GENETICS OF RESISTANCE TO POD BORER, *Helicoverpa armigera* IN CHICKPEA (*Cicer arietinum*)

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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
COLLEGE OF AGRICULTURE, RAJENDRANAGAR
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August, 2005

CERTIFICATE

Mrs. **V. LAKSHMI NARAYANAMMA** has satisfactorily prosecuted the course of research and that the thesis entitled "**Genetics of resistance to pod borer, *Helicoverpa armigera* in Chickpea (*Cicer arietinum*)**" 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.

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CERTIFICATE

This is to certify that the thesis entitled **"Genetics of Resistance to pod borer, *Helicoverpa armigera* in Chickpea (*Cicer arietinum*)"** 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. **V. Lakshmi Narayanamma** 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.

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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
$2\Sigma gca^2$	:	Additive genetic effects
$2\Sigma sca^2$	:	Non-additive genetic effect
<	:	Less than
>	:	Greater than
^0C	:	Degrees Centigrade
/	:	per
%	:	Per cent
a i	:	Active ingradiant
AICPIP	:	All India chickpea improvement project
ANOVA	:	analysis of variance
cm	:	Centimeter
Conc.	:	Concentration
CRD	:	Completely randomized design
et al.,	:	And others
F_1	:	First 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
NS	:	Not-significant
ORS	:	Over all resistance score
PDS	:	Pod damage score
p.m.	:	Post meridian
Prob.	:	Probability

Contd...

Lst of Symbols Contd.....

RBD	:	Randomized block design
RH	:	Relative humidity
SCA	:	Specific combining ability
SE	:	Standard error
Sig.	:	Significant
Viz.,	:	Namely
Vol.	:	Volume
Vs.	:	Between
Wt	:	Weight
μm	:	Micrometer
HPLC	:	High performance liquid chromatography
min	:	Minute
μl	:	Microliter
mM	:	Milli molar
meq	:	Milliequivalent
nm	:	Nano meter

ACKNOWLEDGEMENTS

At the outset, I owe my obeisance to the Almighty for showing his grace and blessings on me for successful completion of my research work. My beloved parents and husband are ineffably and to their benevolent feet I am dedicating this thesis with great pleasure.

Diction is not enough to express my deep and profound sense of gratitude and indebtedness, reverence and heartful thanks to my major chairman Dr. ***M. Sriramulu****, Principal Scientist, co-ordinator, ARI, Rajendranagar, who taught me the way to look into the things regarding subject matter and manner we understand, interpret and present them. His magnanimous attitude, meticulous guidance, transcendent suggestions, kind treatment and constant encouragement have instilled in me the spirit of respect and gratitude.*

I ardently exalt the authentic co-operation, unending inspiration, ever lasting affection, unstinted attention, insightful guidance offered to me by the esteemed co-chairman of my advisory committee Dr. ***C.L.L. Gowda****, Global Theme Leader, Plant Breeding, ICRISAT, Patancheru, who with on his constant untiring interest, dedication and empathy has devoted his valuable time from his busy schedule to mend majority thinking, from conception to completion of this task. Every stage of the present work bears the impression of his prudent counsel, concrete suggestions, careful and constructive criticism and meticulous attention to details. It is my serendipity to have been blessed with privilage of working under his guidance. I owe him a huge debt of gratitude forever for all that I got from him.*

It gives me great pleasure to humbly place on record my profound sense of gratitude and heartfelt thanks to Dr. ***H.C. Sharma****, Principal Scientist, Entomology, ICRISAT, Patancheru, who gave me a sense of direction, helped me to decipher the things that I have collected and gave them a meaningful direction. I bow to mother nature for placing me in both these dextrous hands, in the custody of graceful soul and above all under the guidance of watchful eyes.*

I fervently offer my whole hearted appreciation and gratitude to my Head of the Dept. Dr. ***G.V. Subba Ratnam****, Professor & University head, Dept. of Entomology, College of Agriculture, Rajendranagar, for his encouragement, valuable suggestions and guidance during the course of the study. I deem it previlage to have worked under him and greatfully acknowledge his keen insight into the technological research.*

I owe my respectable regard to Dr. ***S. Sokka Reddy****, Associate Professor, Dept. of Genetics & pl. Breeding, CA, R' nagar, and member of my advisory committee for his marvelous guidance, constructive acclamation and valuable suggestion during my course work and thesis work.*

I am indeed greatly indebted and thankful to my member of advisory committee, Dr. ***Ch. Sreenivasa Rao****, Scientist, Entomology, AICRP on Pesticide Residues, CA, R' nagar, for his keen eye for composition, non sequitor bombast and un compromising damand for logic in argument which benifited me in preperation of this thesis.*

I owe my respectable regards to the staff members, Division of Entomology, Dr. Raman Goud, Dr. Jagadiswar Reddy, Dr. Satyanarayana, Dr. T.V.K. Singh, Dr. Dharma Reddy, Dr. Loka Reddy, Dr. Vijaya Lakshmi, Dr. Swarna Latha, Dr. Koteswar Rao, Narasimha Reddy and Dr. T.B. Gour for their guidance and help during the study.

I express my sincere thanks to Dr. Subhash Chandra, Principal Scientist, Mr. Prasanth and Ms. Rupa, Statistics unit ICRISAT for their help in tabulation, statistical scrutiny and analysis of the data. I express my special thanks to Dr. S. Ramesh, for his valuable suggestions for nice out come of the thesis.

It is time to surface out my genuflect love and affectionate gratitude to my most beloved parents, Sri ***V. Venkateswarlu****, Smt.* ***V. Gangamma*** *and brother, Mr.* ***V. Rama krishna****, who have given me the life, taught the values, concepts of life and whose unparalleled affection, persistant encouragement and lavish blessing in shaping my career will go a long way throughout my life.*

Words seem to be inadequate to express my indebtedness toward my most affectionate husband, Mr. ***N.C. Nagesh****, who missed me and sanctioned his well being for want of my higher education. He has been a fountain of inspiration throughout my life. Without whose help in every walk of life this work would have been impossible to whom I am eternally indebted to my heartbeats.*

I express my profound sense of gratitude to my father-in law, Mr. N. Naganna and Mother-in- law, Smt. N. Chennamma, for all their affection and encouragement in all walks of my life.

With sincere regards I express my thanks to my relatives, sister, Venkata lakshmi, brother-in-law, Narayana swamy, Lakshmi, Vijay, Bharath and grand mother, Munemma.

With bound less affection and love I would heartly offer my warm thanks to Sri. ***S. Chander Rao,*** *for his affection encouragement and support showed on me and whose contribution behind the scene has enabled the successful completion of my Ph.D programme.*

My sincere thanks are due to Mr. Ghaffar, Mr Pampapathy, Mr. Venkateshwarulu, Mr. Anthireddy, Mrs. Sailakshmi, Mr. Aziz, Mr. Das, Mr. Venkateswarlu, Mr. Sankaraiah, Mr. Hisamuddin, Mr. Narayana Chandra, Mr. Venkateswar Rao, Mr. Madhusudhan Reddy, Mr. Harindranath, Mr. Raja Rao, Mr. Vittal Reddy, Mr. Kistaiah, Mrs. Mallamma, Mrs. Vimala, Mrs. Ponnamma, Mrs. Pakiramma and all the other staff of ICRISAT for their cooperation and help.

I feel deep hearted pleasure to convey my regards to my dear juniors, Rajanikanth, Kavitha, Shehnaz and Upender and seniors, Rama Krishna, Gopala swamy and friends Srilakshmi, Srividya, Jayaprada, Sreelatha, Aruna, Anuradha, Pratibha and Srinivas for their warm friendship, cooperation and encouragement.

I am also thankful to Mr. Vidyasagar and Mr. P. S. Rao for neat execution of photographs.

I am thankful to Acharya N.G. Ranga Agricultural University for providing financial help to me in the form of stipend and to the ICRISAT for providing the facilities to work during the course of research.

V. Lakshmi Narayanamma

Date: 27/8/05 ***(LAKSHMI NARAYANAMMA V.)***

DECLARATION

I, **V. LAKSHMI NARAYANAMMA,** hereby declare that the thesis entitled **"Genetics of Resistance to pod borer, *Helicoverpa armigera* in Chickpea (*Cicer arietinum*)"** 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 : 27/8/05

Place : Hyderabad

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ABSTRACT

Name of the author	:	**V. LAKSHMI NARAYANAMMA**
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Year of submission	:	2005

Key words: *Helicoverpa armigera*, Chickpea, Gene action, Maternal effect, Inheritance, Resistance.

The present research was undertaken to elucidate the **"Genetics of resistance to pod borer, *Helicoverpa armigera* in chickpea (*Cicer arietinum*)"**. These studies were focussed on the nature of gene action and maternal effects, plant resistance mechanisms and inheritance and interaction of different components of resistance and grain yield. These studies were carried out at the International Crops Research Institute for the Semi-Arid Tropics, Patancheru, Andhra Pradesh, India, during 2003-05.

Eight desi (ICC 12475 or ICC 506, ICC 12476, ICC 12477, ICC 12478, ICC 12479, ICC 4918, ICC 12426 or ICCC 37 and ICC 3137) and one kabuli (ICCV 2 or ICC 12968) parents were selected based on earlier screening trials to study the genetics of resistance to pod borer, *Helicoverpa armigera*, using a full diallel cross. The genotype, ICCV 2 was the earliest to flower and mature followed by ICC 4918, ICCC 37, ICC 12478 and ICC 12477, while ICC 12479, ICC 12476 and ICC 3137 were late to flower and mature. These genotypes can be effectively utilized in breeding programmes for early maturity.

The genotype, ICC 12478 suffered significantly lower damage followed by ICC 506, ICC 12479 and ICC 12477. ICC 3137 was highly susceptible to *H. armigera* damage and recorded lowest seed yield. Most of the crosses with ICC 506, ICC 12478 and ICC 12479 suffered lower damage due to pod borer, while those with ICC 3137 suffered higher damage. ICCC 37 recorded higher yield followed by ICC 12479 and ICC 12476.

A full diallel trial was conducted to know the gene action and maternal effects if any. Additive gene action was predominant for days to initial flowering, days to 50 % flowering, days to maturity, pod borer damage (%), pods plant^{-1}, seeds plant^{-1}, seeds per pod and 100- seed weight, while non- additive gene action was important for yield plant^{-1}, total plot yield and yield (kg ha^{-1}). The additive : dominance (A : D) ratio is greater than unity for the characters days to initial flowering, days to 50 % flowering, days to maturity, borer damage (%), pods plant^{-1}, seeds plant^{-1}, seeds per pod and 100- seed weight indicating over dominance, while for yield plant^{-1}, total plot yield and yield (kg ha^{-1}) the ratio is less than unity, indicating partial dominance.

There was no maternal inheritance for maturity traits, pod borer damage, grain yield and yield (kg ha^{-1}). The hybrid, ICC 12476 × ICCC 37 showed positive and significant SCA effects for seeds per pod, but ICCC 37 × ICC 12476 showed negatively significant SCA effects for number of seeds pod^{-1}. So the hybrid ICCC 37 × ICC 12476 may be showing cytoplasmic inheritance for the number of seeds/ pod.

The three mechanisms of resistance *viz.*, non-preference for oviposition, antibiosis and tolerance to *H. armigera* in chickpea genotypes were studied under laboratory, green house and field conditions. Oviposition studies under no choice, dual choice and multi choice laboratory and multi choice field conditions revealed that the resistant genotype, ICC 506 recorded lowest number of eggs, followed by ICC 12476, ICC 12477 and ICC 12478. The susceptible genotypes, ICC 12426 and ICC 4918 recorded the highest oviposition. The genotypes ICC 12475, ICC 12476, ICC 12477, ICC 12478 and ICC 12479 were least preferred by *H. armigera* females for oviposition compared to ICC 4918, ICC 3137 and ICCV 2.

The detached leaf assay not only gives an idea of the relative feeding by the larvae on different genotypes but also provides useful information on antibiosis component of resistance in terms of larval weight. Survival rate and larval weights were lowest on the resistant check, ICC 12475 followed by ICC 12476, ICC 12477, ICC 12478 and ICC 12479, suggesting that water soluble compounds in the leaf exudates (malic and oxalic acid) were primarily responsible for the resistance of the genotypes to *H. armigera*.

The genotypes ICC 12476, ICC 12477, ICC 12478 and ICC 12479 were found to be resistant and their levels of resistance were comparable to the resistant check, ICC 12475 under no-choice caged conditions. Under un-infested conditions, the per plant yield was greater in ICC 12426 followed by ICC 12478 and Annigeri. The resistant cultivars ICC 12478 and ICC 12475 recorded total higher yield. At the podding stage of the crop, when plants were infested with the third instar larvae, the recovery resistance was very poor, as most of the plants were damaged.

Larval biology on leaf material and on artificial diet with lyophilized leaf and pod powder recorded lowest larval and pupal weights and prolonged larval and pupal periods on the resistant genotype, ICC 506. Highest growth index, adult index, oviposition index and pupal index were recorded on ICC 12426 and ICC 4918, while lowest on resistant check, ICC 12475.

HPLC profile of leaf exudates showed that the malic acid was negatively correlated with damage rating at flowering (-0.28*), at maturity (-0.32**) and pod damage (-0.22*). Oxalic acid showed negatively significant correlation with damage rating during detached leaf assay (-0.22*). Acetic acid showed a negative correlation with larval weight (-0.45*), damage rating at flowering (-0.33**) and maturity (-0.26*). Citric acid showed negative and significant correlation with damage rating at flowering (-0.23*). Oxalic acid and malic acids has been reported to have an antibiotic effect on larvae, and it is possible that the antibiotic properties of oxalic acid may negate differences due to ovipositional antixenosis and determine the size of the larval population and therefore pod damage on a particular genotype.

The genotypes, ICC 12476, ICC 12477, ICC 12478, ICC 12479 and ICCV 2 were on par with the resistant check, ICC 12475 for pod borer damage under protected conditions. ICC 12475, ICC 12426, ICC 12478 and ICC 12479 recorded higher grain yield under un-protected conditions. The genotypes ICC 12475 (3.77) and ICC 12478 (6.59) recorded lowest reduction in grain yield under un-protected conditions, as compared to ICC 3137, ICC 12476, ICC 12477, ICC 12479, ICCV 2, ICC 4918 and ICC 12426, indicating the presence of tolerance mechanism in chickpea to *H. armigera.* The tolerant lines can be used in further breeding programs and the mechanisms responsible for the resistance can be exploited to develop resistant varieties.

Interaction of different components of resistance with grain yield showed, significant and positive correlation under protected conditions between larvae and eggs (0.89**), leaf damage and egg number (0.82*), yield per plant and egg number (0.77*), yield per plant and larva number (0.76*), yield per plant and egg number (0.82*) and pod damage (%) and larva number (0.91**). Significantly negative correlation was recorded between yield per plant and borer damage (%) (-0.79*), under un-protected conditions. These correlations and interaction of different components of resistance and grain yield will help in gene pyramiding.

Chapter I

Introduction

CHAPTER-I
INTRODUCTION

Chickpea (*Cicer arietinum* Linn.), also known as Bengal gram or gram, channa, garbanzo etc., is one of the most important pulse crops of India and is considered as "king of pulses" (Bhatt and Patel, 2001). Globally, chickpea is the third most important food legume grown in 11 m ha with an average production of 7.8 million tonns and an average productivity of 820 kg ha^{-1} (FAO, 2003 and Gowda *et al.*, 2005). It is grown in over 45 countries in all the five continents. India has more than 80 % of the world's chickpea area (10.6 million ha) and ranks fifth in area and fourth in production among food grains (Chhabra *et al.*, 1990), but ranks first among the food legumes (pulses). It is a source of high quality protein for the people in many developing countries, including India.

The genus *Cicer* originated in South-Eastern Turkey and spread to other parts of world, including Africa, America, Australia and Asia. It is adapted to relatively cooler climates. The crop is grown on conserved moisture and is rarely irrigated or fertilized. The largest area under cultivation is in the Indian sub-continent.

Chickpea is a diploid (2n = 16), highly autogamous crop, with natural cross pollination ranging between zero and one percent. Chickpeas are often divided into two major groupings *viz.,* Desi types (smaller angular seeds with sharp edges with variously pigmented flowers), are traditionally grown in warmer climates in South Asia and East Africa and Kabuli types (large round seeds, ram's head shape, white or pale cream or beige coloured and flowers are nonpigmented) suited to the more temperate climates of West Asia. A third type, designated as intermediate, is characterized by small to medium size, pea-shaped and cream coloured seeds. This type is found more often in germplasm collections than in farmer's fields. Desi type accounts for 90 % of world production, the remainder being kabuli (Singh *et al.*, 1985). In India, both types of chickpeas are grown in diverse agro-ecological niches normally in the post-rainy season, exploiting residual moisture.

The current productivity level of chickpea in India is 872 kg ha^{-1}, which is far lower than its potential (up to 4 t ha^{-1}) realized at research stations, demonstration plots and farmer managed on-farm trials (Gowda *et al.*, 2005). The productivity of chickpea crop has not witnessed any significant jump as compared to the cereal crops, because of several biotic and abiotic constraints. Among the many biotic factors responsible for low yield, damage due to insect pests is the major limiting factor (Bhagwat *et al.*, 1995). Chickpea crop is attacked by nearly 57 species of insect and other arthropods in India (Lal, 1992). Among them, pod borer *Helicoverpa armigera* (Hubner) (Lepidoptera: Noctuidae) is most important, and accounts for about 90 to 95 % of the total damage caused by all the insect pests (Sachan and Katti, 1994).

Helicoverpa armigera is a polyphagous, multivoltine and cosmopolitan pest and is reported to feed and breed on 182 species of host plants belonging to 47 families in India (Sithanantham, 1987 and Pawar, 1998). High polyphagy, mobility, high reproductive rate and diapause are major factors contributing to its serious pest status (Fitt, 1989 and Sharma *et al.*, 2005).

H. armigera is an insatiable feeder on chickpea plant. It infests the crop at the seedling stage and continues to devour flowers, pods and developing seeds until crop maturity (Reed *et al.*, 1987). The larvae prefer nitrogen rich plant parts such as flowers and pods (Fitt, 1989). A single larva damages several pods per day leading to severe losses in crop yield (Patankar *et al.*, 1999). The yield loss in chickpea due to pod borer has been estimated to be 10 to 60 % under normal weather conditions (Vaishmpayam and Veda, 1980), and 50 to 100 % in favourable weather conditions, particularly when there are frequent rains and cloudy weather during the cropping season. Annual yield loses attributable to this pest in India alone are over Rs.1000 crores (Saminathan *et al.*, 2003).

Insecticide application for pod borer is uneconomical under subsistance farming and is largely beyond the means of resource poor farmers. For effective control of this pest an understanding on its host preference and the peak periods of occurrence, and the influence of temperature, relative humidity and rainfall on population dynamics is important to evolve suitable strategies for integrated pest management (Akhauri *et al.*, 1996). Host plant resistance (HPR) assumes a pivotal 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 in return (Robinson, 1996 and Sharma, 2005). Since pod borer is highly polyphagous and well adapted to several crops and wild hosts in India (Bhatnagar and Davies, 1978), the screening and breeding for resistance to this insect pest is difficult. Host plant resistance to *Heliothis virescens* (Fab.) in legumes was first reported by Leuck *et al.*, 1967. Since then the literature on *Helicoverpa armigera* resistance in legumes has expanded rapidly. Studies on host plant resistance in chickpea crop to pod borer have identified sources with lower susceptibility or those which can tolerate the pest incidence. The complex nature of resistance makes it very difficult to predict a definite IPM strategy for its control. Again, the resistance varies over space and time (Armes *et al.*, 1992a and Singh *et al.*, 1994).

