain important genetic parameters within a short period (Griffing, 1950). Further, more genetic information can be obtained with one generation involving F_1s and their parents than several generations by using other methods (Joshi *et al.*, 1961).

The genetic interpretation of diallel statistics is dependent upon the fulfillment of certain assumptions about the parent material. The assumption of no epistasis, no multiple alleles and uncorrelated gene distributions are difficult to evaluate independent of each other. There are conflicting reports of the assumption regarding independent distribution of genes will result in biased estimate of general and specific combining ability components of variance (Baker, 1978).

One of the main advantages of diallel analysis is in determining the genetic nature of important quantitative characters. The results obtained in the present study on combining ability and gene action are discussed below to draw conclusions regarding the nature of inheritance of different characters.

Table 23: **Rank correlation between combining ability (Griffing, 1956) and *per se* performance of parents and crosses in 10 x 10 desi and 8 x 8 kabuli chickpea diallels.**

S.No	Character	GCA and *per se* performance of parents				SCA and *per se* performance of crosses			
		F_1 desi	F_2 desi	F_1 kabuli	F_2 kabuli	F_1 desi	F_2 desi	kabuli F_1	F_2 kabuli
1	Day to 50% flowering	0.96**	0.93**	0.86**	0.95**	0.35*	0.22	0.25	0.7**
2	Days to maturity	0.83**	0.94**	0.88**	0.9**	0.47**	0.52**	0.42*	0.65**
3	100 seed weight	0.94**	0.98**	0.76*	0.12	0.40*	0.29	0.45**	0.13
4	Total pods per plant	0.65*	0.89**	0.67*	0.55	0.81**	0.54**	0.60**	0.87**
5	Seeds per pod	0.69*	0.82**	0.66	0.66*	0.57*	0.48**	0.52	0.73**
6	Yield per plant	0.67*	0.86**	0.21	-0.45	0.87**	0.55**	0.72**	-0.29
7	Plot yield	0.65*	0.34	0.33	0.45	0.64**	0.79**	0.74**	0.81**
8	Pod damage (%)	0.71*	0.68*	0.52	0.45	0.62**	0.72**	0.86**	0.85**
9	Damage AT*	0.88**	0.94**	0.78	1**	0.61**	0.17	0.87	0.59**

* Significant at 5% probability; ** Significant at 1% probability; AT* Angular transformed

Total variance in a population consists of additive, dominance, epistasis, environmental variances and their interactions. Additive variance (σ^2A) is defined as the variance of breeding value that arises from the additive as well as dominance gene action. The dominance (σ^2D) variance is the variance due to dominance deviation and epistatic variance arises due to non-allelic interaction of genes. The computations of σ^2A and σ^2D will apply in the absence of epistasis. The GCA variance includes additive variance and additive x additive interaction variance. The general predictability ratio indicates the relative importance of GCA and SCA values in determining progeny performance. This ratio was calculated based on the paper of Baker (1978).

5.2.2.1 Days to 50% flowering

In desi trial the range of parents for days to 50% flowering was 47 to 77 days with a mean value of 65 days. The range was 51 to 78 days with a mean of 63 days in F_1 crosses. Only GCA variance was significant for days to 50% flowering indicating the importance of additive gene effects for this triat. Further, σ^2A was comparatively more than σ^2D and this also emphasizes additive gene action for the expression and inheritance of flowering gene. The results were in accordance with results obtained in 28 diallel trials conducted at ICRISAT indicating that days to 50% flowering was predominantly under additive inheritance and highly predictable (Singh *et al.*, 1992). In F_2s significant GCA variances indicate additive gene action. According to Griffing analysis, ICC 4918, ICC 12475, ICC 12479 and ICC 12426 were good general combiners, where as for Gardner and Eberhart method along with these genotypes ICC 14876 was also good general combiner. ICC 12475 x ICC 12426 and ICC 12475 x ICC 12476 were good specific combiners.

In F_1 kabuli diallel both GCA and SCA variances were significant emphasizing the importance of additive, additive x additive interactions and also non-additive effects. GCA variance was greater than SCA variance indicates the importance of additive gene action for inheritance of flowering. In F_2s significant GCA variance indicates the importance of additive gene action. ICC 12968 was the best general combiner for days to 50% flowering and the crosses ICC 12492 x ICC 12968 and ICC 12495 x ICC 4973 were good specific combiners.

In F_2s ICC 12475 and ICC 4918 in desi trial and ICC 12968 and ICC 12491 among the kabuli parents were best general combiners for early flowering. F_2s of ICC 12475 x ICC 12476 in desi and the F_2s with ICC 12968 i.e. ICC 12495 x ICC 12968, ICC 12493 x ICC 12968, ICC 12968 x ICC 4973 and ICC 12968 x ICC 4962 and ICC 12492 x ICC 12495 were showing significant effect for specific combining ability. ICRISAT (1981 and 1982) reported good general combining ability of ICC 4918 and ICC 12968 for early flowering.