Screening of chickpea genotypes for resistance to *H. armigera* has been in progress at various national programmes and at ICRISAT. The work at ICRISAT resulted in the identification of lines with low to moderate levels of resistance to *H. armigera* (Lateef and Sachan, 1990, Lateef, 1985, Sharma, 2001 and Sharma *et al.*, 2003). Extensive breeding efforts in many countries and at the two international agriculture research centers (ICRISAT and ICARDA) have led to the development of over 300 improved varieties.

Concerted efforts to screen chickpea genotypes/ cultivars have led in the identification of many chickpea cultivars exhibiting low level of resistance to *Helicoverpa armigera* (Chabhra and Kooner, 1980; Lateef 1985; Lateef and Sachan, 1990 and Sachan, 1990).

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). The identification of sources of resistance and the knowledge of mechanisms involved is essential for increasing the levels and diversify the basis of resistance and to transfer such resistance into high yielding cultivars. Though the genetics of chickpea is not well understood, efforts to investigate variability through molecular markers and to develop a genome map have recently been initiated (Sharma and Crouch, 2004, Crouch *et al.*, 2005 and Sharma and Gaur, 2005).

Chickpea has abundant genetic variation for qualitative and quantitative traits. The extensive variation available in *Cicer* is important to chickpea improvement.

Exploitation of hybrid vigour in chickpea will depend on the direction and magnitude of heterosis, biological feasibility and the nature of gene action. Development and adaptation of high-yielding varieties is one of the most important steps for increasing chickpea production. Several chickpea genotypes have been identified with exploitable levels of resistance to *H. armigera* (Dias *et al.*, 1983, Lateef, 1985 and Lateef and Sachan, 1990).

Breeding for resistance to *H. armigera* was initiated at ICRISAT in mid 1980s and the major emphasis was to transfer resistance from less susceptible lines into high yielding adapted cultivars. Increased use of different sources of resistance was made to combine resistance from different sources. However, the success in transferring resistance to high-yielding lines has not been very successful, although some lines with reasonably good levels of resistance and higher yield have been reported. The limited progress is attributed to lack of adequate knowledge of the inheritance of various mechanisms of resistance.

Keeping these in view the present investigation on "Genetics of Resistance to pod borer, *Helicoverpa armigera* in Chickpea (*Cicer arietinum*)" was planned with the following objectives.

1. To understand the nature of gene action, including maternal effects, if any.
2. To study the mechanisms and inheritance of different components of resistance.
3. To study the interaction of different components of resistance and grain yield.

Results of the above studies are discussed in the following chapters, along with suggestions for crop improvement in future to develop varieties with high levels of resistance to *H. armigera* pod borer.

Chapter II
Review of literature

CHAPTER-II

REVIEW OF LITERATURE

Pulse crops (grain and food legumes) are the major source of protein for people in the developing nations, particularly where animal proteins are not a common ingredient in the diet. Among the food legumes, chickpea (*Cicer arietinum* L.) occupies first place in South Asia, and accounts for 12 % of world's production (Ryan, 1994). In India, it constitutes about 47.3 % of total pulse production (Lal *et al.*, 1986). However, its productivity is constrained by a complex of biotic factors including diseases (wilt, collar rot, Botrytis grain mold and *Ascochyta* blight) and insect pests (pod borer, leaf miner, cut worms, termites and bruchids) and moisture stress among abiotic stresses in India.

Gram pod borer, *Helicoverpa armigera* (Hubner) (Lepidoptera : Noctuidae) is the major biotic constraint limiting the production and productivity of chickpea (Srivastava and Srivastava, 1990a and 1990b, Lateef, 1985 and Reed *et al.*, 1987). The monetary loss due to *H. armigera* damage in India in chickpea has been estimated upto 2,030 million rupees annually (Lal *et al.*, 1985). In the semi-arid tropics, losses due to *H. armigera* damage in chickpea have been estimated at $ 325 million (ICRISAT, 1992 and King, 1994) and over $ 5 billion in all crops, despite nearly $1 billion spent on chemical control of this pest (Sharma, 2005).

Surveys conducted by ICRISAT scientists in India between 1977 to 1982 have shown that the pod damage ranges from 0 to 84.4 %, with an average of about 8 % (Bhatnagar, 1980; Bhatnagar and Davies, 1978 and Bhatnagar *et al.*, 1982). In the early eighties < 20 % of chickpea farmers use insecticides on their crops (Reed *et al.,* 1980) and avoidable loss, expressed as a percentage of the yield of the protected crop has been estimated to be 9 to 60 % (Sithanantham *et al.,* 1984).

So far, use of insecticides has been the major approach for controlling this pest on different crops but the undesirable side effects of chemical insecticides and development of resistance to insecticides has necessiated a shift to a more eco-friendly approach for controlling this pest (Mc Caffery *et al.,* 1989 and Kranthi *et al.,* 2002).

However, the situation is quite different now as more and more farmers resort to insecticides application to control this pest. As a route, an intensive screening and breeding programme was initiated at ICRISAT in 1976 to develop cultivars with resistance to *H. armigera* (Reed and Pawar, 1982 and Lateef, 1985).

Table 1 : Sources of resistance to pod borer, *Helicoverpa armigera* in chickpea

Genotype	Remarks	Reference
E 370 and C 235	Suffered 4.6 to 6.1 % pod damage compared to 15.1 % damage in 856-3/27.	Srivastava *et al.,* (1975)
GL 645, P 1324-11, P 1697, P 6292-1, Dulia, 6-28, GGP Chaffa and selection 418.	Suffered < 5 % pod damage compared to 36 % damage in standard checks.	Chabhra and Kooner (1980)
L 345, C 235, ICP 6037 and BR 70	Suffered < 5 % pod damage compared to 19.2 % in P 3090.	Reed *et al.,* (1980)
Prabhat, Chaffa, 2-52-2, 3-1A-3, Double pedicellate, N 59, 3-70, Pinnate, Himayatsagar, Alternaria, *Cicer* gigas and Hirwa Channa	Suffered < 10 % pod damage compared to 29 to 32 % damage in green pod and Chryanthifolia mutants.	Borikar *et al.,* (1982)
H 77-58, ICC 18, Kanpur local, Gonda II local and Mirzapur local	Suffered < 10 % pod damage compared to 30 % in H 76-105.	Dias *et al.,* (1983)
Desi early maturity	Showed resistance score of 34	Lateef (1985)

ICC 506, ICC 10619, ICC 6663, ICC 10667 and ICC 10817.	compared to 8 to 9 of IC 73266-3-4-1P	
Desi medium maturity ICC 738-8-1-1P-BP, IC 7341-12-1-B, IC 7394-18-2-1P-BP	Showed a relative resistance score of < 5 compared to 8 to 9 of ICC 3137	Lateef (1985)
Kabuli medium-late ICC 10870 and C 5264	Showed a resistance score of 3 to 6 compared to 6 to 9 of ICC 8835 and L 550.	Lateef (1985)
ICC 5810, ICC 11525, ICC 10136, ILC 1919, ILC 1932, IIC 1922, ILC 1929, BR 77 and H 208.	Suffered less damage than ILC 1931	Prasad *et al.*, (1990)
BG 275, RSG 44, RSG 94, Pant G- 144, GL 769, Anupam, JG 74, H 208 and 475-35.	Suffered less damage than BG 257	Prasad *et al.*, (1990)
Desi short duration ICC 506, ICCV 7 (ICCX 730041-1-1P-BP), ICC 10667, ICC 6663, ICC 10619, ICC 10817, ICCL 861992, ICCL 86103, ICCX 73008-8-1-1P-BP-EB, ICCX 730162-2-1P-B-EB, ICCX 730213-9-1-3HB, C-10, PDE 2, PDE 5, DPR/CE 72, DPR/CE 1-2, DPR/CE 3-1 and DPR/CE 2-3	DR< 3.8 compared to 6.0 of Annigeri	Lateef and Sachan (1990)
Desi medium duration ICC 4935-E-2793, ICCX 730094-18-2-1P-BP-EB, BDN 9-3, ICCX 730185-2-4-H1-EB, ICCX 730190-12-1H-B-EB, ICCX 730025-11-3-1H-EB, ICC 3474-4EB, ICC 5800, S 76, N 37and PDE -1. ICCL 86101, ICCL 86102, ICCL 86103 and ICCL 86104.	DR< 4.6 compared to 8.5 of ICC 3137.	Lateef and Sachan (1990)
Desi- long duration ICC 10243, ICCX 730020-11-1-1H-B-EB, GL 1002, Pant G 114 and PDE 7.	DR< 4.3 compared to 6.0 of H 208.	Lateef and Sachan (1990)

Kabuli medium duration ICC 10870, ICC 5264-E10, ICC 8835, ICC 4856, ICC 7966, ICC 2553-3EB, ICC 2695- 3EB, ICC 10243 and ICCX 730244-17-2-2H-EB.	DR< 5.4 compared to 6.0 of L 550.	Lateef and Sachan (1990)
GL 645 (Kabuli), Dhulia, 6-28, GGP Chaffa, P 1324-11, P-1697, P-6292 and selection 418.	Sufferd < 5 % pod damage compared to 16.1 to 36 % damage in G 130 and L 550.	Chabhra *et al.*, (1990)
ICC 506, ICC 2397,ICC 6341, ICC 4958 and ICC 8304.	Suffered < 12 % pod damage compared to 42 % in ICC 14665.	Bhagwat *et al.*, (1995)
PDE-2-1, ICC 16, Annigeri, BGM 42 and C 21-79. BG 372, B 390, GNG 469, PDE 2-1 and PDE 3-2.	These lines had 6-9 larvae per meter row compared to 32 larvae in H 86-18. Performed better than H 82-2 based on pod damage and grain yield.	Chauhan and Dahiya (1995).
Pusa-261	Less susceptible	Reddy *et al.*, (1996).
BJ 256	Less susceptible	Kotilal *et al.*, (1996)
C 235	Less susceptible	Ahmad and Kotwal (1996).
Vijay and Vishal	Less susceptible	Deshmukh *et al.*, (1996 a,b).
Line 1230 and C 44	Line 1230 was resistant, while C 44 gave consistently high yields	Parvez *et al.*, (1996).
ICC 506, ICC 6663, ICC 10619 and ICC 10667	Less susceptible	Singh (1997)
ICCV 7	Less susceptible	Singh *et al.*, (1997)
DHG 84-11, P 240, DHG 88-20, ICP 29, DHG 86-38, SG 90-55, KBG 1-1H 83-83,NP 37,DHG 87-54, GNG 669 and SG 89-11.	These varieties were better or on par with the commercial cultivars 240, P 256, C235 and BR 77.	Singh and Yadav (1999 a,b)

JG 74	Less susceptible	Das and Kataria (1999).

(Source : Sharma *et al.*, (2003) and Dua *et al.*, 2005).

More than 14,000 chickpea accessions have been screened for resistance to the *H. armigera* and mainly 15 lines with varying degree of resistance have been identified (Lateef, 1985, Sharma *et al.*, 2003 and Salimath *et al.*, 2003). Genotypes (Table 1) reported to be less susceptible to *H. armigera* in India (Sharma *et al.*, 2003) have been utilized into the breeding programs to enhance the levels of resistance to *H. armigera* in high yielding varieties (Lateef and Sachan, 1990; Singh *et al.*, 1991 and Dua *et al.*, 2005).

2.1 GENE ACTION AND MATERNAL EFFECTS

2.1.1 Breeding for resistance

Breeding for resistance to pod borer is one of the most economical, practical and environmentally sound method to manage the pest. There is variation in host-plant resistance against this pest. Screening of chickpea world germplasm at ICRISAT, Patancheru resulted in the identification of several sources with low to moderate levels of resistance to *H. armigera*. Resistance to *Helicoverpa* appears to be a complex trait, and it is likely that resistance (involving different components and mechanisms) is polygenic. Breeding for resistance to insect pests results in a net return of $ 300 per $ 1 of investment in research (Dua *et al.*, 2005). Breeding for resistance to *Helicoverpa* at ICRISAT began in 1977/78 with the confirmation of resistance in lines such as ICC 506 (Gowda *et al.*, 1983, Lateef, 1985 and Lateef and Sachan, 1990).

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) and Singh and Paroda (1989), reported the importance of both GCA and SCA effects for days to maturity, pods per plant, seeds per pod and seed yield and indicated 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.

Dhaliwal and Gill (1973), Gupta and Ramanujam (1974), Gowda and Bahl (1976 and 1978), Singh and Mehra (1980), Malhotra *et al.*, (1983) and ICRISAT (1981, 1982, 1983, 1984 and 1985a and 1985b), demonstrated additive genetic effects (2σ GCA^2) were greater than non-additive effects (σ SCA^2) for days to flowering and 100 seed mass.

Studies at ICRISAT using a 6 × 6 desi and 4 × 4 kabuli diallels, indicated additive genetic variance for pod borer resistance ICRISAT (1981). Additional studies with 6 × 6 diallel with desi short duration cultivars and 6 × 6 diallel with desi medium long duration cultivars suggested additive genetic variance for pod borer resistance (ICRISAT, 1982), while in 6 × 6 desi and 5 × 5 kabuli diallels there was preponderance of SCA effects for borer damage in the medium duration desi types (ICRISAT, 1983). Studies conducted using two desi diallel trials reported that GCA variances were significant for most of the characteristics suggesting the importance of additive genetic variance (ICRISAT, 1984). 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 types. ICRISAT (1985a), reported that for pod borer damage, the SCA component was in higher magnitude indicating non-additive gene action for borer resistance in chickpea.

In order to prolong the life of the insect resistant cultivars, emphasis has been laid on breeding chickpea varieties with more than one component of resistance to *H. armigera* and the development and use of cultivars with tolerance component of resistance. Any resistant cultivar with genes conferring antixenosis and antibiosis might last longer in the field than a cultivar possessing only one component of resistance. The breeding of chickpea cultivars with polygenic resistance combining antixenosis, antibiosis and tolerance would slow down the break down of chickpea resistance to *H. armigera* (Pimbert, 1990).

2.1.2 Nature of gene action

The term diallel was introduced by Schmidt (1919), which is a Greek word, and implies all possible crosses involving collection of male and female parents. Hayman (1954a), defined "diallel cross" as the set of all possible matings between several genotypes. The analysis for diallel crosses was given by Hayman (1954a and 1954b), 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 in linkage equilibrium, and to estimate general and specific combining ability effects from crosses of fixed lines. Diallel analysis is one of the most important biometrical techniques available to 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 be used and in selecting breeding materials that show the greatest promise for success. It has also been used successfully by quantitative geneticists attempting to gain a better understanding of the nature of gene action in determining quantitative traits, which are of utmost importance in agriculture.

Using a diallel cross, the total genetic potential is partitioned into general and specific combining ability effects, while the general combining ability has been attributed to additive effect of genes, the specific combining ability has been attributed to the dominance and epistatic interactions. The concept of combining ability was proposed by Sprague and Tatum (1942), who defined general combining ability (GCA) as the average performance of the lines in hybrid combinations, and specific combining ability (SCA) as the deviation of certain crosses from the average performance of the lines, and suggested that combining ability can be studied by making all possible crosses in a set of inbred lines.

Griffing (1956), showed that the total genetic variance among single cross progeny is equal to twice the general combining ability component of variance ($\sigma_g^2 \times 2$) plus the specific combining ability component of variance (σ_s^2). Based on this relationship, the relative importance of general and specific combining ability in determining progeny performance should be assessed by estimating the components of variance and expressing them in the ratio, $2\ \sigma_g^2 / (2\ \sigma_g^2 + \sigma_s^2)$. The closer the ratio to unity, the greater the predictability based on general combining ability alone. When the analysis is based on a model with fixed effects, one would use equivalent components of mean squares. General combining ability involved both additive and additive × additive interaction effects.

Gilbert (1958), evaluated the assumptions required for the genetic interpretation of diallel statistics. Hayes and Paroda (1974), concluded that the exclusion of the parents from diallel analysis increases the precision of gca and sca estimates.

Sokol and Baker (1977), 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 nonallelic gene actions operating in the inheritance.

Baker (1978), reviewed the critical issues in the use of diallel analysis. The statistical description provided by diallel analysis can be used to answer questions concerning the importance of specific combining ability and the predictability of hybrid performance using general combining ability or parental performance.

Walters and Morton (1978), stated that gca of the parents are not based on progeny performance, as 'gi' (general combining ability of i^{th} parent) parameter gives only the additive contribution of varieties based on parents.

Singh *et al.*, (1982), stated that among all the other methods, diallel cross technique is efficient for the analysis of the nature of gene action of quantitative traits in chickpea. It provides useful information indicating the nature of inheritance of various characters.

Malhotra *et al.*, (1983), reported that additive and non additive type of gene action were important for seed yield, 100- grain weight, seeds per pod and pods per plant with the preponderance of additive type of gene action. However, for the number of primary and secondary branches, only additive type of gene action was present. The parents T 3 and L 345 were the best general combiners for seed yield, pods per plant and number of primary and secondary branches and L 144 for 100-grain weight.

Yadavendra and Kumar (1987), reported that non additive type of gene action was prominent for number of branches, pods per plant, seeds per pod and grain yield per plant in chickpea. However, for days to flowering, maturity, plant height and 100-grain weight, additive type of gene action was important. The parents, Chaffa and Dohad yellow were good combiners for grain yield, pods per plant and seeds per pod and BEG 482 for grain yield and 100 grain weight. For exploitation of additive genetic variability, normal pedigree method and diallel selective mating system and population breeding for non-additive genetic variability have been suggested for improvement in chickpea.

Mandal and Bahl (1987), found gca estimates to be non-significant for all the traits except for pods per plant and days to flowering. Yadavendra and Kumar (1987), reported high gca estimates for seed yield, pods for plant, early flowering, days to maturity and 100- seed weight. Salimath and Bahl (1989), reported appreciable additive effects for pods per plant, 100- seed weight and biological yield. Kumar and Bahl (1988), reported additive genetic variance for 100- seed weight. Mandal and Sadhu (1989), reported days to 50 % flowering, seed weight and seeds per pod to be under predominant control of additive gene action. Jaiswal *et al.*, (1989), reported dominance genetic variance for a majority of the traits. Both additive and non-additive gene effects were equally important for 100- seed weight and yield per plant.

Singh *et al.*, (1992), analysed 28 diallel trials over eight years according to method 4 and model 1 of Griffing (1956) in two locations to estimate genetic variances. 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, number of branches, pods per plant and seeds per pod. Both general combining ability and specific combining ability varied significantly with generation. Components of GCA mean square were invariably much larger than GCA × generation interaction components, indicating either F_1 or the F_2 generation can be used to estimate the GCA components effectively.

Jha *et al.*, (1997), conducted a line × tester analysis involving six lines and four testers to study nature of gene action and combining ability in chickpea. Days to first flower, primary branches, secondary branches, pods per plant and seeds per pod were predominantly under the control of additive genetic effects, days to maturity and plant height were under the control of dominance genetic effects, while for 100-seed weight and yield per plant both additive and dominance gene effects were equally important. Different lines were best general combiners for different traits. Lines showing significant sca effects were not necessarily good general combiners.