The value of general predictability ratio 0.94 (desi F_1s) 0.98 (kabuili F_1s) and 0.95 (desi F_2s) and 0.98 (kabuli F_2s) was very close to unity indicating that in the prediction of performance of single cross progenies, GCA is important. Rank correlation in F_1 and F_2 diallel (Tables 16 and 17 respectively) indicated the ranking based on *per se* performance of parents and respective GCA value was same, and the selection of parents based on their *per se* performance was equally effective as on the basis of their GCA values. However, the ranking of crosses was different than *per se* performance especially in kabuli crosses emphasizing the importance of SCA for selection of crosses. For F_2s also the rank correlation was not as strong as in the case of parents and GCA values.

5.2.2.2 Days to maturity

Significant GCA variance and non-significant SCA variance in both F_1 and F_2 desi trials indicated the importance of additive gene action for maturity. In F_1 desi chickpea trial the average heterosis was not significant and the vareital effects were also not significant. ICC 12479, ICC 4918, ICC 12475 and ICC 12426 were good general combiners for early maturity. The significant and negative 'g_i' values represent early maturity taken as desirable trait. The F_1 cross ICC 12479 x ICC 4918 was showing significant specific combining ability for early maturity. Good general combining ability of ICC 4918 for early flowering and maturity was reported in several studies (ICRISAT, 1981 and 1983) and ICC 12475 for early maturity (ICRISAT 1984 and 1985).

The average heterosis for days to maturity was not significant in kabuli trial and ICC 12968 was good general combiner for early maturity followed by ICC 12491. ICC 12492 x ICC 12968 and ICC 12495 x ICC 12494 were good specific combiners for early maturity. The extent of variation in parents for days to maturity was from 104 to 116 days and in crosses from 105 to 117 days and was not significant. Only GCA variance was significant for days to maturity in both F_1s and F_2s indicating the importance of additive gene action. SCA variance was not significant. Among the, 28 diallel trials conducted at ICRISAT, in most of the trials GCA components were significant for days to maturity (Singh *et al.*, 1992).

High predictability ratio in kabuli trial 0.97 in both F_1s and F_2s followed by desi (0.86 in F_1s and 0.94 in F_2s) were close to unity indicated the importance of GCA in predicting the performance of single cross progenies (ICRISAT, 1981; 82, 83, 84 and 85). Rank correlation indicating the ranking based on *per se* performance of parents and crosses and respective GCA and SCA values was same (only in F_1 kabuli SCA rank performance was significant at 5% level) indicating that the selection of parents on the basis of their performance was equally effective as based on their GCA values. Similarly, for single crosses also the *per se* performance indicated their worth fairly well. However, the rank correlation was not as strong as in case of parents and GCA values.

5.2.2.3 100-seed weight

Among desi parents seed weight ranged from 12.46 to 23.74 g, and in crosses the range was from 12.51 to 21.78g. Among kabuli parents it ranged from 13.87 to 23.42 g, and in crosses from 15.59 to 22.73g. In both desi and kabuli F_1 and F_2 trials both GCA and SCA variances were found to be statistically significant. The magnitude of GCA variance was very high compared to SCA variance. The estimate of σ^2A was predominant over σ^2D indicating more importance of additive gene action in governing the character, compared to non-additive gene action. Earlier reports supporting these results were made by Gupta and Ramanujan, 1974, Asawa and Tewari, 1976, Gowda and Bahl, 1978, Singh and Mehra, 1980 and ICRISAT 1981, 82, 83, 84 and 85, Tewari and Pande, 1987 and Shivkumar *et al.*, 2001. Malhotra and Singh, 1997 reported that both additive and non-additive gene effects were important, with the preponderance of additive gene action for seed size and partial dominance of small over large seed size suggests that it is governed by recessive gene.

High predictability ratios in both the trials indicated the importance of GCA in predicting the performance of single cross progenies. Rank correlation was highly significant for rankings based on *per se* performance of parents and GCA value in desi and *per se* performance of crosses and SCA values in kabuli chickpea. It indicates that selection of parents on the basis of their *per se* performance in desi and selection of crosses on basis of their *per se* performance in kabuli chickpea were equally effective as on the basis of their respective GCA and SCA values. But in desi crosses and kabuli parents it was not so strong. General predictability ratios were close to unity, indicated the importance of GCA in the prediction of performance of F_2s. There was similarity between the ranking of desi parents based on GCA and *per se* performance (r_s = 0.98). On the other hand, the ranks of kabuli parents based on *per se* performance and GCA effects differed to a large extent (r_s = -0.119). For the crosses, the ranking based on *per se* performance was not significant.

Since both dditive and additive x additive gene action contributes to this component, so seed mass can be used effectively as an indirect selection criterion for improving sed yield in chickpea (Singh and Paroda, 1986). The bold seeded parents ICC 3137, ICC 12426 and ICC 4918 in desi trial and ICC 12968, ICC 12495 and ICC 4962 were good general combiners for increased seed mass.

5.2.2.4 Total number of pods per plant

Desi Parents differed considerably for number of pods per plant. It ranged from 41 to 133. F_1s of like ICC 12476 x 12490, ICC 12476 x ICC 12478 and ICC 12477 x ICC 12479 showed very high number of pods because of low plant stand. F_1s of ICC 12475 x ICC 12426, ICC 12476 x ICC 3137 and ICC 12477 x ICC 4918 were good specific combiners for increased pod number per plant. Among desi parents ICC 12478, ICC 14876, ICC 12479, ICC 12478 and ICC 4918 were the best general combiners with significant positive GCA effects. Among the F_2s eight were with significant positive SCA effects of which ICC 12477 x ICC 4918 and ICC 12490 x ICC 4918 were best specific combiners.

Very high GCA and SCA mean squares were manifested for number of pods per plant. The general predictability ratio (0.86) indicated that both GCA and SCA were important in determining the performance of single cross progenies. σ^2D was higher than σ^2A implying the role of dominant gene action in the expression and inheritance of this character. In F_2 desi trial both GCA and SCA variances were significant but σ^2s was higher than σ^2g and average heterosis significantly positive indicates more importance of dominant gene action governing the effect. Earlier reports indicating the importance of both GCA and SCA variances for number of pods per plant have been made by ICRISAT (1982, 83, 84, and 85), Malhotra *et al.*, (1983), Singh and Paroda, (1989) and Singh *et al.*, (1991).

In kabuli trial both GCA and SCA variances were significantly greater than zero. σ^2D was greater than σ^2A implying the role of dominant gene action in the expression and inheritance of this character. Significantly positive average heterosis also confirms the dominant gene action according to Gardner and Eberhart analysis. Dominant gene action for pod number was reported by ICRISAT (1981). ICC 12492, ICC 12493 and ICC 12968 were good general combiners for increased pod yield. F_1s of ICC 12495 x ICC 12968, ICC 4973 x ICC 12494, ICC 12491 x ICC 12492 and ICC 12491 x ICC 4973 were good specific combiners for increased pod yield but in first two crosses the increased pod number was because of low plant stand. F_2s of ICC 12492 x ICC 12495 and ICC 4973 x ICC 4962 were good specific combiners for increased pod yield.

There was difference in the ranking of parents based on *per se* performance and GCA effects. But ranking of F_1s crosses based on their mean and SCA effects was almost same. The general predictability ratio (0.92) indicated that the GCA was important in determining the performance of F_2s in desi chickpea and in kabuli (0.58) indicates the importance of both GCA and SCA in determining the performance of F_1s. There was similarity between the ranking of desi parents in F_2 trial based on GCA and *per se* performance (r_s = 0.89) and SCA and mean performance in kabuli F_2s (r_s = 0.87) showed effectiveness of selections based on performances of parents in desi and F_2s in kabuli chickpea. For desi F_2s and kabuli parents there were no strong correlations.

5.2.2.5 Seeds per pod

For number of seeds per pod relatively narrow range was exhibited and the GCA and SCA variances were relatively small but significant. The predictability ratios 0.94 in desi and 0.92 in kabuli chickpea pointed out that in the performance of single cross progenies GCA variances were important. Among the 28 diallel trials conducted by ICRISAT the highest variation in the estimates of components of GCA and SCA mean squares were recorded for plant height and seeds per pod. The results, which indicate the importance of both GCA and SCA effects for seeds per pod, are in accordance with Singh *et al.* (1982), Malhotra *et al.* (1983) and Singh and Paroda, (1984) who concluded both additive and non-additive genetic effects were important for this character and predominance of non- additive component was reported by Shivkumar (2001).

ICC 12490 and ICC 12426 among desi and ICC 4962, ICC 12493 and ICC 12494 among kabuli parents were good general combiners for increased seeds per pod. ICC 12490 x ICC 14876 and ICC 14876 x ICC 4918 among desi and ICC 12492 x ICC 12495, ICC 12493 x ICC 4973, ICC 12968 x ICC 4962 and ICC 12491 x ICC 4973 among kabuli crosses were good specific combiners. Rank correlation between GCA effects *vs.* parental means and SCA effects *vs.* mean performance of crosses differed to large extent.

5.2.2.6 Seed yield per plant

The combining ability variances were significant for both GCA and SCA in both the F_1 trials. The predictability ratios 0.58 in desi and 0.75 in kabuli trials showed that GCA alone is not sufficient for inferences regarding the performance of single cross progenies. Of the two genetic parameters σ^2D was relatively more than σ^2A in both desi and kabuli, which emphasized that non-additive gene action was involved in the inheritance and expression of yield per plant. Average heterosis was significant and positive and indicated the importance of dominant gene action. In both the F_2 trials both GCA and SCA variances were significant indicating the importance of additive and non-additive genetic effects. Predominance σ^2 D (22.62) over σ^2 A (3.5) in kabuli chickpea indicates importance of non-additive gene action. But in desi chickpea σ^2 D (3.9) is slightly greater than σ^2 A (2.4). Significantly positive average heterosis in both desi and kabuli F_2s indicates that the average dominance was predominant contributing factor to heterosis (h_{ij}).