Patel *et al.*, (1998), conducted an experiment to study the inheritance of yield and yield components in desi × desi (D × D), desi × kabuli (D × K) and kabuli × kabuli (K × K) crosses of chickpea using generation mean analysis. Predominance of epistatic gene action was observed for secondary branches, number of pods, seeds per pod and seed yield in all the crosses. However, for number of primary branches, test weight and seeds per pod, additive gene action was important in D × D and D × K crosses. For primary branches in K × K cross, dominance was more important. D × D and K × K crosses also showed significance of additive component for number of pods and seed yield but in D × K cross it was non- additive.

Sharma *et al.*, (2003), stated that studies on diallel and line × tester crosses at ICRISAT and elsewhere, indicated additive gene action was predominant in short duration desi chickpeas. However, non-additive gene action has been reported to be important in medium and long duration desi types and in kabuli type chickpeas.

The genetic interpretation of data from diallel experiments is valid only with certain assumptions: (i) diploid segregation, (ii) homozygous parents, (iii) No difference between reciprocal crosses, (iv) genes independently distributed between the parents, (v) no non-allelic interaction, (vi) Independent action of non-allelic genes, in the diallel cross and (vii) No multiple allelism.

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

2.1.3 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 1 involves parents, one set of F_1s and reciprocal F_1s and described the methods of analysis for combining ability considering Eberhart's model I (fixed effect) and model II (random effect). The degrees of freedom for GCA was P-1 and for SCA P (P-1)/2, where as P stands for number of parents.

2.1.4 Gardner and Eberhart (1966) method

Singh and Paroda (1984), compared five different methods of diallel analysis [(Griffing (1956) – Model 1, method 2 and Model 1, method 4; Morley Jones (1965) ; Gardner and Eberhart (1966) - Analysis 3 ; Gardner and Eberhart (1966) - Analysis 2, and Walters and Morton (1978)] using data from a half diallel cross of a fixed set of nine homozygous varieties and one set of their single cross progenies in chickpea.

They concluded that the analysis proposed by Gardner and Eberhart (1966) appears to be superior as it provides information on the additive effects of varieties, their average and individual contribution to heterosis in crosses in addition to gca and sca effects and variances.

It is advantageous over other methods because

1. This model assumes arbitrary gene frequencies at all loci between the parents, it is equally applicable to a fixed set of both homozygous varieties as well as those mating at random.
2. The variety and cross means can be predicted, and if S_{ij} and h_i heterosis effects are negligible, the predicted variety cross means have smaller standard errors than the observed variety cross means.
3. The estimates of various genetic effects from a halfdiallel cross and related populations are defined more clearly as functions of gene frequencies and additive and dominance effects for individual loci.
4. Heterosis effects are further subdivided to provide additional information about the varieties involved. The estimates obtained are particularly useful in making predictions and choosing breeding materials and breeding methodologies.
5. An analysis of variance with appropriate F-tests is provided for various types of gene action involved.
6. The variety effects as presented by Gardner and Eberhart, depend only on additive and additive × additive gene action regardless of the gene frequencies or correlated gene distribution (Sokol and Baker, 1977).
7. Heterosis can easily be calculated from the estimates obtained in this model, as $h_{ij}=2S_{ij}-S_{ii}-S_{ij}/2$.

When parents are homozygous lines and only the diallel cross is considered Gardner and Eberhart (1966) model is similar to Hayman's (1954a and 1954b) model, but in addition the problem of fixed set of parents has also been 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.

Griffing's (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 is referred as 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 × additive epistasis and to permit multiple alleles at all loci.

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 and specific combining ability varies significantly with generation, and components of GCA mean squares were invariably much larger than GCA ×

generation interaction components indicating that either the F_1 or F_2 generation can be used to estimate the GCA components effectively. Combined diallel analysis of F_2s over locations was revealed the importance of combining ability × location interactions (Singh *et al.*, 1992).

Germplasm lines such as ICC 506, ICC 10619 and ICCL 84205 with low borer damage have been found to be useful in the breeding programs for *H. armigera* resistance (Singh *et al.*, 1991). Parental performance is a good indication of resistance to *H. armigera* in F_2 and F_3 progenies (ICRISAT, 1981). Pedigree selection for low borer damage under pesticide free conditions has been found to be effective in identifying pod borer resistant lines. Chaturvedi *et al.*, (1997), summarized research findings on *H. armigera* resistance in chickpea and tabulated data on sources and inheritance of resistance based on results from trials during 1986-94 and suggested that ICC 506 and ICCV 7 were good sources of resistance for *H. armigera.*

Malhotra and Singh (1997), reported that 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 suggested that seed size is governed by recessive genes. Singh and Gupta (1997), reported the importance of both additive as well as non-additive components of variance for pods per plant, 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 for pods per plant, seeds per plant, seeds per pod and seed yield.

Sreelatha (2003), conducted two diallel (desi and kabuli) trials 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 gene effects (σ^2A) were greater than non-additive effects (σ^2D) indicating the importance of additive gene action. However there was prepondarence of SCA (specific combining ability) effects for pod borer resistance in the kabuli chickpea, indicating that non-additive genetic variation may be important in some sources of resistance.

2.2 MECHANISMS AND INHERITANCE OF DIFFERENT COMPONENTS OF RESISTANCE

2.2.1 Sources of resistance

Chabhra and Kooner (1980), reported that, out of 332 strains Dulia 6-28, GGP Chaffa, GL-645 (kabuli), P-1324-11, P-1692-1 and selection 418, out of 332 strains were less susceptible to pod borer. Chabhra *et al.*, (1990) observed 3.4 % to 59.5 % pod borer damage in different maturity groups of chickpea and identified five genotypes to be less susceptible to pod borer, where as Lateef and Sachan (1990), on the basis of national trials identified several genotypes as resistant in desi short, medium and long duration group. Two of these selections, ICCX 730008 and PDE 2 were identified by AICPIP in 1986 as donor parents for *Helicoverpa* resistance breeding programs in India.

2.2.2 Inheritance of resistance

Studies on inheritance of resistance have indicated that resistance to *H. armigera* in chickpea may be additive (ICRISAT, 1984).

Chabhra *et al.*, (1993), studied the performance of chickpea crosses in F_2 and F_3 generations against *H. armigera*. In the F_2 generation, pod damage varied from 14 to 24% as against 13 to 23 % in the parents, and 43 % in the susceptible check. In the F_3 generation, pod damage ranged from 5 % to 18 % in crosses and 16 % to 23 % in parents as against 44 % in the susceptible check.

Gowda *et al.*, (2005) evaluated a series of half-diallel crosses involving early, medium and late maturity desi and kabuli type chickpea (*Cicer arietinum* Linn.) genotypes with stable resistance to *H. armigera* pod borer along with the parents at two locations in India to understand the inheritance of pod borer resistance and grain yield. Inheritance of resistance to pod borer and grain yield was different in desi and kabuli types. In desi type chickpea, additive component of genetic variance was important in early maturity and dominance component was predominant in medium maturity group, while in late maturity group, additive as well as dominance components were equally important in the inheritance of pod borer resistance. Both dominant and recessive genes conferring pod borer resistance seemed equally frequent in the desi type parental lines of medium maturity group. However, dominant genes were in overall excess in the parents of early and late maturity groups. In kabuli medium maturity group, parents appeared to be genetically similar, possibly due to dispersion of genes conferring pod borer resistance susceptibility, while their F_1s were significantly different for pod borer damage. Contrary to medium maturity group, association of genes conferring pod borer resistance and susceptibility in the parents could be attributed to the similarity of parents as well as their F_1s. Grain yield was predominantly under the control of dominance gene action irrespective of the maturity groups in desi type. In all the maturity groups, dominant and recessive genes were in equal frequency among the desi parental lines. Dominant genes, which tend to increase or decrease grain yield are more or less in equal frequency in parents of early maturity group, while in medium and late maturity groups, they were comparatively in unequal frequency in desi type. Unlike in desi type, differential patterns of genetic components were observed in kabuli type. While only dominance genetic component was important in early and late maturity group, only additive gene action was involved in the inheritance of grain yield in medium duration group in kabuli type. The dominant and recessive genes controlling grain yield are asymmetrically distributed in early and medium maturity groups in kabuli type. The implications of the inheritance of the pod borer resistance and grain yield are discussed in the context of strategies to enhance pod borer resistance and grain yield in desi and kabuli types of chickpea.

2.2.3 Biology of *Helicoverpa armigera*

The females of *H. armigera* start laying eggs some hours after dusk, initially alternating with feeding, and later becoming the predominant activity until soon after midnight The eggs are laid singly, late in the evening, mostly after 2100 hr to midnight. On the host plants, the eggs are laid on the lower surface of the leaves along the midrib, when the plants are still very small (Jayaraj, 1982). Moths are highly selective in their choice of host plant in a suitable condition of development (Hardwick, 1965). In contrast to other hosts, oviposition on chickpea declines from the onset of flowering (King, 1994).

The physiological state of an insect is the product of numerous interacting factors such as age, feeding status, 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 than the females with low eggs laid (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 influenced the choice for oviposition.

Mullick and Singh (2001), conducted the bioassay in the laboratory to evaluate the effect of larval food, i.e, leaves and flower buds of four leguminous plants *viz.*, chickpea, pigeonpea, blackgram and cowpea on the pre-oviposition period, fecundity and longevity of *H. armigera* females. Pre-oviposition period of females reared during larval stages on chickpea leaves was significantly shorter compared to those reared on leaves of the host plants. The fecundity of females fed during larval stages on cowpea and pigeonpea leaves was statistically not different. However, it was significantly greater than the fecundity of females reared on blackgram and chickpea leaves. Leaves of different test plants did not influence longevity of females. The fecundity indices of females reared on cowpea (56.21) and pigeonpea leaves (44.73) were statistically similar, but significantly higher compared to those reared on blackgram (39.38) and chickpea (37.89) leaves. No significant differences were observed in the pre-oviposition period of females, fed on flower buds of different leguminous plants during the larval stages.

2.2.4 Mechanisms of resistance

Knowledge of the mechanisms, nature and inheritance of resistance is critical for developing germplasm with durable and stable resistance to insects. In view of limited success in the past in developing crop cultivars with resistance to these pests by using known sources of resistance, there is a need to identify genotypes with different mechanisms (genes) of resistance. Resistance genes from diverse sources need to be combined (gene pyramiding) to increase the levels, and diversify the bases of resistance to this pest. All the three mechanisms, antixenosis, antibiosis and tolerance have been reported against *H. armigera* in chickpea (Chabhra *et al.*, 1990).

Table 2 : Characters associated with resistance to *Helicoverpa* in chickpea

Crop	Mechanism	Characters
Chickpea	Non-preference	Pod shape, pod wall thickness, foliage colour and glabrousness
	Antibiosis	Malic acid, crude fibre, non-reducing sugars, low starch, cellulose, hemicelluloses, lignin in the pod wall, trypsin inhibitors and HG proteinase inhibitor.
	Escape	Earliness and cold tolerance

Source : (Dua *et al.*, 2005)

2.2.4.1 Oviposition non-preference

During the course of evolution, plants acquire several defense mechanisms against insect pests to reduce the damage. Resistance is evident during the vegetative and podding stages of the crop. In general, desi chickpea are less susceptible to *H. armigera* than the kabuli types. Antixenosis for oviposition and antibiosis are important mechanisms of resistance to *H. armigera* resistance in some chickpea genotypes (Lateef, 1985 and Srivastava and Srivastava, 1990a and 1990b). To date more antibiosis, than antixenosis or tolerance has been reported in legume crops (Clement *et al.*, 1994).

Many morphological characteristics that are associated with oviposition insect for non-preference 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, podwall thickness, foliar colour and crop duration seems to influence the *H. armigera* infestation in chickpea (Ujagir and Khare, 1987 and 1988).

Oviposition non-preference is one of the components of resistance to *H. armigera* in chickpea (Cowgill and Lateef, 1996 and Sison *et al.*, 1996). Fewer eggs were recorded on resistant line, ICC 506 than on ICCC 37 and Annigeri over two seasons in multi-choice field and laboratory conditions. Lateef (1985), recorded 38 eggs per 5 plants in ICC 506 compared to 64 eggs per plant on Annigeri among the early flowering genotypes. Similarly, 57 and 77 eggs per 5 plants were recorded in ICC 10619 and ICC 3137 respectively, among the medium maturity genotypes. Among the late flowering genotypes, there were 36 eggs on ICC 7320-11-1, 53 on ICC 5264-E9, and 57 on ICC 8835.

Srivastava and Srivastava (1989), reported oviposition non-preference as the cause of observed differences in pod damage among eight chickpea genotypes. They found direct relationship 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.

Ramnath *et al.*, (1992), observed that pigeonpea was most preferred host and cotton the least preferred host. The order of preference was pigeon pea > bhendi > chickpea > tomato > cotton. Among the cotton genotypes, the trichome density was positively correlated with ovipositional response. Cowgill and Lateef (1996), recorded fewer eggs on ICC 506, than the susceptible controls (ICCC 37 and Annigeri). These observations were confirmed by the laboratory studies.

Bhagwat and Sharma (2000), reported that the resistant genotypes, ICC 506, ICCV 10, ICCL 86102 and ICCV 95992 had a pod damage rating of 3 (1 = less susceptible to 9 = highly susceptible scale) to *H. armigera* due to low oviposition.

Sreelatha (2003), studied oviposition of *H. armigera* under no choice, dual choice and multi-choice laboratory and multi-choice field conditions revealed that desi types (ICC 12475, ICC 12476, ICC 12477, ICC 12478, ICC 12479, ICC 12490 and ICC 14876) were less preferred for oviposition compared to kabuli type genotypes (ICC 12491, ICC 12493, ICC 12494, ICC 12495, ICC 12968, ICC 4973 and ICC 4962).

2.2.4.2 Antibiosis

Antibiosis is the adverse effect of a plant on some aspects of the insect's biology (Painter 1951 & 1958). Antibiosis is expressed in terms of larval mortality, decreased larval and pupal weights, prolonged larval and pupal development, failure to pupate and reduced fecundity and egg viability (Yoshida *et al.*, 1995 and Mann, 2002). From the nutritional point of view, although there are a few documented examples, antibiosis may occur from one or more of the following reasons.

1. The absence of some nutritional material such as vitamins or essential amino acids in the plant.
2. The deficiency of certain nutritional materials, especially amino acids, vitamins or specific sterols.
3. The balance in available nutrients, especially sugars, proteins or sugar-fat or nitrogen-sugar ratio.
4. Secondary plant metabolites.

Chickpea varieties differ in their susceptibility to *H. armigera* due to differences 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 1990a), Cowgill and Lateef (1996), Dodia *et al.*, (1996), Sison *et al.*, (1996), Yoshida *et al.*, (1995), Yoshida (1997) and Sharma *et al.*, (2003 and 2005).

Rembold and Winter (1982), found that the threshold for low pod borer damage is 250 mg malate/ ml of exudates. Rogers (1981), reported that *H. armigera* larvae bred on a purple flowered chickpea cultivars (desi type) produced small pupae and adults with reduced fecundity, while those bred on a white flowered cultivars (kabuli type) produced normal sized individuals with normal fecundity.

Srivastava and Srivastava (1990a), assessed the antibiosis in terms of larval survival, larval and pupal weights, egg viability, adult longevity, fecundity and Howe's growth index among genotypes. Using D^2 cluster analysis, they grouped the chickpea genotypes into five groups (1) ICCX 730041 and ICC 10817, (2) ICC 3137 and K 850, (3) ICC 10613 and C 235, (4) ICCL 79048 and (5) ICC 1403. Larval weight contributed maximum to the variation followed by larval period, pupal weight and pupal period.

Life table analysis by Sharma and Yadav (2000) indicated that there was considerable variation for net reproductive ratio (142.1 to 268.6), mean generation time (39.1 to 45.2 days), intrinsic rate of daily increase (0.12 to 0.14), finite rate of daily increase (1.13 to 1.15) and weekly multiplication rate (2.57 to 3.02) on different genotypes of chickpea. Based on weekly multiplication rate, NDG 90-27, BG 1027 and BG 267 showed greater antibiosis to the pod borer than P 256. Net reproductive rate was greater on BG 1027 than on other genotypes tested. Increasing order of suitability to *H. armigera* was IPCK 94-4, BDG 80, ICPK 94-2, H 89-961, C 235, L 550 and P 256. Mean generation time was shorter on C 235 as compared to P 256. Pupae of *H. armigera* reared on ICC 506 and ICCV 7 weigh less than those reared on ICCC 37 (Cowgill and Lateef, 1996). Larvae reared on leaves or pods of ICCV 7 weighed significantly lower than those reared on ICCC 37.

There were considerable differences in numbers of *H. armigera* larvae on different chickpea genotypes. Lateef (1985), recorded 58 larvae per 5 plants on ICC 506 compared to 103 larvae on Annigeri, 99 on ICC 10619 versus 202 on ICC 3137, and 112 on ICC 7320-11-1 versus 147 on ICC 8835. Olla and Saini (2002), studied the feeding preference of the third instar larvae of *H. armigera* on different plant parts of chickpea. In no-choice feeding tests, H 92-67, H 91-47 showed less leaf and flower damage than H 86-18, H 89-96 and HK 89-131. Pods of H 92-67, H 91-47 and L 550 were also less preferred than that of H 86-18. In multi-choice tests, H 92-67, H 91-47 and C 235 were less preferred than the other genotypes tested.

Olla and Saini (1999), evaluated eight chickpea genotypes in the laboratory for feeding preference by the fifth instar *H. armigera* larvae and suggested that H 92-67 and H 91-47 were the most resistant, while H 86-18, HK 89-96 and HK 89-131 were highly susceptible. However C 235 and L 550 showed moderate level of resistance.

Sreelatha (2003), recorded reduced larval and pupal weights and prolonged larval and pupal periods on leaves, pods and 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) as compared to that on susceptible genotypes (ICC 12426, ICC 3137, ICC 4973 and ICC 4962).

Sharma *et al.,* (2005), standardized the detached leaf assay to screen for resistance to pod borer in chickpea, pigeon pea, peanut and cotton under uniform insect pressure under laboratory conditions. This technique keeps the leaves in turgid condition for ≈ 1 wk. The experiment can be terminated when the larvae have caused > 80 % leaf damage in the susceptible check or when differences in leaf feeding between the resistant and susceptible check are maximum. Detached leaf assay can be used as a rapid screening technique to evaluate germplasm, segregating breeding materials and mapping populations for resistance to *H. armigera* in a short span of time with minimal cost and under uniform insect infestation.

Sharma *et al.*, (2005), standardized a cage technique to screen chickpeas for resistance to *Helicoverpa armigera* (Hubner). Leaf feeding by the larvae was significantly lower on ICC 506 than on ICCC 37 when the seedlings were infested with 20 neonates per 5 plants at 15 days after seedling emergence or 10 neonates per three plants at the flowering stage. Maximum differences in pod damage were observed when the plants were infested with six third instar larvae per three plants in the greenhouse, and with eight larvae per plant under field conditions. Larval weights were significantly lower on ICC 506 than on ICCC 37 across growth stages and infestation levels. At the podding stage, percentage of reduction in grain yield was significantly greater on ICCC 37 and Annigeri than on ICCV 2 and ICC 506. The no-choice test can be used to screen segregating breeding material and mapping populations for resistance to *H. armigera*. It also provides useful information on antibiosis mechanism of resistance to *H. armigera*.