ICC 12476 and ICC 12475 were good general combiners and 10 crosses recorded significant SCA effects. Among the kabuli parents ICC 12495 and ICC 12968 were good general combiners for yield. Among desi parents, in F_2 trial ICC 4918 and ICC 12426 were best general combiners and in kabuli chickpea ICC 12495 and ICC 12492 were good general combiners. Among desi, F_2s of ICC 12490 x ICC 4918, ICC 12479 x ICC 4918, ICC 12477 x ICC 4918 and ICC 3137 x ICC 4918 were with highly significant positive GCA effects and were good specific combiners. Among kabuli chickpea, F_2s of ICC 12492 x ICC 12494 and ICC 12495 x ICC 4962 were good specific combiners.

High value of rank correlation for F_1 crosses (SCA vs *per se* performance) and relatively less for parents (GCA vs *per se* performance) indicated that effective selection was possible for crosses and it was difficult for parents based on their *per se* performance. The importance of both additive and non-additive gene effects for seed yield was reported by Singh *et al.* (1991) and predominance of non-additive component by Shivkumar (2001).

In F_2 predictability ratio (0.96) was near to unity in desi, indicates the importance of GCA variance in the performance of F_2s and in kabuli (0.61) indicates both GCA and SCA variances were important for the performance of F_2s. Rank correlations indicate the ranks of parents based on *per se* performance and GCA effects differed to a large extent. But for the F_2s, the ranking based on *per se* performance more or less coincided with that based on SCA effects.

5.2.2.7 Plot yield

In both desi and kabuli F_1 trials GCA and SCA variances were significantly greater than zero and average heterosis was positive and significant for yield. The σ^2D was relatively more than σ^2A emphasizing the predominance of non-additive gene action in the inheritance and expression of yield. The results were in accordance with Gupta and Ramanujan (1974), Gowda and Bahl (1978) and Yadavendra and Kumar (1987) and Shiv kumar *et al.* (2001) who reported that non-additive genetic effects is of major importance for seed yield but in desi F_2s GCA variances were significant indicating the importance of additive gene action while in kabuli trial both GCA and SCA variances were significant which indicates both additive and non additive gene actions were important in governing this character. Predominance of σ^2 D over σ^2 A in kabuli chickpea emphasizes the importance of non-additive gene action.

Among desi chickpea parents ICC 12475 and ICC 12479 were good general combiners for increased yield. Good general combining ability for yield and reduced pod damage of ICC 12475 was reported by ICRISAT (1982). Predictability ratios, 0.84 in F_1 desi and 0.77 and 0.62 in kabuli F_1 and F_2s respectively indicates both GCA and SCA were important for this character. In F_2 desi predictability ratio (0.90) close to unity indicates the importance of GCA for this character. The F_1s of ICC 12475 x ICC 4918 and ICC 12490 x ICC 3137 were good specific combiners for high yield. The F_2s of ICC 12477 x ICC 12478, ICC 12475 x ICC 14876 and ICC 12476 x ICC 12490 were good specific combiners for high yield.

Among the kabuli parents ICC 12968 (Griffings analysis) and ICC 12968, ICC 12491 and ICC 12495 (Gardner and Eberhart analysis) were good general combiners for yield. F_1s of ICC 12495 x ICC 4962 and ICC 12491 x ICC 12492 were good specific combiners according to Gardner and Eberhart analysis and along with these ICC 12492 x ICC 12968, ICC 12493 x ICC 4973, ICC 4973 x ICC 12494 and ICC 12495 x ICC 12968 were good specific combiners according to Griffing analysis. In F_2 trial ICC 12492 and ICC 4973 were good general combiners and the F_2s of ICC 12495 x ICC 4962 and ICC 12492 x

ICC 12494 were good specific combiners for high yield. The rank correlations indicated that effective selection was possible for F_1 and F_2 crosses based on their *per se* performance. The results, which indicate the importance of both GCA and SCA effects for days to maturity, pods per plant, seeds per pod, and seed yield were in close agreement with those reported by Lal (1972), Singh and Mehra (1980), Singh *et al.*, (1982), Malhotra *et al.*, (1983) and Singh and Paroda (1989). Importance of non-additive genetic effects for these characters was reported by Gowda and Bahl (1978) and Yadavendra and Kumar (1987).

5.2.2.8 Pod borer damage (%)

In desi chickpea the damage percentage in parents ranged from 6.43 % (ICC 12479) to 22.69 % (ICC 3137), and in F_1s the range was from 7.05% (ICC 12478 x ICC 12479) to 23.98% (ICC 4918 x ICC 3137). Both GCA and SCA variances were statistically significant. Magnitude of GCA variance was comparatively greater than SCA variance indicating more importance of additive gene action in governing the pod borer resistance. In F_2s only GCA variance was significant indicating additive gene action in governing their character.

The resistant parents ICC 12479, ICC 14876 and ICC 12478 proved to be the best general combiners with significantly negative GCA effects and low pod borer damage. According to Gardner and Eberhart along with the above parents the resistant check ICC 12475 was also good general combiner. The results were in accordance with ICRISAT, (1983). Among the crosses with the resistant parent ICC 12475 the cross ICC 12475 x ICC 12479 (7.11%) showed least damage and its SCA effect was negative but not significant. ICC 14876 x ICC 4918, ICC 14876 x ICC 3137, ICC 12478 x ICC 4918 and ICC 12476 x ICC 4918 were good specific combiner with respect to reduced pod borer damage. F_1s of ICC 12478 x ICC 12479 (7.05%) and ICC 12475 x ICC 12479 (7.11%%) showed least pod borer damage and their SCA effects were negetive but not significant. In F_2 desi trial, ICC 12475, ICC 14876, ICC 12477, ICC 12478 and ICC 12479 were best general combiners for reduced pod borer damage and F2s of ICC 12476 x ICC 3137, ICC 14876 x ICC 4918 and ICC 14876 x ICC 12426 were good specific combiners for reduced susceptibility.

In F_1 kabuli diallel the pod damage of parents ranged from 10.1% to 18.5% and in crosses from 8.03% to 19.3%. GCA variance was statistically significant but SCA variance was not significant in both F_1 and F_2 trials. The magnitudes of GCA variances were almost equal to SCA variances in both F_1s and F_2s. This indicates the importance of both additive and non-additive gene action in kabuli chickpea for pod borer damage. The results were in accordance with ICRISAT (1984) and Singh and Paroda (1989), who discussed the importance of non-additive genetic effects for pod borer resistance in kabuli chickpea. Negative average heterosis was desirable with respect to reduced *H. armigera* damage. ICC 12492 was good general combiner for reduced damage according to Griffings analysis and the varietal effects due to ICC 12492 were significant according to Gardner Eberhart analysis. ICC 12492, ICC 12493, ICC 12495 and ICC 12968 were good general combiners according to Gardner and Eberhart and heterotic effect due to none of the varieties was significant.

The F_1s of ICC 12493 x ICC 12494, ICC 12493 x ICC 12495 and ICC 12495 x ICC 12494 were good specific combiners according to both the methods of analysis and ICC 12492 x ICC 4973 according to Gardner and Eberhart analysis. The F_2s of ICC 12495 x ICC 4973, ICC 12491 x ICC 12494, ICC 12492 x ICC 12493 and ICC 4973 x ICC 4962 were best specific combiners for reduced pod borer damage.

The predictability ratio was near to unity in F_1s and F_2s of desi chickpea and it was comparatively less in F_1s and F_2s of kabuli chickpea indicating the importance of GCA in predicting the performance of single cross progenies in desi chickpea. Rank correlation indicated the ranking based on *per se* performance of crosses and respective SCA values was same which infers that the selection of crosses on the basis of their performance was equally effective as on the basis of their SCA values. But it was not so effective in case of GCA values and *per se* performance of parents but when the damage percentages were transformed to their respective angular values, for parents also the *per se* performance indicated its worth in selecting parents based on their *per se* performance.

In F_2s high value of rank correlation ($r_s = 0.95$ in desi and 1.0 in kabuli) for GCA vs. *per se* performanc indicated that the effective selection was possible for parents based on their performance. But for F_2s there was difference in the ranking based on *per se* performance and SCA effects.

In diallel analysis GCA is a function of additive genetic effects but may partially include some dominance effects where parents are included in the analysis to estimate the variance (Singh and Paroda, 1984). Additive genetic effects (2Σ gca^2) were greather than non additive effects (2Σ sca^2) for days to 50% flowering, days to maturity, 100-seed weight, damage percentage in desi diallel and days to flowering, days to maturity and 100-seed weight in case of kabuli diallel. Earlier reports support these results Dhaliwal and Gill, (1973); Gupta and Ramanujam 1974; Asawa and Tewari 1976; Gowda and Bahl 1978; Singh and Mehra 1980; Malhotra *et al.*, 1983; ICRISAT, 1981, 82, 83, 84 and 85; Gowda *et al.*, 1983; Singh *et al.*, 1992). Thus days to flowering, 100-seed weight can be improved by a simple selection scheme such as the pedigree method, since both additive and additive x additive genetic effects are predominant for these characters and are easily fixable in the early generations. Seed mass, which is highly heritable and important yield component can be used effectively as an indirect selection criterion for improving seed yield.

The results which indicate the importance of both GCA and SCA effects in the study were pods per plant, seed yield per plant, and yield kg ha^{-1} were in close agreement with Lal (1972); Gupta and Ramanujam, 1974; Asawa and Tewari 1976; Sikka, 1978; Gowda and Bahl, 1978; Singh and Mehra, 1980; Singh *et al.*, 1982; Malhotra *et al.*, 1983; Yadavender and Kumar, 1987; Singh and Paroda, 1989 and Shivkumar 2001). Non-additive genetic effects to be as major importance for these characters.