Sharma *et al.*, (2005) studied the antibiosis mechanism of resistance to pod borer, *Helicoverpa armigera* in wild relatives of chickpea. Accessions ICC 17257, IG 70002, IG 70003, IG 70012 (*Cicer bijugum*), IG 69948 (*C. pinnatifidum*), IG 69979 (*C. cuneatum*), IG 70032, IG 70033, IG 70038 and IG 72931 (*C. judaicum*) showed lower leaf feeding, a drastic reduction in larval weight and poor host suitability index at the vegetative and/or flowering stages of crop growth as compared to the cultivated chickpeas. Based on percentage pods damaged by 5th day (< 52 % pods damaged compared to 90 % pods damaged in Annigeri), and percentage weight gain by the larvae (< 35 % weight gain compared to 3.6 % weight gain on ICCV 2), accessions IG 69979 (*C. cuneatum*), IG 7003, IG 70022, IG 70016, IG 70013, IG 70012, IG 70010, IG 70001, IG 70018 and IG 70002 (*C. bijugum*) and IG 72953 (*C. reticulatum*) showed high levels of resistance to *H. armigera*. Larvae of *H. armigera* weighed < 50 mg when reared on *C. pinnatifidum* (IG 69948 and IG 70039) and *C. judaicum* (IG 72931) compared to 301.95 mg on *C. arietinum* (ICCC 37, the cultivated chickpea). Larval weights on many accessions of the wild relatives of chickpea were much lower than those on the cultivated chickpeas, indicating the existence of different mechanisms of resistance to *H. armigera*. There was no pupation and adult emergence when the larvae were reared on accessions of *C. pinnatifidum* (IG 69948 and IG 70039) and *C. judaicum* (IG 69980, IG 70032, IG 70033 and IG 72931). The wild relatives of chickpea showing high levels of antibiosis to *H. armigera* can be used to introgress diverse resistance genes into cultivated chickpea to increase the levels and diversify the basis of resistance to this insect.

2.2.4.2.1 Physico-chemical factors associated with resistance to *H. armigera* in chickpea

The number of pods, percentage pod damage and grain yield are important parameters to select for resistance to *H. armigera* (Singh and Yadav, 1999a). The biological yield in chickpea is positively correlated with number of pod bearing nodes, number of branches and pods and plant height (Bhatia *et al.*, 1993), and therefore, these characteristics may play an important role in genotypic susceptibility to pod borer. Leaf hairiness has considerable influence on oviposition preference by the *H. armigera* females. Trichomes in chickpea might play a major role on genotypic resistance/ susceptibility to this pest. Glabrousness in Chaffa mutant is governed by a single recessive gene (Pundir and Reddy, 1989).

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

Acid exudates in chickpea plants are associated with resistance to *H. armigera*. The acidic fraction consists of 94.2 % malic acid, 5.6 % oxalic acid and 0.2 % acetic acid (Van der Maesen, 1972). Malic acid acts as a deterrant to the *H. armigera* larvae, and pod borer resistant lines have more amounts of malic acid than the susceptible lines (Rembold, 1981)

Srivastava and Srivastava (1989), reported that the low level of acidity in the genotype ICC 14665 was associated with susceptibility to *H. armigera*, and there was a positive correlation between the number of eggs laid and number of larvae present on susceptible genotypes, ICC 3137, K 850 and ICC 1043. 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.*, 1989b).

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.

Bhagwat *et al.*, (1995) observed that low acidity of the leaf exudates and malic acid content were associated with the susceptibility of this genotype to *H. armigera* at 65 and 75 days after sowing. However, this trend was not apparent at 90 days after sowing.

Patnaik and Senapati (1995), studied the influence of acidity on the incidence of *H. armigera* in 13 desi early maturing chickpea cultivars. The egg and larval counts were negatively correlated with increasing concentrations of acid exudates in the leaf extracts of the test cultivars. Low density of eggs (0.7 to 1.6/10 plants) and larvae (3.0 to 4.0/10 plants) were associated with high acidity (24.2 to 25.3 milliequivalents) while the cultivars with low acid content (13.5- 15.1 meq) harboured more eggs (> 2.7/10 plants) and larvae (> 5.9/10 plants). However, resistance expressed by resistant lines PDE – 3-3, 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.

The larvae reared on the leaves and pods of resistant lines (ICC 12475 and ICC 14876) and pupae formed from these weigh substantially less than those reared on the susceptible genotypes (ICC 4918 and ICC 3137) (Cowgill and Lateef, 1996).

Singh (1999), studied the effects of artificial diets made of powdered seed materials of chickpea (*Cicer arietinum*), soybean (*Glycine max*) and maize (*Zea mays*) on the growth, consumption and feeding preferences of *H. armigera* larvae. Food consumption and growth of final instar larvae were minimal on maize diet. The nutritive value of the soybean diet was higher, but the consumption rate of larvae was highest on chickpea diet as compared to other test diets.

A high percentage of crude fibre, 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 podwall inhibit the pod damage. In less susceptible genotypes (Desi 3108, GI 1002 and LCG 3508) the chemical components such as malic acid, sugar, crude fibre, cellulose and lignin in the plant parts are responsible for their resistance (Chabhra *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 proteinase inhibitor among chickpea genotypes provided biochemical basis for adoption of *H. armigera* to the protein inhibitors of *Cicer* species (Patankar *et al.*, 1999).

2.2.4.2.2 The HPLC profiles of leaf exudates

Broils *et al.*, (1998) used a high performance liquid chromatography (HPLC) method for the identification of active constituents of *Hypericum perforatum* using a wide pore RP – 18 column and a water-methanol-acetonitrile-phosphoric acid mobile phase system. The identification of its flavonoid, naphthodianthrone and phloroglucinol constituents was performed using combined HPLC-diode array detection (DAD) analysis, HPLC-thermospray and HPLC-electrospray mass spectrometry. Chlorogenic acid, quercetin, quercitrin, isoquercitrin, rutin, hyperoside, 13,II8-biapigenin, pseudohypericin, hypericin, hyperforin and adhyperforin were separated by an aqueous phosphoric acid-acetonitrile-methanol gradient within 50 min.

2.2.4.3 Tolerance

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

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, nutrient and growth regulation. 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).

Shukla *et al.*, (1998), discussed the tolerance of chickpea cultivars against pod borer, *Helicoverpa armigera.*

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.

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Lateef and Sachan (1990), stated that some of the chickpea lines were found to suffer considerably less borer damage than others due to tolerance to pod borer. This has necessitated the need for selecting genotypes with greater ability to tolerate or recover from the pod borer damage (Lateef, 1985 and Srivastava and Srivastava, 1989).

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.

Bhatt and Patel (2001), screened the chickpea cultivars for their resistance to gram pod borer, *H. armigera.* The cultivars Chaffa and ICCV 10 recorded lowest larval population. Chaffa was the most tolerant cultivar which recorded the lowest pod damage rate (9.5 %).

Patnaik and Senapati (2001), studied the comparative tolerance of chickpea cultivars against *H. armigera* . The cultivars PDE 3-1, PDE 5-1, PDE 7-2, ICC 506 and Keonjhar local had comparatively low larval population than other cultivars. However ICC 506 and PDE 7-3 exhibited the highest tolerance to *H. armigera.*

Suryawanshi *et al.*, (2003), screened 53 chickpea cultivars for resistance to gram pod borer. The cultivars such as Phule G- 222-2, 97121, 9525-8-39, 9421-1, 409-4, 9426-2, 9329-1, 92307, 96005, 97125, 950103-5-11 and Vijay were found to be tolerant to pod borer.

Sreelatha (2003), reported that the extent of loss in yield due to *H. armigera* damage in 18 chickpea genotypes under protected and unprotected field conditions can be used as an indicator of tolerance mechanism in chickpea genotypes.

Reduction in grain yield was lowest in resistant check ICC 12475, followed by ICC 4918, ICC 12490, ICC 12493 and ICC 12476.

2.3 TO STUDY THE INTERACTION OF DIFFERENT COMPONENTS OF RESISTANCE AND GRAIN YIELD

Crop yield may fluctuate due to sensitivity of varieties to different growing seasons or climatic conditions. Yield, being the most important economic trait, knowledge about its inheritance is useful to bring about genetic improvement of a crop.

The importance of yield 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 similar environments within its intended area of production.

Pimbert (1990), stated that breeding of chickpea cultivars with polygenic resistance combining insect antixenosis, antibiosis and tolerance would slow down the breakdown of chickpea resistance to *H. armigera* and improves the grain yield.

Srivastava *et al.*, (1975), studied 20 chickpea lines and found significant variation in the percent of pods damaged. They found no correlation between seed yield and pod damage by *H. armigera* .

Gowda and Bahl (1976), studied the performance of 21 F_1 hybrids involving seven chickpea cultivars. They concluded that there is good possibility of increasing seed yield by exploiting some of the yield components particularly, number of branches and pods plant^{-1}. For 100- seed weight majority of crosses showed negative correlation.

Gowda *et al.*, (1983), studied the interaction between borer damage and grain yield. Although complete resistance is not available, ICC 506 has shown consistently lower pod damage over the years and improved yields under unsprayed conditions.

Patnaik *et al.*, (1985), evaluated the resistance of chickpea varieties against pod borer, *Helicoverpa armigera*. The cultivar RSG 130 showed lowest pod infestation of 20 % and recorded 753.6 kg of seed yield.

Singh *et al.*, (1991), screened 49 cultivars of chickpea for their resistance to *Helicoverpa armigera*. ICCV 6 ranked first with mean seed yield of 2630 kg ha^{-1} compared to 1170 kg ha^{-1} in L 550.

Singh and Singh (1995), reported positive and significant correlation between pod borer damage and number of pods per plant, 100-grain weight and single plant yield in chickpea.

Bhatt and Patel (2001), screened the chickpea cultivars against gram pod borer. The cultivar ICCC 4 recorded lowest larval population and highest grain yield (1250 kg ha^{-1}).

Durairaj and Shanower (2003), studied the reaction of eight short duration pigeonpea genotypes against pod borer. ICPL 4 recorded lowest average percent of damage by pod borers (41.6 %) and the highest average seed yield (328.5 kg ha^{-1}). The varieties ICPL 151, ICPL 86012 and ICPL 8034 had lower damage by pod borers and has higher seed yields.

A better knowledge of inheritance of pod borer resistance in conjugation with malic acid content is very essential to develop appropriate breeding strategies for improving grain yield and host plant resistance to pod borer in chickpea (Salimath *et al.*, 2003).

2.3.1 Correlation co-efficients

Correlation coefficient is an important statistical tool for determining the association between two characters. Strong association or its absence between any two traits influences selection for combination of these characteristics.

Seed yield is a complex character. For augmenting yield, the role of component characters is well appreciated. Understanding of the inter-relationship between seed yield and its components and among the components themselves is necessary to improve seed yield. A review of literature for correlations of yield with yield contributing traits is presented hereunder.

Correlation studies in chickpea genotypes have been reported by Salimath and Bahl (1986), Mishra *et al.*, (1988), Singh *et al.*, (1989) and Chavan *et al.*, (1994) who reported significant positive correlation of seed yield with number of primary braches per plant, secondary branches per plant and pods per plant and suggested selection for these characters to improve yield.

Paliwal *et al.*, (1987) reported that seed yield per plant was positively correlated with plant height ($r = 0.47$) and recommended pods per plant and seeds per pod as selection criteria to improve seed yield.

Sindhu and Prasad (1987) and Malik *et al.*, (1988) observed that 100-seed weight, pods per plant and seeds per pod were positively correlated with seed yield in chickpea lines. Choudhury and Mian (1988) studied 13 genetically divergent chickpea lines and observed positive and significant association between number of secondary branches and plant height, seed yield and pods per plant and seed yield and 100-seed weight. Their results indicated that selection would be effective for primary branches per plant, pods per plant and 100-seed weight.

Jivani and Yadavendra (1988), Sharma and Maloo (1988), Uddin *et al.*, (1990), Rao *et al.*, (1994) and Tripathi *et al.*, (1995) observed that seed yield was positively correlated with number of branches per plant, pods per plant and 100-seed weight. They suggested that these characters could be taken as selection criteria for seed yield improvement.

Sandhu and Mandal (1989) observed that seed yield was positively correlated with primary and secondary branches per plant, pod number and seed number per plant. Seed weight was negatively correlated with seed number and seeds per pod. Sandhu *et al.*, (1989) evaluated 123 genotypes and found that grain yield was positively correlated with pods per plant, seeds per pod and secondary branches.

Yadav (1990), conducted studies on F_2 population of three chickpea crosses which indicated that seed yield was significantly and positively correlated with number of seeds per plant, number of pods per plant, number of secondary branches, 100-seed weight and plant height.

Bejiga *et al.*, (1991) studied F_2 - F_6 generations of nine crosses of chickpea and observed that seed yield per plant was positively and significantly correlated with number of primary and secondary branches, number of pods and seeds per plant and 100-seed weight. They also observed significant positive correlations between number of pods per plant and seeds per plant.

Chhina *et al.*, (1991) evaluated 14 cultivars of chickpea under rainfed conditions and obtained high positive correlations of seed yield with pods per plant.

Jahhar and Mane (1991) found grain yield to be significantly correlated with all yield components except plant height in variety PG 5 (Vishwas) of gram. Kharrat *et al.*, (1991) crossed local Spanish cultivars of the kabuli type with two ICRISAT lines (one desi and one kabuli) and found that seed yield per plant was significantly and positively correlated with pods per plant, seeds per plant and seed size. There was no correlation of seed size with seeds per plant. They suggested the use of desi-kabuli introgression for the improvement of seed yield.

Pundir *et al.*, (1991) found negative correlation between 100-seed weight and seeds per pod. Sandhu *et al.*, (1991) in two different studies on genetically diverse lines of chickpea for yield related characters found that seed yield was positively associated with seeds per pod.

Abdali (1992) worked out correlations on F_4 and F_5 generations of three chickpea crosses which revealed that grain yield was highly associated with number of pods (0.78 -0.94) and number of seeds (0.79 - 0.93). Number of pods per plant was significantly and positively correlated with number of seeds per plant.

Bouslama *et al.*, (1992) and Varghese *et al.*, (1993) reported significant positive association of seed yield with pods per plant and 100-seed weight, and considered these traits as important yield components in selection of better genotypes in chickpea. Dasgupta *et al.*, (1992) observed significant and positive correlations of seed yield with pods per plant, seeds per plant and 100-seed weight. They observed significant positive correlations between seeds per plant and seeds per pod and between pods per plant and seeds per plant in 28 genotypes of chickpea. They observed significant negative correlation between seeds per pod and 100-seed weight.

Lal *et al.*, (1993) reported in chickpea that seed yield was positively and significantly correlated with pod number and negatively correlated with 100-seed weight.

Singh and Rheenen (1994), crossed JG 62 and MS 24, evaluated them along with their F_1s, F_2s and backcross progenies. The seeds per pod were positively correlated with seed yield in segregating generations ($r = 0.18$). Deshmukh and Patil (1995) revealed that grain yield was positively correlated with pods per plant and harvest index in chickpea varieties and their F_1 hybrids.

Singh *et al.*, (1995) studied 15 chickpea F_2 and F_3 generations and reported that seed yield per plant had a significant positive correlation with pods per plant in both generations.

Mathur and Mathur (1996), showed significant positive correlations of grain yield per plant with pods per plant and 100-grain weight in 34 chickpea varieties. Ozdemir (1996) showed that the relationship between seed yield and number of pods per plant was significant and positive. Chand and Singh (1997) observed that number of pods and seeds per plant were the most important yield contributing characters in chickpea. Manjare *et al.*, (1997) reported that grain yield per plant had positive correlations with number of pods per plant, 100-seed weight and number of grains per pod.

Chapter III

Materials and Methods

CHAPTER-III
MATERIALS AND METHODS

Present studies were carried out at the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Patancheru, India (latitude 17°27'N, longitude 78°28'E and altitude is 545 m above mean sea level) during 2003-2005, to elucidate the "Genetics of resistance to pod borer, *Helicoverpa armigera* in chickpea (*Cicer arietinum*)". The materials used in conducting the experiments and the various methods employed during the course of investigation are presented below.

3.1 NATURE OF GENE ACTION AND MATERNAL EFFECTS

To understand the nature of gene action and maternal effects, nine parents (eight desi and one kabuli) based on earlier screening trials at ICRISAT were selected. Among these ICC 12475 or ICC 506, ICC 12476, ICC 12477, ICC 12478, ICC 12479 and ICCV 2 or ICC 12968 were resistant, and ICCC 37 or ICC 12426, ICC 3137 and ICC 4918 or Annigeri were susceptible (ICRISAT, Chickpea breeding). The characteristics of the genotypes are presented in Table 3. Full diallel cross (including reciprocals) was made during 2003-04 post-rainy season in the field and greenhouse (Plate 1).

3.1.1 Layout of the experiment

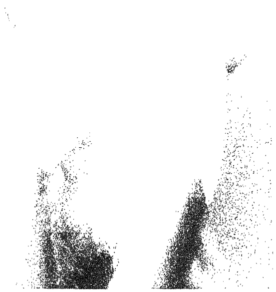
The selected parents were sown on 20th October, 2003. Second planting was done on 10th November, 2003 to synchronise the early and late flowering varieties of the first planting. Plot size was four rows of 2 m long (4 × 2 m) planted at 60 × 10 cm, row-to-row and plant-to-plant spacing respectively (Plate 2).

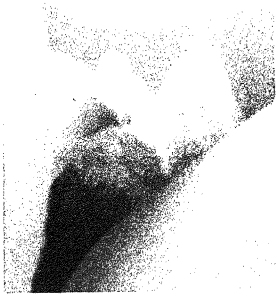
Healthy buds, that were ready to open on the same day were hand emasculated in the morning between 0830 to 1000 hrs and those expected to open the next day

Table 3 : Characteristics of the chickpea genotypes evaluated for nature of gene action and inheritance of resistance to *H. armigera* (ICRISAT, patancheru, post-rainy season, 2003-04).

Genotype	Pedigree	Days to 50 % F	Days to Maturity	Seeds pod^{-1}	100 seed Wt. (g)
DESI					
ICC 3137	P-3659-2	64.3	119.2	1.10	25.25
ICC 4918	ICC 4918	50.9	107.0	1.19	19.93
ICC 12426	ICC 12426 (P 481 X (JG X P-1630) (ICCL 80074)	54.6	102.0	1.36	19.23
ICC 12475	BEG 78	55.4	104.4	1.21	16.07
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
KABULI					
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

Plate I : Crossing chickpea genotypes in the field, ICRISAT, Patancheru, 2003-04.





A : Emasculation of chickpea flower

B : Pollination

were emasculated in the evening between 1500 to 1630 hrs (Plate 1A). Buds emasculated in morning were pollinated in the evening, while those emasculated in evening were pollinated the next day morning (Plate 1B). Different colored threads were used to differentiate the crosses. After maturity, the pods resulting from hybridisation were harvested and seeds were collected.

3.1.2 F_1 diallel experiment

During the 2004-05 post-rainy season, eighty one entries *i.e.* seventy two F_1s (36 direct crosses + 36 reciprocals) and nine parents were sown on 29th October, 2004 in completely randomized block design with 3 replications. Plot size was 2 rows of 2m long with a spacing of 60 cm between the rows and 10 cm between the plants with in a row (Plate 3).

3.1.2.1 OBSERVATIONS

3.1.2.1.1 Plant count two weeks after emergence

The total plants present in two rows were counted at two weeks after seedling emergence.

3.1.2.1.2 Tagging of the plants

Five random plants (two in one and three in another row) were tagged for observations at random.

3.1.2.1.3 Egg and larval counts

Number of eggs and larvae were counted during the vegetative (15 DAE), flowering (45 DAE) and pod formation (60 DAE) stages of the crop on 5 tagged plants at random.

3.1.2.1.4 Days to initiation of flowering/ podding

Days to initiation of flowering and days to initiation of podding were recorded on 5 tagged plants.

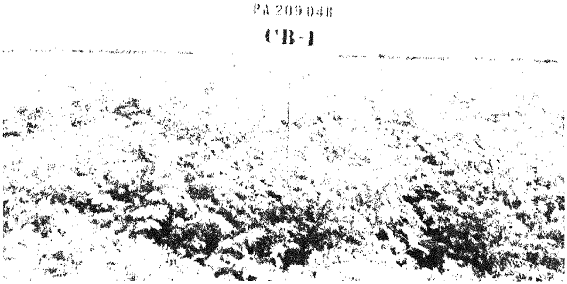


Plate 2 : Chickpea genotypes of 9 x 9 full diallel (72 F_1s + 9parents) to syudy the nature of gene action and maternal effects, ICRISAT, Patancheru, 2003-04.

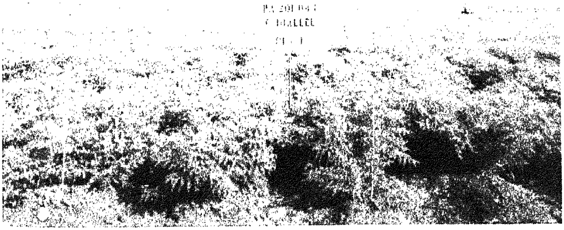


Plate 3 : Evaluation of 81 entries (72 F_1s + 9 parents) to study the nature of Gene action and inheritance of different components of resistance, ICRISAT, Patancheru, 2004-05.

3.1.2.1.5 Days to 50 per cent flowering

Number of days from sowing to 50 per cent of the plants producing their first flowers in a plot was recorded as days to 50 per cent flowering.

3.1.2.1.6 Days to maturity

Number of days from sowing to 75 per cent maturity of the pods in a plot was recorded as days to maturity.

3.1.2.1.7 Flower colour

Colour of the flowers in each plot was recorded (pink for desi and white for kabuli).

3.1.2.1.8 Insect damage scores

.1.3.8.1 Overall resistance score (ORS)

Overall resistance score due to *H. armigera* damage during the flowering stage 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 (Source : Sharma *et al.* 2005a).

3.1.3.8.2 Pod damage score (PDS)

Pod damage scores were recorded on a 1 to 9 scale before harvesting when the crop reached the maturity stage (1 = < 10 % pods damaged; 9 = > 80 % pods damaged) (Source : Sharma *et al.* 2005a and b)

3.1.2.1.9 Plant stand at harvest

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

3.1.2.1.10 Pod borer damage (%)

Pod damage by *H. armigera* larvae was quantified by expressing the number of pods bored as a percentage of the total number of pods.

3.1.2.1.11 Pods per plant.

Total number of pods were counted in five plants and expressed as number of pods per plant.

3.1.2.1.12 Seeds per plant

Total number of seeds were counted in five plants and expressed as number of seeds per plant.

3.1.2.1.13 Seeds per pod $= \dfrac{\text{Number of seeds per plant}}{\text{Number of pods per plant}}$

3.1.2.1.14 Yield per plant

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

3.1.2.1.15 Yield per plot

Seeds in a plot after threshing was sundried, weighed, and the yield of five 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.

3.1.2.1.16 Hundred seed weight

Seed weight was calculated based on seed number and hundred dry seed weight.

3.1.3 Statistical analysis

The data were subjected to analysis of variance and the nature of gene action, maternal effects, GCA, SCA variances and additive and non-additive effects were studied based on diallel analysis following the method of Griffing Method 1, model 1 (1956).

3.2 MECHANISMS AND INHERITANCE OF DIFFERENT COMPONENTS OF RESISTANCE

Nine parents (ICC 3137, ICC 12476, ICC 12477, ICC 12478, ICC 12479, ICCV 2, ICC 4918, ICC 12475 and ICCC 37) during 2003-04, and the seventy two F_1s and nine parents during the 2004-05 season were evaluated for different components of resistance *viz.*, oviposition non-preference, antibiosis and tolerance. ICC 12475 and ICCC 37 were used as resistant and susceptible checks respectively.

3.2.1 Mechanisms of resistance

3.2.1.1 Insect culture

H. armigera larvae and adults used in bio-assays, biology studies and oviposition experiments in the laboratory and for no-choice cage technique in glasshouse were obtained from a laboratory culture maintained at ICRISAT, Patancheru, India. The laboratory culture was supplemented with field collected population every six months to maintain the heterogeneity of the laboratory culture. Field-collected larvae of *H. armigera* were reared in the laboratory on the natural host for one generation before being introgressed into the laboratory culture to avoid contamination with the nuclear polyhedrosis virus, bacteria or fungi (Sharma *et al.* 2005c). The *H. armigera* culture was maintained on an artificial diet (Armes *et al.* 1992). The *H. armigera* neonates were reared in groups of 200 to 250 in 200 ml plastic cups having a 2 to 3 mm layer of artificial diet on the bottom and the sides for 5 days. After 5 days, the larvae were transferred individually to six-cell well plates (each cell well 3.5 cm in diameter, 2.0 cm in depth) to avoid cannibalism (Plate 4). Each cell well had sufficient amount of diet (7 ml) to support larval development until

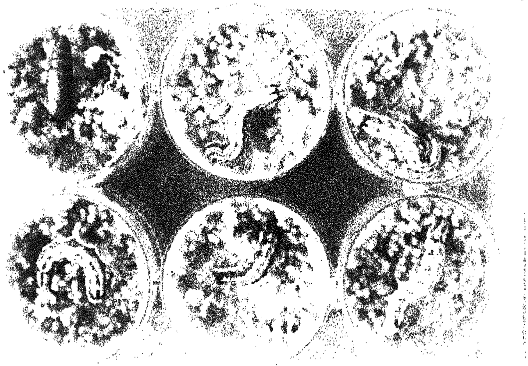
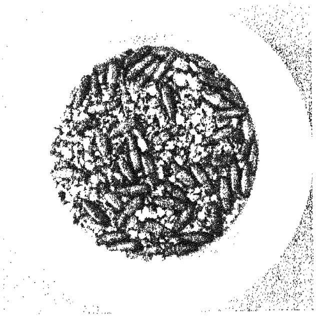


Plate 4 : Recovery of *Helicoverpa armigera* on artificial diet in the laboratory.

Plate 5 : Pupae of *Helicoverpa armigera*.



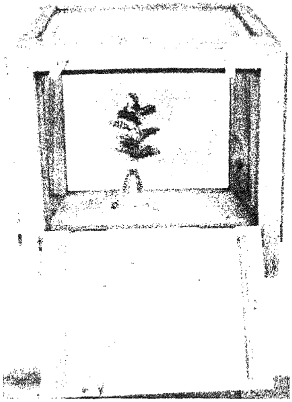
pupation. The pupae were removed from cell wells, sterilized with 2 per cent sodium hypochlorite solution for 2 min, and kept in groups of 50 in plastic jars containing vermiculite (Plate 5). Upon emergence, 10 pairs of adults were released inside an oviposition cage (30 × 30 × 30 cm). Adults were provided with 10 per cent sucrose or honey solution on a cotton swab for feeding. Diaper liners, which have a rough surface for the females to lay eggs, were hung inside the cage as an oviposition substrate. The liners were removed daily, and the eggs were sterilized for 1 min in 2 per cent sodium hypochlorite solution, dried under a table fan, and then placed inside the plastic cups with diet. After egg hatching, the larvae moved to the artificial diet, and the liners were removed after 4 days. Neonate larvae were used for bioassays and biology studies under laboratory conditions and for no-choice cage technique under greenhouse conditions.

3.2.2 Preference and non-preference

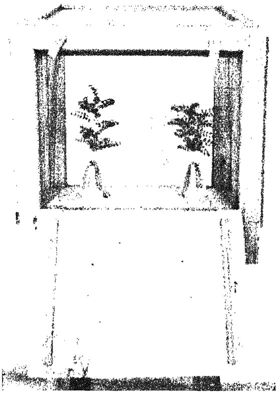
The oviposition preference of *H. armigera* moths towards different genotypes of chickpea was studied under no-choice, dual-choice and multi-choice conditions in the laboratory for parental generation, and only dual-choice test was performed for the hybrids.

For oviposition tests, fresh flowering branches (20 cm) brought from the field/ greenhouse, were placed in a conical flask (150 ml) filled with 5 per cent sugar solution and plugged with cotton wool. Three to four branches from a genotype (two straight and the other two in opposite directions) were placed in each conical flask.

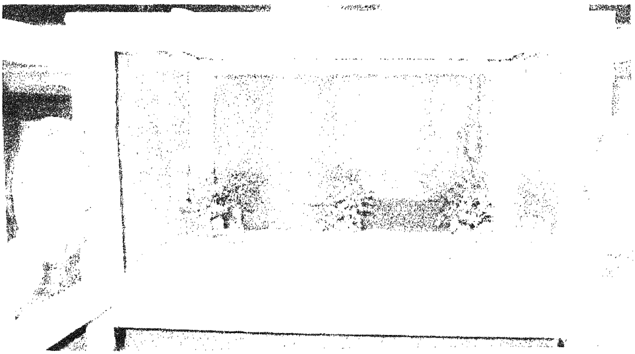
For no-choice test, a conical flask with chickpea branches from a single genotype was placed at the center of cage (Plate 6A). For dual-choice tests, two flasks one with branches of a test genotype and the other with branches from a susceptible check (ICCC 37) were placed at the opposite ends in a wooden cage of 30 × 30 × 30



A : No-choice conditions



B : Dual-choice conditions



C : Multi-choice conditions

Plate 6 : Oviposition non-preference for *Helicoverpa armigera* under cage conditions.

cm. Three sides of the cage were fitted with a glass pan, while the fourth side was covered with muslin cloth for aeration and to facilitate the release of moths inside the cage. A swab of cotton wool soaked with 10 % sucrose solution was placed in the center of each cage in a petri-dish as a feed for adults. The chickpea plant branches offered as oviposition site were replaced every alternate day, while the sucrose solution was changed every day (Plate 6B).

Three pairs of moths were released inside each cage for no-choice and dual choice tests. There were five replications in no-choice test, while the experiment was replicated 10 times in dual-choice tests. The eggs laid on chickpea branches were counted, removed gently with the help of camel hairbrush, and placed in a petridish and the branches discarded. The oviposition studies were conducted till the females continued to lay eggs.

Non-preference for oviposition under multi-choice conditions was studied by keeping all the nine test genotypes (ICC 12475 (resistant check), ICC 12476, ICC 12477, ICC 12478, ICC 12479, ICC 4918, ICCC 37 (susceptible check), ICC 3137 and ICCV2) inside a wooden cage (80 × 70 × 60 cm). Conical flasks containing chickpea branches were arranged inside the wooden cage in completely randomized block design. Ten pairs of adult moths were released inside the cage. Moths were provided with sucrose solution in a cotton swab (Plate 6C). Throughout the experiment, the moths were allowed to oviposit on the test genotypes. To avoid predation by the ants, tanglefoot ® glue was applied to all the four legs of the wooden table. The experiment was replicated three times. Relative oviposition preference (ROP) with respect to susceptible check (ICCC 37) in no-choice and multi-choice tests was calculated as follows.

$$ROP = \frac{\text{No. of eggs laid on test genotype - No. of eggs laid on susceptible check}}{\text{No. of eggs laid on the susceptible check}} \times 100$$

Per cent oviposition in dual-choice test was calculated as follows.

$$\frac{\text{No. of eggs laid on the genotype}}{\text{No. of eggs laid on the genotype + No. of eggs laid on the susceptible check}} \times 100$$

(Source : Sharma, 2005).

3.2.2.1 Statistical analysis

Number of eggs laid were transformed to square root values ($\sqrt{0.05 + x}$), and the data was subjected to general ANOVA under no-choice and multi-choice conditions. Paired "t" test was performed on the mean number of eggs laid on the test genotypes to test the null hypothesis under dual-choice conditions.

In the second season for F_1s only dual-choice test was carried out to quantify oviposition non-preference component of resistance. Seventy two crosses (36 direct + 36 reciprocals) and the nine parents were evaluated for oviposition preference in relation to the susceptible check (ICCC 37). The experiment was replicated 10 times. Data were subjected to paired t- test.

3.2.3 Antibiosis

3.2.3.1 Detached leaf assay studies

The plants grown in greenhouse were used in the bioassays conducted in the laboratory at 27 ± 2°C, 65-75 % RH and a photoperiod of 12:12 [L:D] h. Plastic cups (4.5 × 11.5 cm diameter) were used in this experiment, had a moistened filter paper attached to the lid to keep the chickpea leaves in a turgid condition. Agar-agar (3.5 %)

was boiled and poured in a slanting manner into cups with a thickness of 2.5 cm on one side of the plastic cup. The solidified agar-agar was used as a substratum for holding a chickpea branch (a terminal branch with 3 to 4 fully expanded leaves and a terminal bud) in a slanting manner inside the cup and in a turgid condition. Care was taken to see that the chickpea branches did not touch the inner walls of the cup. Ten neonate *H. armigera* larvae per replication were released on the chickpea leaves (Plate 7A).

The experiment was conducted in CRD with five replications. The experiment was repeated during three different stages of the crop. For vegetative and flowering stages ten neonate larvae per replication were released per cup, whereas at the podding stage, plastic cups of 9 × 6.5 cm were used for bioassays (Plate 8). Twigs with similar number of pods (8 to 10) were collected from the field and placed in agar-agar substratum and a third instar pre-weighed larva was released in each cup as explained above. The experiment was terminated when more than 80 per cent of the leaf area was consumed in the susceptible control or when there were maximum differences between the resistant and susceptible checks (generally at 5 to 6 days after releasing the larvae on the leaves) (Plate 7B).

$$\text{Weight gain (\%)} = \frac{\text{Final weight of the larva} - \text{Initial weight of the larva}}{\text{Initial weight of the larva}} \times 100$$

(Source : Sharma *et al.* 2005)

3.2.3.1 Observations

The test genotypes were evaluated for leaf feeding visually on 1 to 9 scale (1=, < 10 % and 9=, > 80 % leaf area/ pods damaged). The number of larvae survived after the feeding period was recorded, and larvae were placed in 25 ml plastic cups individually. The weights of larvae were recorded at 4 hours after separating them

Plate 7A : Detached leaf assay
(Before feeding)

Plate 7B : Detached leaf assay
(After feeding)

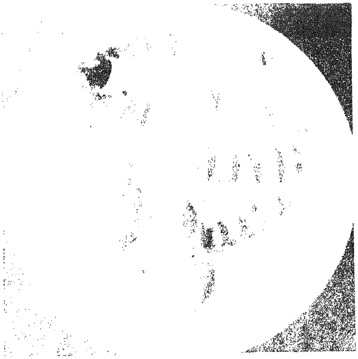


Plate 8 : Detached leaf assay at the podding stage.

from the food. The data are expressed as percentage of larval survival and mean weight of the larvae. In bioassays during podding stage, data were also recorded on number of pods subjected to infestation, number of damaged pods and weight gain by the larvae.

3.2.3.1.2 Statistical analysis

Data were subjected to analysis of variance by using GENSTAT release 5.2. The data on detached leaf assay was subjected to analysis of variance. The significance of differences between the treatments was measured by F- test at P = 0.05, whereas the treatment means were compared using the least significant difference (LSD) at P = 0.05.

In the second season (F_1s) the bioassay studies were conducted during the flowering stage. All the 81 test genotypes (72 F_1s + 9 parents) were evaluated, and there were five replications. Experimental procedure, observations recorded and statistical analysis were carried out as described above.

3.2.3.2 Relative susceptibility of chickpea genotypes to *H. armigera* under no-choice caged conditions

3.2.3.2.1 Vegetative stage

Chickpea plants were raised on a sterilized mixture of black soil (Vertisols), sand and farmyard manure (2:1:1). The soil was filled into medium sized plastic pots (30 cm in diameter, 30 cm in depth). In each pot, 12 seeds, six on one side and the another six on opposite side of the pot, were sown at 5 cm below the soil surface. The plants were watered as and when needed. Ten seedlings (five of each set) with similar growth were retained in each pot 10 days after seedling emergence. There were five pots for each genotype. The plants were raised in the greenhouse, which was cooled by desert coolers to maintain the temperature at 27 ± 5°C, and relative humidity of 65 to 90 per cent. There was no pesticide application on the test plants. These pots were used for conducting no-choice cage technique (Plate 9).

Nine genotypes (ICC 12475 (resistant check), ICC 12476, ICC 12477, ICC 12478, ICC 12479, ICC 4918, ICC 12426 (susceptible check), ICC 3137 and ICC 12968) were bioassayed in this experiment. There were five replications in a randomized block design.

Five plants in each pot were infested with 20 neonate larvae of *H. armigera* at 45 days after seedling emergence. Plants were covered with a plastic jar cage (11 cm diameter, and 26 cm in height) with two wire mesh screened windows (4 cm diameter) on the sides (Plate 10). The top of the plastic jar cage was covered with a lid fitted with the wire mesh screen to facilitate the release of larvae. Twenty neonate larvae were counted in the laboratory, placed in 25 ml plastic cups, and taken to the greenhouse for infestation. The larvae were released on the plants inside the cage, and the lower end (up to 2 cm) of the cage was pushed into the soil to avoid the escape of the larvae. Five plants outside the cage in the same pot served as un-infested control (Plate 11). The experiments were terminated, when resistant and susceptible control differences were maximum (Plates 12 and 13A, B and C).

3.2.3.2.1.1 Observations

Observations were recorded on leaf damage rating (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), larval survival and larval weight as explained above. The infested plants were allowed to recover insect injury, and raised till harvest of the crop. The plants were grown till maturity and data on number of plants survived, total yield and yield loss (%) on infested and un-infested plants were recorded to calculate the plant recovery rate.