The parents used in the present investigation constitute a selected set of desi and kabuli chickpea varieties. Hence, the information regarding the genetic behavior of these parents, F_1s and F_2s can be made use of in breeding program. The genetic information and combining ability of the parents to be used in crossing program where significant correlation is established between the *per se* performance and GCA effects, choice of parents based on *per se* performance is advisable. Such correlation was present in the present study for all the characters; except for yield plant^{-1} in desi parents. Among kabuli parents significant correlation was established for pod borer damage percentage, days to 50% flowering and days to maturity. Similarly, the choice of F_2s based on *per se* performance can be made for days to maturity, pods plant^{-1}, seeds pod^{-1}, seeds plant^{-1}, yield plant^{-1}, yield plot^{-1} in desi and days to 50% flowering, days to maturity, pods plant^{-1}, seeds pod^{-1}, seeds plant^{-1}, yield plant^{-1}, yield plot^{-1} and pod borer damage percentage in kabuli F_2s. F_3 s were effected with wilt and reliable data was not available.

5.2 MECHANISMS OF RESISTANCE TO *H. armigera* IN CHICKPEA

5.3.1 ANTIBIOSIS TO *H. armigera* IN CHICKPEA

The current study has shown significant variation in growth and survival of *H. armigera* reared on chickpea leaves and pods. This is similar to the observations of Sison and Shanower (1993) showed that *H. armigera* larvae reared on leaves and flowers of pigeonpea had lower larval weights and longer development times than those reared on pods. Differences in nutrient availability of different plant parts may affect the growth and survival of *H. armigera* on chickpea. However, differences in the amount of acidic exudates consumed by first-instar to third-instar may also be important. Larger larvae consume the whole pod and seeds. In comparison, the larvae that were reared on leaves ingested plant material with surface exudates throughout their development and thus exhibited low survival and slower rates of growth and development (Dias *et al.*, 1983).

The mean larval weights, pupal weights and larval survival were high when the larvae were reared on lyophilized leaf and pod powder compared to those reared on leaves and pods. This may be because of more nutrients available in the artificial diet. When the larvae were reared on lyophilized pod powder the larval survival and weight grain were high suggesting that chickpea pods were more nutritious than leaves. Reduced larval and pupal weights, and prolonged larval and pupal periods (ICC 12475, ICC 12476, ICC 12477, ICC

12478, ICC 12479, ICC 14876, ICC 12490, ICC 12491 and ICC 12495) compared to susceptible genotypes (ICC 12426, ICC 3137, ICC 4973 and ICC 4962) indicated that antibiosis is one of the component of resistance to *H. armigera* in chickpea.

Larval period was longer in resistant genotypes compared to susceptible ones, and the standard diet. These results suggested that a growth inhibitor or antifeadent substance or both existed in the resistant genotypes. The larval survival, larval weight, pupal weights, pupation and adult emergence were consistently lower in the resistant genotypes than the susceptible ones, and the standard diet (Yoshida and Shanower, 2000). Slower larval growth, which results in prolonged development may increase the probability of predation, parasitism, and infection by pathogens, results in reduced population of the pest on the crop (Shanower, 1990).

5.2.2 RELATIVE SUSCEPTIBILITY OF CHICKPEA GENOTYPES TO *H.armigera* UNDER NO-CHOICE CAGED CONDITION

Glasshouse screening under no-choice caged conditions is simple, rapid and is not influenced by the external factors and therefore, provides a reliable means of evaluating insect damage on the test genotypes. In this technique, all the test genotypes were exposed to uniform insect pressure, and the cages prevented emigration of the larvae from the plants being evaluated.

The genotypes ICC 12479, ICC 12477, ICC 12476, ICC 12478, ICC 12490, ICC 14876, ICC 12491 and ICC 12495 were found to be resistant, and their levels of resistance were comparable to the resistant check, ICC 12475. Reduced damage rating, low larval survival and larval growth in these genotypes indicated that antibiosis is one of the components of resistance. In some of the genotypes, the plants recovered from the leaf feeding and survived. In susceptible genotypes (ICC 12426, ICC 3137, ICC 4973, ICC 4962 and ICC 4918) some plants failed to recover because of heavy damage.

Leaf damage, larval survival and weight gain by the larvae during flowering stage was lower compared to that at the vegetative stage. This may be due to increase in acidity in leaves with age (Koundal and Sinha 1981). As amount of acid exudates on leaves is responsible for resistance in chickpea (Lateef 1985, Rembold *et al.* 1990, Patnaik and Senapati, 1995) the resistance levels also increased during the flowering stage

5.2.3 RELATIVE PREFERENCE OF *H. armigera* LARVAE TOWARDS WASHED AND UN-WASHED CHICKPEA LEAVES

Significantly greater feeding was recorded on washed leaves compared to unwashed leaves in ICC 12475, ICC 12478, ICC 12479, ICC 14876, ICC 12495 and ICC 12494. This suggested that water-soluble compounds in the leaf exudates (malic and oxalic acid) were primarily responcible for the resistance of the genotypes to *H. armigera*. Leaf exudate plays an important role in *H. armigera* resistance in chickpea (Rembold, 1981; Rembold and Winter, 1982; Srivastava and Srivastava, 1989; Rembold *et al.*, 1989 and 1990; Rembold and Weigner, 1990 and Yoshida, 1997).