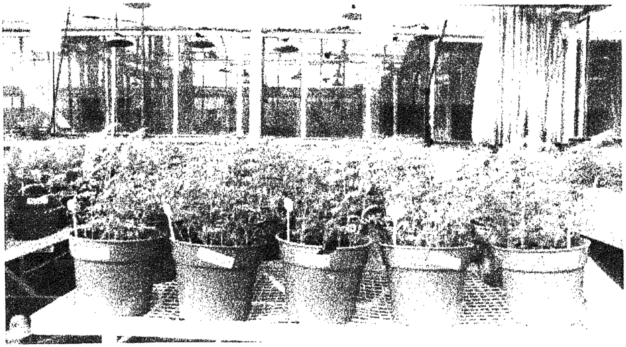


Plate 9 : Plants grown for no-choice cage screening in the green house

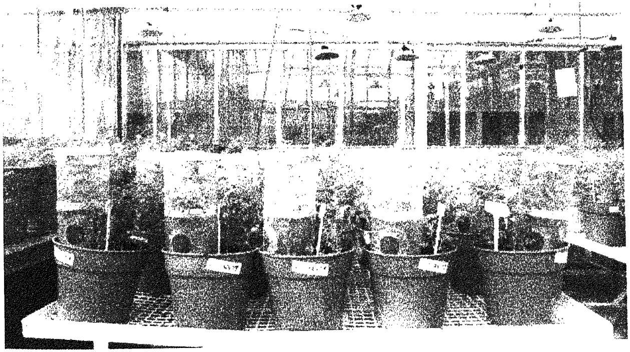
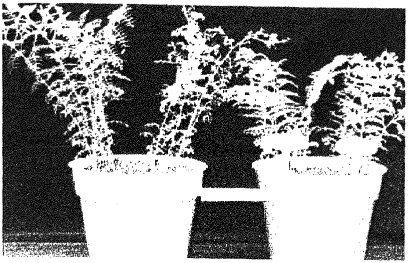


Plate 10 : No-choice cage screening for resistance to *Helicoverpa armigera* under green house conditions.

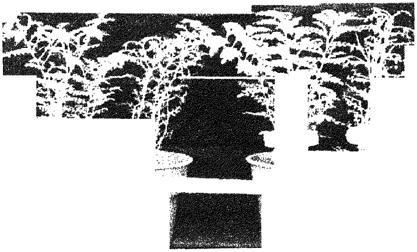
Plate 11 : Leaf feeding by *Helicoverpa armigera* on chickpea (plants to the left were infested with the larvae, while those on the right side were un-infested).

Plate 12 : Difference in leaf feeding by *Helicoverpa armigera* on the susceptible (ICC 12426/ ICCC 37) and the resistant (ICC 12475/ ICC 506) genotypes.



A : Resistant cultivars

B : Moderately resistant cultivars



C : Susceptible cultivars

Plate 13 : Different levels of resistance/susceptibility to *Helicoverpa armigera* in chickpea under no-choice cage screening.

$$\text{Yield loss (\%)} = \frac{\text{Yield in un-infested plant} - \text{yield in infested plant}}{\text{Yield in un-infested plant}} \times 100$$

3.2.3.2.2 Flowering and podding stages

The experiment was also repeated during flowering and podding stages of the crop. In this experiment, for each pot, 10 seeds were sown at 5 cm depth. Six seedlings (three of each set) with similar growth were retained. There were five replications in randomized block design.

Three plants in each pot were infested 60 days after seedling emergence at the flowering stage and 75 days after seedling emergence during the podding stage. Twenty neonate larvae per replication during the flowering stage, and six pre-weighed third- instar larvae during the podding stage were released. Observations were recorded as described above.

3.2.3.2.2.1 Statistical analysis

Data on percentage of pre-weighed larval survival and mean weight of the larvae were subjected to general ANOVA. Standard error of mean, LSD (5%) and CV% were calculated using GENSTAT release 5.2.

3.2.3.2.3 Survival and development of *H. armigera* on different chickpea genotypes

Neonate *H. armigera* larvae were fed on chickpea leaves of nine test genotypes (ICC 12475, ICC 12476, ICC 12477, ICC 12478, ICC 12479, ICC 4918, ICCC 37, ICC 3137 and ICCV2) grown in the greenhouse during the 2003-04 post-rainy season at ICRISAT, Patancheru, India up to seven days. Afterwards the larvae were held individually in plastic jars (11 cm diameter and 13 cm height) at 25°C and fed on chickpea branches with pods. Larval weights were recorded on 10th and 20th

day after release of the larvae and after pupal formation weight of the one day pupa was also recorded. The food was changed everyday. The experiment was conducted in a completely randomized design with 9 genotypes as treatments. There were five replications and each replication had 10 larvae.

Data was recorded on larval weight, larval duration, number of larvae pupated, larval survival (%), pupal weight, pupal period, pupal survival (%), adult emergence (%), sex ratio, no.of eggs laid/ female, viability of eggs (%), adult longevity, growth index, pupal index, adult index and oviposition index as follows.

3.2.3.2.3.1 Formulae

$$\text{Growth index} = \frac{\text{Per cent pupation}}{\text{Average duration of larval period}}$$

$$\text{Pupal index} = \frac{\text{Average pupal weight (mg) on test host}}{\text{Average pupal weight (mg) on standard host}}$$

$$\text{Adult index} = \frac{\text{Average adult (male/ female) longevity on test host}}{\text{Average adult (male/ female) longevity on standard host}}$$

$$\text{Oviposition index} = \frac{\text{Average number of eggs laid on test host}}{\text{Average number of eggs laid on standard host}}$$

(Source : Dubey *et al.* 1981)

3.2.3.2.3.2 Statistical analysis

The data were subjected to Duncan's new multiple range test (DMRT) and pair wise comparisons to know the significance of differences among the genotypes tested.

3.2.3.2.4 Survival and development of *H. armigera* on artificial diet impregnated with leaves and pods of different chickpea genotypes

3.2.3.2.4.1 Artificial diet for *H.armigera*

To raise the *H armigera* culture in the laboratory, 75 g 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 an electronic balance and were poured into a hand held mixer. One 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 (3.5 x 5 cm) and allowed to cool in a laminar airflow cabinet.

To study the antibiosis component of resistance, 20 g of freeze dried powder of leaves and pods of chickpea was impregnated into the artificial diet along with 55 g of chickpea flour, described in section 3.2.1.1. Chickpea branches with tender, green leaves (30 DAS) and tender green pods (60 DAS) with developing seeds were collected from pesticide-free plots. The leaves and pods were frozen at -20°C and lyophilized (Plate 14). The freeze dried leaves and pods were powdered in a blender to get fine powder (< 80 mesh). There were three replications each with 10 neonate larvae per treatment.

Data was recorded on larval weight, larval duration, number of larvae pupated, pupal weight, pupal period, adult emergence, sex ratio, number of eggs laid/ female, viability of eggs (%), adult longevity, growth index, adult index and oviposition index. Experimental procedure, observations and statistical analysis were same as explained above (Plate 15).

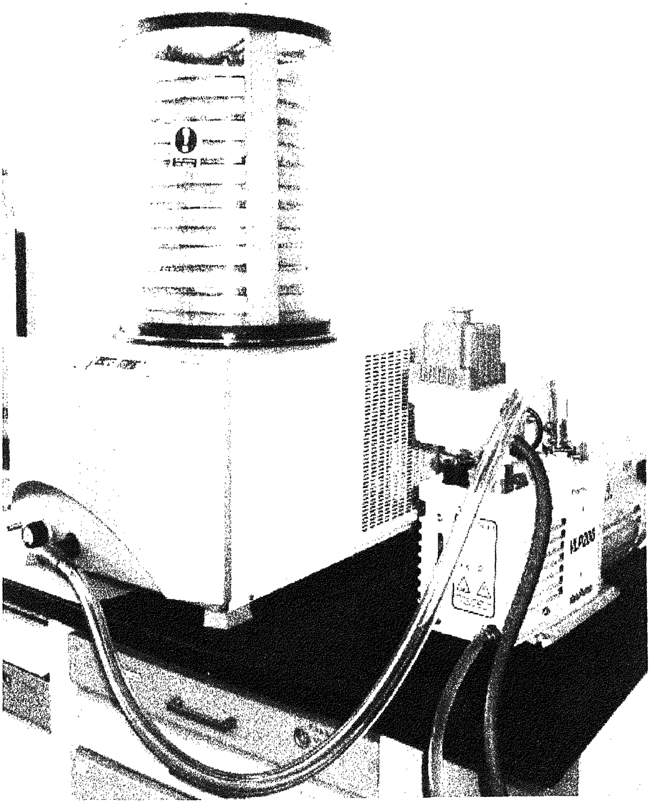


Plate 14 : Lyophiliser used for freeze drying of the samples for use in diet impregnation assay.

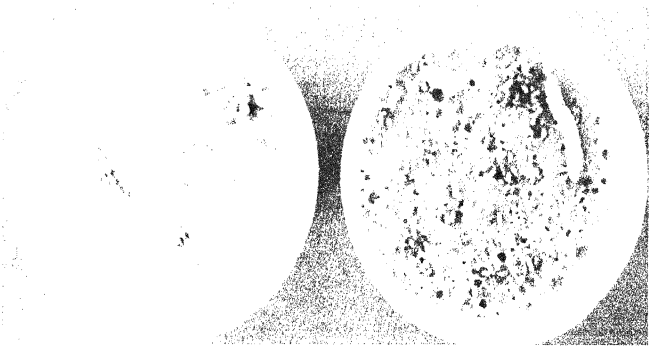


Plate 15 : Difference in larval growth on Standard diet (L) and Diet impregnated with lyophilised leaf powder (R).

In the second season, leaf samples were collected from all the 81 treatments (72 F_1s + 9 parents). The samples were freeze dried in a lyophilizer and were powdered. Artificial diet was prepared by using 20 g of lyophilized leaf powder along with 55 g of chickpea flour.

For 72 F_1s a portion of artificial diet of each treatment was poured into three plastic cups of 4.5 × 11.5 cm and the remaining was kept in the refrigerator for further use. Ten neonate larvae were released in each cup and allowed to grow for 7days. The surviving larvae were placed singly into 25 ml plastic cups and the unit weight of the larva was recorded. Ten fully grown larvae per treatment were reared individually using the remaining artificial diet to avoid the laborious experimentation. Larval weight was recorded on 10^{th} day after release and the experimental procedure, observations and statistical analysis were carried out as above.

For the nine parents the experiment was conducted with three replications, and each with 10 larvae, and all the observations were recorded as above.

3.2.5.4 Estimation of acid exudates in leaves through High Performance Liquid Chromatography (HPLC)

Chickpea plants (9 parents and 72 F_1s) grown in the greenhouse were used for acid exudates collection. Plastic vials of 12 × 1.5 cm were used for collecting the acid exudates. The weight of the vial along with 5 ml of distilled water was recorded (W_1), and then ten first fully expanded leaflets were collected for each genotype at the flowering stage (45 DAE) and placed in plastic vials (Modified form of Yoshida *et al.* 1997). Then weight of the vial + leaves was recorded (W_2). The fresh weight of the leaves was computed by substracting W_1 from W_2. The contents were vortexed thoroughly and centrifuged for 5 min at 4000 rpm. The leaves were taken out from each vial separately on a filter paper and were arranged on a transparent sheet and the leaf area was measured with a leaf area meter (LI-COR MODEL 3100). The leaf samples were dried at 55^{0}C for 3 days and the dry weight of the leaves was recorded. The water extracted chemicals in the supernatant were filtered through 0.45 μ pore size Millipore filter. Two ml of extract was taken into screw top vial (12 × 32 mm) with an injection needle. These contents were sonicated for 10 min for dissolving the solutes and degassing of solvents, and used for HPLC analysis.

3.2.5.4.1 Description of the instrument

The high performance liquid chromatography system consisted of a PCM 11 reciprocating piston pump. The detection was performed with a Waters 2996 photodiode array detector working in the range of 190 to 800 nm. It consists of Waters 2695 separations module, alliance Atlantis column with dC_{18} 5 μm pore size and 46 × 250 mm column. The chromatographic data were recorded and processed by the Millennium^{32} software version 4.0. Analysis were carried out at 22^{0}C (Plate 16).

3.2.5.4.2 Solvents

Mobile phase consisted of 25 mM KH_2PO_4 pH 2.5, and 6.805 gm, H_3PO_4 Potassium phosphate was mixed in 2 lit of distilled water.

Flow rate	0.8 ml/ min
Run time	20 min/ sample
Analysis	Organic acids
Injected sample volume	20 μl

3.2.5.4.3 Statistical analysis

3.2.5.4.4 Analysis of variance

Analysis of variance was done for each parameter separately. The significance of differences between the genotypes was tested by F-test and the treatment means were compared using LSD (least significant difference).

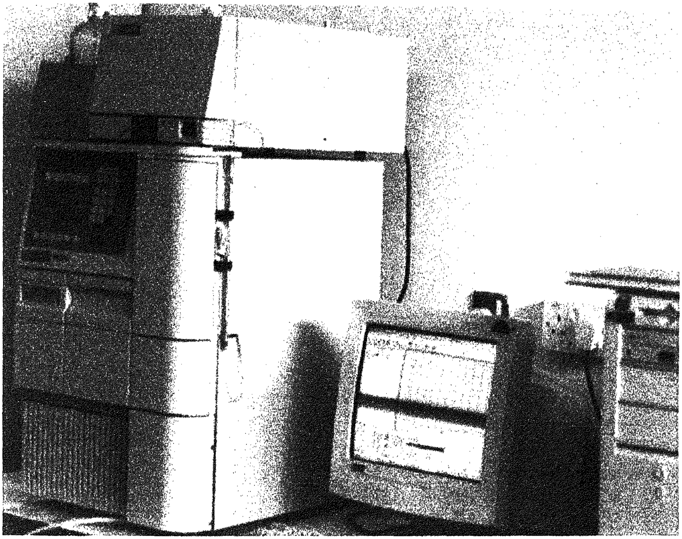


Plate 16 : High performance liquid chromatography used for estimate of organic acids on leaf surface of different genotypes.

3.2.5.4.5 Significance of correlation coefficient

The significance of correlation coefficients was tested by comparing the observed values of correlation coefficients with that of the table values of correlation coefficients for (n-2) degrees of freedom.

$$t = \frac{r\sqrt{n-2}}{\sqrt{1-r^2}}$$

where r is the estimate obtained from n pairs and compared to the standard 't' value at 5 % and 1 % levels of significance.

3.2.5.4.6 Similarity co-efficient

Similarity co-efficient among the nine parents and their 72 F_1 hybrids was performed by using similarity matrix.

3.2.4 Tolerance

To study the tolerance component of resistance in chickpea to pod borer, *H. armigera* field experiments were conducted at ICRISAT, Patancheru, during 2003-04 and 2004-05 post-rainy seasons. The loss in yield of nine chickpea genotypes (ICC 12475, ICC 12476, ICC 12477, ICC 12478, ICC 12479, ICC 4918, ICCC 37, ICC 3137 and ICCV 2) was studied by comparing the grain yield under protected and unprotected condition (Plates 17 and 18). Trial was conducted with three replications in a randomized block design. Plot size was four rows of 2 m long (4 × 2 m), planted at 60 × 10 cm row-to-row and plant-to-plant spacing.

To avoid damage from *H. armigera,* the protected plots received insecticide application as and when needed (Tables 4 and 5). Egg and larval counts were recorded on 10-tagged plants in the middle two rows 1 day before, and 1 day after spraying in the protected plots.

Table 4 : Spray schedule in protected plots for *H. armigera* tolerance studies (ICRISAT, Patancheru, 2003-04).

Age of the crop	Name of the chemical	Dose ha^{-1} (kg)	Quantity of the chemical used (g)	Area of the crop (ha)
20 DAS	Acephate + Sandovit	1.000	100	0.03
43 DAS	Acephate + Sandovit	1.000	100	0.03
55 DAS	Acephate + Sandovit	1.000	200	0.03
61 DAS	Acephate + Sandovit	1.000	300	0.03
68 DAS	Acephate + Sandovit	0.750	200	0.03
89 DAS	Acephate + Sandovit	1.000	300	0.03
99 DAS	Acephate + Sandovit	1.000	300	0.03

Table 5 : Spray schedule in protected plots for *H. armigera* tolerance studies (ICRISAT, Patancheru, 2004-05).

Age of the crop	Name of the chemical	Dose ha^{-1} (kg)	Quantity of the chemical used (g)	Area of the crop (ha)
25 DAS	Acephate + Sandovit	1.000	100	0.03
39 DAS	Acephate	1.000	100	0.03
60 DAS	Acephate	1.000	200	0.03
76 DAS	Acephate	1.000	200	0.03
89 DAS	Acephate	1.000	300	0.03
115 DAS	Acephate + Sandovit	0.750	200	0.03

Sandovit was used as surfactant @ 1ml/lit

Plate 17 : Tolerance of chickpea genotypes to *Helicoverpa armigera* under protected conditions, ICRISAT, Patancheru, 2003-05.

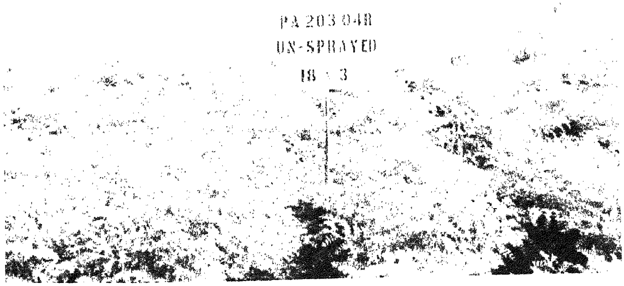


Plate 18 : Tolerance of chickpea genotypes to *Helicoverpa armigera* under Un-protected conditions, ICRISAT Patanmcheru. 2003-05.

The egg and larval counts were taken during the vegetative stage and continued at weekly intervals until harvest of the crop. Data were recorded for pod damage (%), days to 50 per cent flowering, days to maturity, yield per plant, 100 seed weight, pods per plant, seeds per plant and seeds per pod on ten tagged plants in the middle two rows. Seed yield per plot was recorded after harvest. Loss in grain yield due to *H. armigera* damage was calculated by using the following formula.

$$\text{Loss in grain yield} = \frac{\text{Yield in protected plot} - \text{Yield in unprotected plot}}{\text{Yield in protected plot}} \times 100$$

Source: (Taneja and Nawanze, 1989)

3.3 INTERACTION OF DIFFERENT COMPONENTS OF RESISTANCE AND GRAIN YIELD

To study the interaction of different components of resistance, insect damage score was given on the basis of 1-9 scale (section : 3.1.2.1.8) at the flowering stage and just before maturity of the crop. The egg and larval counts were taken during vegetative stage, flowering and podding stages. Data on healthy pods, bored pods, number of seeds/ plant, number of pods/ plant, pod damage (%), 100-seed weight, seeds per pod, yield per plant, yield (kg ha^{-1}) and seed yield per plot was recorded after the harvest of the crop.

3.3.1 Statistical analysis

Correlation studies were computed between the yield, borer damage (%), pod damage score, insect damage score, number of eggs and larvae as dependent variable and insect as independent variable.

Chapter IV

Results

CHAPTER IV

RESULTS

The studies on "Genetics of resistance to pod borer, *Helicoverpa armigera* in chickpea (*Cicer arietinum*)" were conducted at the International Crops Research Institute for Semi-Arid Tropics (ICRISAT), Patancheru, Andhra Pradesh, India. The experiments were carried out during the 2003/04 and 2004/05 post-rainy seasons. The results of the experiments conducted in the laboratory, glasshouse and field conditions are presented in this chapter.

4.1. NATURE OF GENE ACTION AND MATERNAL EFFECTS

The nature of gene action in chickpea was studied under field conditions at ICRISAT, Patancheru, 2004-05 post rainy season and the results were presented hereunder.

It is evident from the tables that the analysis of variance indicated significant differences among the parents and crosses for all the characters studied (Table 6).

4.1.1 Mean performance of parents

4.1.1.1 Days to initiation of flowering

First flowers were observed in ICCV 2 (34.3 days), while Annigeri (37.3 days), ICCC 37 (40.0 days), ICC 12478 (46.7 days), ICC 12477 (47.3 days) and ICC 506 (48.3 days) were the medium duration varieties. Days to initiation of flowering was longest in ICC 12479 (53.3 days), ICC 12476 (63 days) and ICC 3137 (65.3 days).

Table 6 : Characteristics of F_1s, 9 x 9 full diallel for *H. armigera* resistance, ICRISAT, Patancheru, post-rainy season, 2004-05.

	Days to Initial flowering	Days to 50% flowering	Days to maturity	Insect damage score		Flower colour
				At flowering	At maturity	
Parents						
ICC 506 ®	48.3	55.7	108.0	2.5	3.2	pink
ICC 12476	63.0	73.0	112.3	1.3	2.3	pink
ICC 12477	47.3	60.3	107.0	4.5	3.2	pink
ICC 12478	46.7	57.3	107.3	2.0	3.0	pink
ICC 12479	53.3	71.0	109.7	1.0	2.2	pink
ICC 3137	65.3	76.0	115.7	4.8	6.3	light pink
Annigeri	37.3	53.7	107.0	3.8	4.2	pink
ICCC 37 (S)	40.0	59.3	107.3	2.7	3.7	pink
ICCV 2	34.3	36.0	102.0	4.7	4.2	white
F_1s						
ICC 12476 X ICC 506	57.7	62.7	109.7	1.3	2.8	pink
ICC 12476 X ICC 12477	57.7	64.3	108.0	2.8	3.2	pink
ICC 12476 X ICC 12478	61.7	65.7	109.3	1.8	3.0	pink
ICC 12476 X ICC 12479	60.0	65.3	109.0	2.0	3.5	pink
ICC 12476 X ICC 4918	50.7	61.7	108.3	2.0	2.8	pink
ICC 12476 X ICC 3137	48.3	64.0	112.3	3.0	3.7	light pink
ICC 12476 X ICCV 2	49.0	58.7	108.0	3.0	2.8	light pink
ICC 12476 X ICCC 37	56.7	64.7	109.7	1.7	2.7	pink
ICC 12477 X ICC 506	55.0	59.0	108.5	3.0	3.0	pink
ICC 12477 X ICC 12476	56.7	65.7	109.3	2.2	2.5	pink
ICC 12477 X ICC 12478	51.3	59.3	107.7	2.2	3.0	pink
ICC 12477 X ICC 12479	58.0	63.7	107.3	4.5	3.2	pink
ICC 12477 X ICC 4918	53.7	59.0	107.0	2.5	2.5	pink
ICC 12477 X ICC 3137	45.3	63.0	109.7	3.8	3.5	light pink
ICC 12477 X ICCV 2	46.3	57.0	109.0	1.8	3.0	light pink
ICC 12477 X ICCC 37	51.3	59.0	106.7	1.7	2.8	pink
ICC 12478 X ICC 506	40.7	58.0	107.7	1.7	2.7	pink
ICC 12478 X ICC 12476	55.0	64.0	108.7	2.3	2.5	pink
ICC 12478 X ICC 12477	51.0	58.3	108.7	3.5	3.3	pink

Contd----

Contd---- table 6

F_1s	Days to Initial flowering	Days to 50% flowering	Days to maturity	Insect damage score		Flower colour
				At flowering	At maturity	
ICC 12478 X ICC 12479	49.3	62.3	107.3	2.7	3.5	pink
ICC 12478 X ICC 4918	47.7	54.7	107.0	1.8	3.0	pink
ICC 12478 X ICC 3137	40.3	64.3	110.7	2.5	3.3	light pink
ICC 12478 X ICCV 2	44.0	59.7	110.7	2.2	3.2	light pink
ICC 12478 X ICCC 37	41.7	56.7	107.0	3.0	3.0	pink
ICC 12479 X ICC 506	53.3	60.0	108.3	1.0	2.3	pink
ICC 12479 X ICC 12476	57.7	64.0	108.7	1.5	2.8	pink
ICC 12479 X ICC 12477	53.3	59.0	107.0	1.7	2.3	pink
ICC 12479 X ICC 12478	48.7	61.7	107.0	1.8	3.0	pink
ICC 12479 X ICC 4918	45.3	57.3	107.3	2.0	3.0	pink
ICC 12479 X ICC 3137	46.7	61.0	111.3	3.8	3.3	light pink
ICC 12479 X ICCV 2	42.7	53.3	106.0	2.2	3.2	light pink
ICC 12479 X ICCC 37	43.7	58.0	107.0	2.7	3.7	pink
ICC 506 X ICC 12476	51.0	60.7	107.3	2.8	4.0	pink
ICC 506 X ICC 12477	48.0	57.3	107.3	3.5	4.7	pink
ICC 506 X ICC 12478	46.3	56.0	107.0	1.7	3.2	pink
ICC 506 X ICC 12479	53.0	58.3	107.3	1.8	2.8	pink
ICC 506 X ICC 4918	40.7	55.0	109.3	1.7	2.7	pink
ICC 506 X ICC 3137	47.0	57.3	107.3	2.3	3.2	light pink
ICC 506 X ICCV 2	39.0	54.3	106.7	1.5	2.7	pink
ICC 506 X ICCC 37	50.3	58.0	110.0	2.0	2.5	light pink
ICC 3137 X 506	49.3	67.7	113.7	3.2	3.7	light pink
ICC 3137 X ICC 12476	52.0	66.0	114.0	3.7	4.0	light pink
ICC 3137 X ICC 12477	49.0	64.7	113.3	3.3	3.5	light pink
ICC 3137 X ICC 12478	38.7	64.7	114.0	3.3	4.2	light pink
ICC 3137 X ICC 12479	51.0	65.0	114.0	3.2	3.7	light pink
ICC 3137 X ICC 4918	38.7	63.3	111.7	4.3	4.5	light pink
ICC 3137 X ICCV 2	57.0	65.3	113.0	3.7	4.7	light pink
ICC 3137 X ICCC 37	37.3	57.3	111.3	3.7	3.8	light pink
ICCC 37 X ICC 506	43.3	55.3	108.0	1.8	3.3	pink
ICCC 37 X ICC 12476	45.3	66.3	109.7	1.7	3.2	pink
ICCC 37 X ICC 12477	46.3	54.3	106.0	2.2	3.3	pink

Contd----

Contd---- table 6

F_1s	Days to Initial flowering	Days to 50% flowering	Days to maturity	Insect damage score At flowering	Insect damage score At maturity	Flower colour
ICCC 37 X ICC 12478	48.3	57.3	109.0	2.3	3.2	pink
ICCC 37 X ICC 12479	47.0	56.0	106.7	2.2	3.3	pink
ICCC 37 X ICC 4918	38.7	53.7	106.7	3.0	2.7	pink
ICCC 37 X ICC 3137	42.7	65.0	114.0	3.8	4.3	light pink
ICCC 37 X ICCV 2	35.0	49.0	105.0	2.7	3.7	light pink
ICC 4918 X ICC 506	37.7	57.3	109.0	2.5	3.7	pink
ICC 4918 X ICC 12476	42.0	60.0	107.3	2.5	3.2	pink
ICC 4918 X ICC 12477	36.7	59.3	106.0	2.7	3.5	pink
ICC 4918 X ICC 12478	43.3	59.7	108.3	2.8	3.0	pink
ICC 4918 X ICC 12479	43.7	58.0	107.7	2.8	3.0	pink
ICC 4918 X ICC 3137	38.7	59.7	111.3	2.3	3.8	light pink
ICC 4918 X ICCV 2	38.3	55.7	108.0	2.8	3.8	pink
ICC 4918 X ICCC 37	37.7	51.7	105.7	3.3	4.0	light pink
ICCV 2 X ICC 506	43.3	53.7	106.0	2.2	3.2	light pink
ICCV 2 X ICC 12476	39.7	52.7	105.7	2.3	3.3	light pink
ICCV 2 X ICC 12477	37.3	49.7	105.3	3.0	3.3	light pink
ICCV 2 X ICC 12478	34.7	51.0	106.0	3.0	3.8	light pink
ICCV 2 X ICC 12479	37.0	53.3	105.7	3.0	3.3	light pink
ICCV 2 X ICC 4918	35.0	49.7	105.0	3.5	3.5	light pink
ICCV 2 X ICC 3137	34.3	46.3	104.0	4.2	4.0	light pink
ICCV 2 X ICCC 37	35.3	46.7	104.5	4.2	4.3	light pink
Mean						
Parents	48.4	60.3	108.5	3.0	3.6	
F_1s	46.3	58.9	108.4	2.6	3.3	
Fp	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	
SE	3.45	1.71	1.2	0.558	0.437	
LSD (5%)	9.65	4.78	3.350	1.56	1.22	
CV (%)	12.9	5.0	1.9	36.4	22.7	

R= Resistant check; S= Susceptible check.

4.1.1.2 Days to 50 % flowering

The parent ICCV 2 (36 days) was the earliest to flower followed by Annigeri (53.7 days), ICC 506 (55.7 days), ICC 12478 (57.3 days), ICCC 37 (59.3 days) and ICC 12477 (60.3 days). While ICC 12479 (71 days), ICC 12476 (73.0 days) and ICC 3137 (76 days) were late to flower.

4.1.1.3 Days to maturity

ICCV 2 (102 days) was the earliest to mature followed by Annigeri (107 days), ICC 12477 (107 days), ICCC 37 (107.3 days) and ICC 12478 (107.3 days). ICC 3137 (115.7 days) and ICC 12476 (112.3 days) were late to mature with an average maturity of 108.5 days.

4.1.1.4 Flower colour

Generally for desi varieties, the flower colour was pink except in ICC 3137, where the colour of the flowers was light pink. The only one kabuli parent i.e. ICCV 2 the flower colour was white.

4.1.2 Yield contributing characteristics

4.1.2.1 Seeds per plant

Significantly highest number of seeds per plant was recorded in ICC 12477 (147 seeds plant^{-1}) followed by ICC 12478 (132 seeds plant^{-1}), while ICC 3137 recorded lowest number of seeds (34 seeds plant^{-1}), with an overall mean of 97 seeds plant^{-1} (Table 7).

4.1.2.2 Number of pods per plant

The genotypes ICC 12477 and ICC 12478 recorded highest number of pods per plant (143 and 131 pods plant^{-1}), while the least number of pods was recorded in ICC 3137 (49 pods plant^{-1}). Every plant recorded on an average of 97 pods.

4.1.2.3 Seeds per pod

The number of seeds per pod ranged between 0.71 (ICC 3137) to 1.11 (ICCC 37). Each pod recorded an average of 1.02 seeds.

4.1.2.4 100-seed weight

The 100- seed weight was highest in ICC 3137 (26.09 g), followed by ICCV 2 (22.68 g), ICCC 37 (19.24 g) and Annigeri (18.59 g). While ICC 12477 (11.22 g) had least 100-seed weight with an average of 17.19 g.

4.1.2.5 Pod borer damage (%)

The genotype ICC 12478 suffered significantly lowest pod borer damage (3.65 %) followed by ICC 506 (6.72 %), ICC 12479 (7.14 %) and ICC 12477 (7.33 %). The highest pod borer damage was observed in genotype ICC 3137 (34.06 %), with an overall average of 11.53 %.

4.1.2.6 Seed yield per plant

The seed yield per plant ranged from 20.14 g (Annigeri) to 8.87 g (ICC 3137), with a mean yield of 15.52 g.

4.1.2.7 Total plot yield

The highest plot yield was observed on the genotype ICCC 37 (666.2 g) followed by ICC 12479 (560.8 g), ICC 12476 (538.4 g) and ICC 3137 (503.5 g). Lowest total plot yield of 284.4 g was observed in ICC 12477, with an average of 456.8 g.

4.1.2.8 Yield (kg ha^{-1})

Significantly highest yield was recorded in ICCC 37 (5552 kg ha^{-1}) followed by ICC 12479 (4674 kg ha^{-1}), ICC 12476 (4486 kg ha^{-1}) and ICC 3137 (4196 kg ha^{-1}), while lowest yield was recorded in ICC 12477 (2370 kg ha^{-1}). The overall mean was 3807 kg ha^{-1}.

Table 7 : *Yield components of 81 chickpea crosses under natural infestation conditions to H. armigera*, ICRISAT, Patancheru, post-rainy season 2004-05.

	Seeds/ plant	Total pods/ plant	Seeds/ pod	100 seed weight (g)	Pod borer damage (%)	Yield/ plant	Total plot yield (g)	Yield (kg/ha)
parents								
ICC 12476	99	102	0.96	14.76	11.18	14.58	538.4	4486
ICC 12477	147	143	1.04	11.22	7.33	16.42	284.4	2370
ICC 12478	132	131	1.01	13.36	3.65	17.53	419.0	3492
ICC 12479	79	79	1.00	14.33	7.14	11.35	560.8	4674
ICC 3137	34	49	0.71	26.09	34.06	8.87	503.5	4196
ICC 4918	109	104	1.03	18.59	11.76	20.14	444.6	3705
ICC 506 ®	101	100	1.02	14.47	6.72	14.62	338.7	2822
ICCC 37 (S)	93	84	1.11	19.24	12.87	17.78	666.2	5552
ICCV 2	81	79	0.99	22.68	9.03	18.42	355.9	2965
F_1s								
ICC 12476 X ICC 12477	119	115	1.05	12.74	6.47	15.29	292.7	2439
ICC 12476 X ICC 12478	140	141	0.99	13.94	8.03	19.66	361.1	3009
ICC 12476 X ICC 12479	126	124	1.04	13.91	6.12	17.41	419.9	3499
ICC 12476 X ICC 3137	88	86	1.03	18.57	10.31	16.37	527.9	4399
ICC 12476 X ICC 4918	119	105	1.13	17.09	9.76	20.14	449.7	3747
ICC 12476 X ICC 506	126	119	1.08	14.85	7.44	18.87	361.6	3013
ICC 12476 X ICCC 37	153	121	1.30	15.48	10.56	23.82	452.9	3774
ICC 12476 X ICCV 2	112	105	1.09	15.42	6.59	17.84	356.7	2973
ICC 12477 X ICC 12476	130	129	1.05	10.89	11.57	14.53	524.1	4367
ICC 12477 X ICC 12478	152	154	0.99	12.70	6.70	19.24	265.9	2216
ICC 12477 X ICC 12479	127	119	1.08	9.80	8.03	12.28	468.9	3907
ICC 12477 X ICC 3137	126	146	0.88	15.72	17.79	20.25	393.1	3276
ICC 12477 X ICC 4918	195	181	1.08	13.81	5.05	26.62	487.7	4064
ICC 12477 X ICC 506	205	193	1.06	12.15	4.62	25.22	617.2	5143
ICC 12477 X ICCC 37	161	147	1.09	15.36	9.30	24.68	522.4	4354
ICC 12477 X ICCV 2	99	99	1.00	15.31	6.16	15.10	398.5	3321
ICC 12478 X ICC 12476	97	95	1.24	14.00	10.86	13.42	508.8	4240
ICC 12478 X ICC 12477	134	130	1.04	12.62	3.69	17.16	551.8	4598
ICC 12478 X ICC 12479	139	141	0.99	14.18	5.51	19.86	445.6	3714

Contd----

Contd---- table 7

F_1s	Seeds/ plant	Total pods/ plant	Seeds/ pod	100 seed weight (g)	Pod borer damage (%)	Yield/ plant	Total plot yield (g)	Yield (kg/ha)
ICC 12478 X ICC 3137	86	94	0.91	19.21	14.58	16.39	508.7	4240
ICC 12478 X ICC 4918	114	107	1.05	16.26	6.14	18.37	452.5	3771
ICC 12478 X ICC 506	129	127	1.02	14.74	1.30	18.94	526.7	4389
ICC 12478 X ICCC 37	104	97	1.06	16.80	6.41	17.67	403.5	3363
ICC 12478 X ICCV 2	104	105	0.99	17.50	5.73	18.09	471.2	3927
ICC 12479 X ICC 12476	111	110	1.03	12.90	6.53	14.22	586.3	4886
ICC 12479 X ICC 12477	128	126	1.02	12.09	3.22	15.48	413.7	3448
ICC 12479 X ICC 12478	141	144	0.98	13.91	5.34	19.62	525.7	4381
ICC 12479 X ICC 3137	97	106	0.92	17.73	10.46	16.95	553.8	4615
ICC 12479 X ICC 4918	105	99	1.07	16.17	5.18	16.88	358.3	2986
ICC 12479 X ICC 506	128	132	1.01	14.50	3.79	18.67	365.9	3049
ICC 12479 X ICCC 37	116	100	1.16	16.01	5.83	18.77	619.3	5161
ICC 12479 X ICCV 2	97	96	1.01	16.68	3.66	15.89	555.1	4626
ICC 3137 X ICC 506	134	139	0.97	19.73	7.97	26.28	501.7	4181
ICC 3137 X ICC 12476	100	104	0.96	20.60	15.20	20.51	576.3	4802
ICC 3137 X ICC 12477	103	113	0.92	18.91	13.03	18.72	433.0	3608
ICC 3137 X ICC 12478	94	106	0.86	20.84	14.80	18.83	467.1	3893
ICC 3137 X ICC 12479	95	101	0.93	19.74	9.47	18.52	410.5	3421
ICC 3137 X ICC 4918	95	115	0.81	24.94	22.59	22.98	356.3	2969
ICC 3137 X ICCC 37	60	71	0.84	22.03	19.26	12.84	462.3	3853
ICC 3137 X ICCV 2	98	101	0.95	22.54	13.61	21.97	442.4	3687
ICC 4918 X ICC 12476	149	130	1.14	16.98	9.65	24.91	395.5	3296
ICC 4918 X ICC 12477	143	129	1.10	15.35	7.29	21.61	374.2	3118
ICC 4918 X ICC 12478	109	110	0.98	18.22	8.72	19.77	526.6	4389
ICC 4918 X ICC 12479	112	114	0.99	17.68	12.32	19.68	472.4	3937
ICC 4918 X ICC 3137	112	119	0.95	21.68	17.31	24.43	544.5	4538
ICC 4918 X ICC 506	129	120	1.07	17.47	6.92	22.14	548.3	4569
ICC 4918 X ICCC 37	80	80	1.00	19.96	9.01	15.79	504.4	4203
ICC 4918 X ICCV 2	120	113	1.05	19.83	11.07	23.47	510.6	4255
ICC 506 X ICC 12476	93	94	1.00	13.19	8.79	12.79	512.2	4269
ICC 506 X ICC 12477	106	101	1.05	13.01	4.24	13.86	561.0	4675
ICC 506 X ICC 12478	97	98	1.00	16.71	4.81	17.38	554.0	4617