Presence of significantly more number of larvae on washed leaves of ICC 12475, ICC 12476, ICC 12477, ICC 12478, ICC 12479, ICC 12490, ICC 14876, ICC 12492, ICC 12493, ICC 12495 and ICC 4973 indicated that the larvae preferred washed leaves than unwashed leaves. Non-significant difference between washed and unwashed leaves of ICC 12426, ICC 3137, ICC 12968, ICC 4962 and ICC 4918 suggested that the amounts of leaf exudates in these genotypes were quite low. Lateef (1985) suggested amount of acid exudates on leaves could be used as criteria for distinguishing chickpea genotypes for resistance to *H. armigera*. Rembold *et al.*, (1990) confirmed it, and recommended it as a marker for resistance in chickpea. Low amount of acidity in the leaf extracts of genotypes was associated with susceptibility to *H. armigera* (Srivastava and Srivastava, 1989, Bhagwat *et al.*, 1995, and Yoshida, 1997). When the larvae were reared on washed and unwashed leaves separately, mean damage rating was high on unwashed leaves compared to the washed leaves.

5.3.4 ANTIXENOSIS FOR *H. armigera* OVIPOSITION IN CHICKPEA

ICC 12426, ICC 3137, ICC 12491, ICC 12493, ICC 12494, ICC 12495, ICC 12968, ICC 4973 and ICC 4962 were preferred for oviposition by *H armigera* moths as compared to ICC 4918. Ovipositional non-preference was not evident in long duration genotypes of chickpea (ICC 3137, ICC 12495, ICC 4973 and ICC 4962). Cowgill and Lateef (1996) reported non-significant oviposition in long duration chickpea genotypes. ICC 12475, ICC 12476, ICC 12477, ICC 12478, ICC 12479, ICC 12490 and ICC 14876 were not preferred for oviposition as compared to ICC 4918. Cowgill and Lateef (1996) reported that ovipositional nonpreference is a component of resistance in ICC 12475.

Kabuli type genotypes (ICC 12491, ICC 12493, ICC 12494, ICC 12495, ICC 12968, ICC 4973 and ICC 4962) were preferred for oviposition compared to desi types (ICC 12475, ICC 12476, ICC 12477, ICC 12478, ICC 12479, ICC 12490 and ICC 14876). Among desi type ICC 3137 and ICC 12426 were most preferred for oviposition.

There was no relation ship between the number of eggs laid and larval abundance ($r_g = 0.122$), number of eggs and pod damage (%) ($r_g = 0.104$). These results were similar to that of Lateef (1985) and Srivastava and Srivastava (1989). These results suggested that a large proportion of the larvae is lost due to biotic and abiotic factors under field conditions and hence, it becomes difficult to obtain reliable data on genotypic resistance /susceptibility under field condition. Therefore, it is important to develop reliable techniques to screen for resistance to *H. armigera* under laboratory and/or field conditions.

5.3.5 TOLERANCE TO *H. armigera* DAMAGE IN CHICKPEA

The larvae of *H. armigera* appeared on chickpea 15 days after sowing when the crop was at vegetative stage. When the crop reached pod formation stage, larvae damaged pods by feeding on the developing grains. There was a significant and positive correlation between the larval population and pod damage ($r_g = 0.198$). The damage with respect to yield parameters was significantly lower in unprotected crop as compared to the crop protected with chemical insecticides.

Significantly high grain yield was recorded in ICC 12478, ICC 12490, ICC 12426, ICC 3137, ICC 12491, ICC 12493, ICC 12494, ICC 12495, ICC 4973 and ICC 4962 under protected conditions. High yield was recorded under unprotected conditions in ICC 12477 and ICC 12968 but the differences were not significant.

Pod damage in unprotected crop was 20.9 % compared to 2.9 % pod damage in the protected crop. Significantly high pod damage was recorded in all the genotypes under unprotected conditions. High pod damage was recorded in ICC 3137 in both protected and unprotected conditions. The pod damage in ICC 3137, which is medium-duration genotypes was extremely high. ICC 3137 started poding earlier than the other medium-duration genotypes and retained green leaves and pod formation as late as the other late duration genotypes. Longer poding period resulted in prolonged exposure to *H. armigera*. The length of poding period may therefore to be one of the factors associated with resistance to *H. armigera*. Genotypes with shorter poding period are preferred and have low pod damage, especially in the medium -duration genotypes (Yoshida, 1997).

Under protected conditions except ICC 12494 and ICC 3137 all the genotypes were on par with the resistant check ICC 12475 for pod borer damage. Under unprotected conditions ICC 12479 (12.3%) and ICC 12493 (11.6%) were on par with the resistant check, ICC 12475.

This study indicated presence of tolerance mechanism in chickpea to *H. armigera* damage. Reduction in grain yield was lowest in ICC 12475 followed by ICC 4918, ICC 12490, ICC 12493 and ICC 12476 indicating tolerance to pod borer damage. CC 12477 and ICC 12968 were highly tolerant as there was an increase in yield under infected conditions.

The chickpea genotypes identified as stable in resistance to *H. armigera* damage can be used in further breeding programs to develop resistant varieties. Diallel analysis revealed the gene action for *H. armigera* resistance and appropriate breeding method can be selected to develop resistant varieties. The mechanisms of resistance to *H. armigera* in less susceptible chickpea genotypes can be exploited to develop resistant varieties.

Summary

SUMMARY

The present investigation **"Stability, Inheritance and Mechanisms of Resistance to *Helicoverpa armigera* (Hub.) in Chickpea (*Cicer arietinum* Linn)"** was conducted at ICRISAT, Patancheru during 2000-02. The results are summarized as follows.

1. The G x E interaction for pod borer resistance was not significant for breeding lines indicating their stability of resistance across seasons. Resistant check ICC 12475 suffered least (5.2%) pod damage and was stable in resistance.

2. Among the breeding lines evaluated, ICCL 87316, ICCL 87317 and ICCV 959962 showed stable resistance to *H. armigera,* same have high grain yield potential. ICCL 87220, ICCL 87315 and ICCL 87314 were moderately susceptible to *H. armigera.* ICCV 96752 was less susceptible but low yielding.

3. The G x E interaction for pod borer resistance'was significant for the germplasm accessions. Among the 28-germplasm accessions tested, the resistant check ICC 12475 was less resistant to *H. armigera* damage and had high yield potential. ICC 12478, ICC 12479, ICC 12440 and ICC 14876 showed stable resistance, and had moderate yield potential.

4. In desi and kabuli chickpea for days to 50% flowering, days to maturity, 100-seed weight and seeds per pod there is preponderance of GCA over SCA variances suggesting the importance of additive genetic variance. For number of pods per plant and seed yield preponderance of SCA over GCA variance suggests the importance of non-additive genetic variance.

5. For pod borer damage GCA variance was significant in desi chickpea and additive variance is greater than dominance variance indicating the importance of additive gene action. But on the other hand in kabuli chickpea both GCA and SCA variances were important for all the characters. The preponderance of SCA for pod borer

damage in the kabuli chickpea indicates that non-additive genetic variation may be important in some sources of resistance.

6. The genetic variability due to additive gene effects in case of pod borer damage can be exploited through the adoption of conventional methods such as pedigree method of selection.

7. Reduced larval and pupal weights, and prolonged larval and pupal periods on resistant genotypes (ICC 12475, ICC 12476, ICC 12477, ICC 12478, ICC 12479, ICC 14876, ICC 12490, ICC 12491 and ICC 12495) compared to susceptible genotypes (ICC 12426, ICC 3137, ICC 4973 and ICC 4962) indicated that antibiosis is one of the components of resistance to *H. armigera* in chickpea. These results suggested that a growth inhibitor or antifeadent substance or both existed in the resistant genotypes.

8. Under no choice caged glasshouse conditions the genotypes ICC 12479, ICC 12477, ICC 12476, ICC 12478, ICC 12490, ICC 14876, ICC 12491 and ICC 12495 were found to be resistant, and their levels of resistance were comparable to the resistant check, ICC 12475. Reduced damage rating, low larval survival and larval growth in these genotypes indicated that antibiosis is one of the components of resistance in chickpea.

9. Greater feeding in washed leaves compared to unwashed leaves in ICC 12475, ICC 12478, ICC 12479, ICC 14876, ICC 12495 and ICC 12494 suggested that water-soluble compounds in the leaf exudates (malic and oxalic acid) were primarily responcible for the resistance of the genotypes to *H. armigera*. Non-significant difference between washed and unwashed leaves of ICC 12426, ICC 3137, ICC 12968, ICC 4962 and ICC 4918 suggested that the amounts of leaf exudates in these genotypes were quite low.

10. ICC 12475, ICC 12476, ICC 12477, ICC 12478, ICC 12479, ICC 12490 and ICC 14876 were not preferred for oviposition as compared to ICC 4918. Ovipositional non-preference was not evident in long duration genotypes of chickpea (ICC 3137, ICC 12495, ICC 4973 and ICC 4962).

11. Kabuli type genotypes (ICC 12491, ICC 12493, ICC 12494, ICC 12495, ICC 12968, ICC 4973 and ICC 4962) were preferred for oviposition compared to desi types (ICC 12475, ICC 12476, ICC 12477, ICC 12478, ICC 12479, ICC 12490 and ICC 14876). Among desi type ICC 3137 and ICC 12426 were most preferred for oviposition.

12. Studies on yield loss under protected and unprotected conditions revealed toleranceas one of the mechanisms of resistance to *H. armigera* in chickpea. Reduction in grain yield was lowest in ICC 12475 followed by ICC 4918, ICC 12491, ICC 12493 and ICC 12476 indicating tolerance to pod borer damage. With chemical insecticide protection in chickpea 2.9% (ICC 12475) to 59.5% (ICC 3137) yield loss can be avoided.

The lines showing high and stable resistance to *H. armigera* can be used in chickpea improvement programs. The resistance mechanisms involved in these genotypes can be exploited to develop varieties resistant to *H. armigera* in chickpea.

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Note: The literature cited was according to the "Guide Lines for Thesis presentation" given by Acarya N. G. Ranga Agricultural University, Hyderabad.