Contd----

Contd---- table 7

F_1s	Seeds/ plant	Total pods/ plant	Seeds/ pod	100 seed weight (g)	Pod borer damage (%)	Yield/ plant	Total plot yield (g)	Yield (kg/ha)
ICC 506 X ICC 12479	121	117	1.04	14.00	3.80	17.37	588.9	4907
ICC 506 X ICC 3137	81	86	0.93	18.99	8.91	15.07	438.3	3652
ICC 506 X ICC 4918	113	105	1.08	17.83	5.35	20.01	447.7	3731
ICC 506 X ICCC 37	82	78	1.06	16.83	3.85	13.56	419.2	3493
ICC 506 X ICCV 2	104	92	1.13	18.38	5.23	19.16	491.2	4094
ICCC 37 X ICC 12476	115	98	1.18	17.61	10.72	20.58	539.9	4499
ICCC 37 X ICC 12477	148	138	1.07	16.74	12.32	24.57	492.2	4101
ICCC 37 X ICC 12478	97	92	1.06	18.73	14.69	17.98	457.9	3816
ICCC 37 X ICC 12479	92	79	1.16	16.49	5.79	15.03	474.4	3954
ICCC 37 X ICC 3137	98	103	0.95	23.04	15.37	22.75	453.1	3776
ICCC 37 X ICC 4918	109	102	1.08	19.21	9.45	21.10	466.5	3887
ICCC 37 X ICC 506	147	138	1.07	19.20	9.36	28.14	530.8	4423
ICCC 37 X ICCV 2	86	79	1.07	21.00	8.63	17.56	451.9	3766
ICCV 2 X ICC 12476	132	129	1.03	18.94	4.66	25.76	483.2	4026
ICCV 2 X ICC 12477	124	116	1.08	16.24	7.24	19.15	286.6	2388
ICCV 2 X ICC 12478	111	111	1.00	17.69	4.76	19.36	454.9	3791
ICCV 2 X ICC 12479	108	108	1.00	16.73	4.23	17.99	434.2	3618
ICCV 2 X ICC 3137	106	105	1.01	21.90	6.69	22.91	173.9	1449
ICCV 2 X ICC 4918	86	92	0.93	22.16	9.79	18.93	594.4	4953
ICCV 2 X ICC 506	120	113	1.05	17.41	5.08	20.90	431.3	3594
ICCV 2 X ICCC 37	100	99	1.02	21.02	7.79	21.36	265.1	2209
Mean	114	111	1.02	17.00	8.84	18.75	461.6	3846
Parents	97	97	0.98	17.19	11.53	15.52	456.8	3807
F_1s	116	113	1.03	16.98	8.51	19.16	462.2	3851
Fp	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
SE	14.55	14.32	0.41	0.734	2.041	2.52	55.32	461
LSD (5%)	40.64	39.9	0.115	2.052	5.7	7.05	154.5	1287.5
CV (%)	22.2	22.3	7	7.5	40	23.3	20.8	20.8

R = Resistant check, S = Susceptible check

4.1.3 Mean performance of crosses

4.1.3.1 Days to initiation of flowering

The crosses ICCV 2 × ICC 3137 (34.3 days), ICCV 2 × ICC 12478 (34.7 days), ICCV 2 × ICC 4918 (35 days), ICCC 37 × ICCV 2 (35 days), ICCV 2 × ICCC 37 (35.3 days), ICC 4918 × ICC 12477 (36.7 days), ICCV 2 × ICC 12479 (37 days), ICC 3137 × ICCC 37 (37.3 days), ICC 4918 × ICC 506 (37.7 days) and ICC 4918 × ICCC 37 (37.7 days) were the earliest to produce their first flowers. The initiation of flowering was late in ICC 12476 × ICC 506 (57.7 days), ICC 12476 × ICC 12477 (57.7 days), ICC 12476 × ICC 12478 (61.7 days), ICC 12476 × ICC 12479 (60 days), ICC 12476 × ICCC 37 (56.7 days), ICC 12477 × ICC 12476 (56.7 days), ICC 12477 × ICC 12479 (58 days), ICC 12479 × ICC 12476 (57.7 days) and ICC 3137 × ICCV 2 (57 days). Days to initiation of flowering ranged between 34.3 days (ICCV 2 × ICC 3137) to 61.7 days (ICC 12476 × ICC 12478), with an overall mean of 46.3 days (Table 6).

4.1.3.2 Days to 50 % flowering

The crosses ICCV 2 × ICC 3137 (46.3 days), ICCV 2 × ICCC 37 (46.7 days), ICCC 37 × ICCV 2 (49 days), ICCV 2 × ICC 4918 (49.7 days), ICCV 2 × ICC 12477 (49.7 days), ICCV 2 × ICC 12478 (51 days), ICC 4918 × ICCC 37 (51.7 days), ICCV 2 × ICC 12476 (52.7 days), ICC 12479 × ICCV 2 (53.3 days), ICCV 2 × ICC 12479 (53.3 days), ICCC 37 × ICC 4918 (53.7 days), ICCV 2 × ICC 506 (53.7 days), ICC 506 × ICCV 2 (54.3 days), ICCC 37 × ICC 12477 (54.3 days), ICC 12478 × ICC 4918 (54.7 days) and ICC 506 × ICC 4918 (55 days) were the earliest to produce 50 % flowering, while ICC 3137 × ICC 506 (67.7 days), IC 12476 × ICC 12478 (65.7 days), ICC 12476 × ICC 12479 (65.3 days), ICC 12477 × ICC 12476 (65.7 days), ICC 3137 × ICC 506 (67.7 days), ICC 3137 × ICC 12476 (66 days), ICC 3137 × ICC 12479 (65 days), ICC 3137 × ICCV 2 (65.3 days), ICCC 37 × ICC 12476 (66.3 days) and ICCC 37 × ICC 3137 (65 days) were late to produce 50 % flowering, with an overall mean of 58.9 days.

4.1.3.3 Days to maturity

ICCV 2 × ICC 3137 (104 days), ICCV 2 × ICCC 37 (104.5 days), ICCV 2 × ICC 4918 (105 days), ICCC 37 × ICCV 2 (105 days), ICCV 2 × ICC 12477 (105.3 days), ICCV 2 × ICC 12479 (105.7 days), ICCV 2 × ICC 12476 (105.7 days), ICC 4918 × ICCC 37 (105.7 days), ICCV 2 × ICC 12478 (106 days), ICCV 2 × ICC 506 (106 days), ICC 12479 × ICCV 2 (106 days), ICCC 37 × ICC 12477 (106 days) and ICC 4918 × ICC 12477 (106 days) were the early maturing crosses. Days to maturity ranged between 104 days (ICCV 2 × ICC 3137) to 114 days (ICCC 37 × ICC 3137, ICC 3137 × ICC 12476, ICC 3137 × ICC 12478 and ICC 3137 × ICC 12479), with an average of 108.5 days.

4.1.3.4 Flower colour

All the hybrids involving ICC 3137 and ICCV 2 (including reciprocal crosses) produced light pink flowers, while the remaining crosses produced pink flowers.

4.1.4 Yield contributing traits

4.1.4.1 Seeds per plant

The highest number of seeds per plant was observed in ICC 12477 × ICC 506 (205 seeds plant^{-1}), closely followed by ICC 12477 × ICC 4918 (195 seeds plant^{-1}), while ICC 12476 × ICCC 37 (153 seeds plant^{-1}), ICC 12477 × ICC 12478 (152 seeds plant^{-1}), ICC 4918 × ICC 12476 (149 seeds plant^{-1}), ICCC 37 × ICC 12477 (148 seeds plant^{-1}) and ICCC 37 × ICC 506 (147 seeds plant^{-1}) recorded > 145 seeds plant^{-1}. The lowest number of 60 seeds plant^{-1} was recorded on ICC 3137 × ICCC 37 followed by ICC 4918 × ICCC 37 (80 seeds plant^{-1}), ICC 506 × ICC 3137 (81 seeds plant^{-1}), ICC 506 × ICCC 37 (82 seeds plant^{-1}), ICCC 37 × ICCV 2 (86 seeds plant^{-1}), ICC 12478 × ICC 3137 (86 seeds plant^{-1}), ICCV 2 × ICC 4918 (86 seeds plant^{-1}) and ICC 12476 × ICC 3137 (88 seeds plant^{-1}), with an average of 116 seeds plant^{-1} (Table 7).

4.1.4.2 Total pods plant^{-1}

The crosses, ICC 12476 × ICC 12478, ICC 12477 × ICC 12478, ICC 12477 × ICC 3137, ICC 12477 × ICC 4918, ICC 12477 × ICC 506, ICC 12477 × ICCC 37, ICC 12478 × ICC 12479, ICC 12479 × ICC 12478 produced more than 140 pods per plant. ICC 12476 × ICC 3137, ICC 3137 × ICCC 37, ICC 4918 × ICCC 37, ICC 506 × ICC 3137, ICC 506 × ICCC 37, ICCC 37 × ICC 12479 and ICCC 37 × ICCV 2 produced less than 90 pods plant^{-1}, with an average of 113 pods plant^{-1}.

4.1.4.3 Seeds per pod

Higher number of seeds per pod was recorded in ICC 12476 × ICCC 37 (1.3 seeds pod^{-1}) followed by ICC 12478 × ICC 12476 (1.24 seeds pod^{-1}), ICCC 37 × ICC 12476 (1.18 seeds pod^{-1}), ICCC 37 × ICC 12479 (1.16 seeds pod^{-1}), ICC 4918

× ICC 12476 (1.14 seeds pod^{-1}) and ICC 12476 × ICC 4918 (1.13 seeds pod^{-1}). The crosses, ICC 3137 × ICC 4918 (0.81 seeds pod^{-1}), ICC 3137 × ICCC 37 (0.84 seeds pod^{-1}), ICC 3137 × ICC 12478 (0.86 seeds pod^{-1}) and ICC 12477 × ICC 3137 (0.88 seeds pod^{-1}) recorded lowest number of seeds pod^{-1}. Each pod resulted on an average of 1.03 seeds.

4.1.4.4 100 seed weight

The 100- seed weight ranged from 24.94 g 100^{-1} seeds (ICC 3137 x ICC 4918) to 9.8 g 100^{-1} seeds (ICC 12477 × ICC 12479). The crosses such as ICCC 37 × ICC 3137 (23.04 g 100^{-1} seeds), ICC 3137 × ICCV 2 (22.54 g 100^{-1} seeds), ICC 3137 × ICCC 37 (22.03 g 100^{-1} seeds), ICC 4918 × ICC 3137 (21.68 g 100^{-1} seeds), ICCV 2 × ICC 4918 (22.16 g 100^{-1} seeds), ICCV 2 × ICCC 37 (21.02 g 100^{-1} seeds) ICCV 2 × ICC 3137 (21.9 g 100^{-1} seeds) and ICCC 37 × ICCV 2 (21.0 g 100^{-1} seeds) are some of the crosses with higher 100- seed weight. ICC 12477 × ICC 12479 (9.8 g 100^{-1} seeds) and ICC 12477 × ICC 12476 (10.89 g 100^{-1} seeds) recorded the lowest weight of 100 seeds, with an average of 16.98 g.

4.1.4.5 Pod borer damage (%)

The cross, ICC 12478 × ICC 506 (1.3 %) suffered lowest pod borer damage closely followed by, ICC 12479 × ICC 12477 (3.22 %), ICC 12479 × ICCV 2 (3.66 %), ICC 12478 × ICC 12477 (3.69 %), ICC 12479 × ICC 506 (3.79 %), ICCV 2 × ICC 12479 (4.23 %), ICC 12477 × ICC 506 (4.62 %), ICCV 2 × ICC 12476 (4.66 %), ICCV 2 × ICC 12478 (4.76 %), and all most all the crosses with ICC 506 suffered lower damage due to pod borer which indicated that the crosses between less susceptible parents were also less susceptible. The crosses such as ICC 12477 × ICC 3137, ICC 12478 × ICC 3137, ICC 3137 × ICC 12476, ICC 3137 × ICC 12478, ICC 3137 × ICC 4918, ICC 3137 × ICCC 37, ICC 4918 × ICC 3137, ICCC 37 × ICC 12478 and ICCC 37 × ICC 3137 suffered > 14 % pod borer damage, with an overall mean of 8.51 % (Table7).

4.1.4.6 Seed yield per plant

Seed yield per plant ranged from 28.14 g (ICCC 37 × ICC 506) to 12.28 g (ICC 12477 × ICC 12479), with an average of 19.16 g. The crosses such as ICC 12477 × ICC 4918 (26.62 g), ICCV 2 × ICC 12476 (25.76 g), ICC 3137 × ICC 506 (26.28 g), ICC 12477 × ICC 506 (25.22 g), ICCC 37 × ICC 12477 (24.57 g), ICC 4918 × ICC 12477 (24.91 g), ICC 4918 × ICC 3137 (24.43 g), and ICC 12477 × ICCC 37 (24.68 g) with higher seed yield per plant were close to ICCC 37 × ICC 506. Lowest grain yield was recorded by the crosses, ICC 12477 × ICC 12476 (14.53 g), ICC 12477 × ICC 12479 (12.28 g), ICC 12478 × ICC 12476 (13.42 g), ICC 12479 × ICC 12476 (14.22 g), ICC 3137 × ICCC 37 (12.84 g), ICC 506 × ICC 12476 (12.79 g), ICC 506 × ICC 12477 (13.86 g), ICC 506 × ICCC 37 (13.56 g).

4.1.4.7 Total seed yield per plot

The cross ICC 12477 × ICC 506 (617.2 g) produced highest seed yield per plot closely followed by, ICC 12479 × ICCC 37 (619.3 g), ICC 12479 × ICC 12476 (586.3 g), ICC 506 × ICC 12479 (588.9 g) and ICCV 2 × ICC 4918 (594.4 g). Contrastingly, ICCV 2 × ICC 3137 produced lowest total seed yield per plot, with an average of 462.2g.

4.1.4.8 Yield (kg ha^{-1})

The crosses ICC 12477 × ICC 506 (5143 kg ha^{-1}) and ICC 12479 × ICCC 37 (5161 kg ha^{-1}) were highly superior produced highest seed yield per ha. ICCV 2 × ICC 4918 (4953 kg ha^{-1}), ICC 506 × ICC 12479 (4907 kg ha^{-1}), ICC 12479 × ICC 12476 (4886 kg ha^{-1}), ICC 3137 × ICC 12476 (4802 kg ha^{-1}), ICC 506 × ICC 12477 (4675 kg ha^{-1}), ICC 12479 × ICCV 2 (4626 kg ha^{-1}), ICC 506 × ICC 12478 (4617 kg ha^{-1}), ICC 12479 × ICC 3137 (4615 kg ha^{-1}), ICC 12478 × ICC 12477 (4598 kg ha^{-1}), ICC 4918 × ICC 506 (4569 kg ha^{-1}) and ICC 4918 × ICC 3137 (4538 kg ha^{-1}) are few of the crosses with higher seed yield per ha. ICCV 2 × ICCC 37 (2209 kg ha^{-1}), ICCV 2 × ICC 3137 (1449 kg ha^{-1}), ICC 12477 × ICC 12478 (2216 kg ha^{-1}), ICCV 2 × ICC 12477 (2388 kg ha^{-1}) and ICC 12476 × ICC 12477 (2439 kg ha^{-1}) were the poor crosses, resulted in poor grain yield, with an average of 3851 kg ha^{-1} (Table 7).

4.1.5 Combining ability effects

Mean squares due to general combining ability (GCA) effects were highly significant for all the characters (P = 0.01 level), while those due to specific combining ability (SCA) effects mean squares and variances for straight crosses were also highly significant (P = 0.01) for all the characters, except 100- seed weight. The SCA variances for number of pods plant^{-1} was significant at P = 0.05 level of significance.

Mean squares due to SCA effects of reciprocal crosses were highly significant for days to initial flowering, days to 50 % flowering, days to maturity, pods plant^{-1}, seeds per plant, seed yield plant^{-1} and 100- seed weight, while for seeds

Table 8 : Estimates of mean squares and variances due to GCA and SCA from F_1 chickpea, 9x9 full diallel, Griffing (1956).

	d.f	Days to initial F	Days to 50% F	Days to maturity	Pod borer damage (%)	pods/ plant	seeds/ plant	seeds/ pod	yield/ plant (g)	100 seed weight	Total plot yield	Yield (kg/ha)
Mean squares												
GCA	8	349.4**	262.9**	34.66**	167.7**	2174.4**	2989.5**	0.046**	26.97**	101.4**	28363.5**	1969692.8**
SCA	36	24.83**	11.83**	2.58**	11.25**	311.7*	400.2**	0.004**	12.6**	0.68	8426.8**	585194.5**
Reciprocal effects	36	24.53**	12.32**	2.87**	5.58	416.5**	466.9**	0.003*	13.06**	1.33**	3561.7	247340.4
Error	160	11.94	2.94	1.44	4.16	205	211.7	0.002	6.38	0.54	3060.2	212511.9
Variances												
$\sigma^2 g$		14.07**	22.24**	13.44**	14.91**	6.97**	7.47**	10.76**	2.14**	147.9**	3.36**	3.36**
$\sigma^2 s$		2.08**	4.02**	1.78**	2.7**	1.52*	1.89**	2.51**	1.98**	1.27	2.75**	2.75**
$\sigma^2 r$		2.05**	4.18**	1.98**	1.34	2.03**	2.2**	1.57*	2.05**	2.47**	1.16	1.16
$\sigma^2 A$		36.08	27.92	3.56	17.39	207.13	287.9	0.005	1.61	11.19	2223.4	154400.4
$\sigma^2 D$		7.15	4.93	0.63	3.93	59.21	104.5	0.001	3.45	0.08	2977.4	206762.3
A : D		2.52	2.83	2.83	2.21	1.75	1.37	1.63	0.23	69.3	0.37	0.37

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

F = Flowering

pod^{-1} the variances were significant at 5 % level of significance. SCA effects due to pod borer damage (%), total plot yield and yield (kg ha^{-1}) were non-significant (Table 8).

4.1.6 General combining ability (GCA) effects

4.1.6.1 Days to initial flowering

The parents ICCC 37 (-3.12**), Annigeri (-5.21**) and ICCV 2 (-6.68**) showed highly significant and negative GCA effects, in contrast to ICC 12476 (7.23**) and ICC 12477 (3.05**) and ICC 12479 (3.34**) which exhibited highly significant and positive GCA effects (Table 9).

4.1.6.2 Days to 50 % flowering

Out of nine parents, four parents showed significant and negative GCA. The genotypes ICC 506 (-1.12**), ICCC 37 (-1.92**), Annigeri (-2.18**) and ICCV 2 (-7.45**) showed highly significant and negative GCA effects, while significant positive GCA effects were observed on ICC 12476 (5.01**), ICC 12479 (2.01**) and ICC 3137 (4.69**).

4.1.6.3 Days to maturity

Five of the nine parents, ICC 506 (-0.72**), ICC 12477 (-1.24**), ICC 12479 (-0.63*), Annigeri (-0.72**) and ICCC 37 (-0.65*) showed significant and negative GCA effects, while the parents ICC 12476 (0.65*) and ICC 3137 (3.37**) showed significant and positive GCA effects.

4.1.6.4 Pod borer damage (%)

Out of nine parents, five parents ICC 506 (-3.02**), ICC 12477 (-0.99*), ICC 12478 (-1.66**), ICC 12479 (-2.53**) and ICCV 2 (-1.68**) showed highly significant and negative GCA effects. Annigeri (1.11*), ICC 3137 (7.02**) and ICCC 37 (1.39**) showed significant positive GCA effects.

4.1.6.5 Pods per plant

ICC 12477 (23.46**) recorded significant and positive GCA effects, whereas three of nine parents, ICC 3137 (-11.44**), ICCV 2 (-9.963**) and ICCC 37 (-11.592**) recorded significant and negative GCA effects.

4.1.6.6 Seeds plant^{-1}

The parent ICC 12477 (25.163**) recorded significant and positive GCA effects, while highly significant and negative GCA effects were showed by ICC 3137 (-22.389**) and ICCV 2 (-9.652**).

4.1.6.7 Seeds per pod

Only two parents ICC 12476 (0.048**) and ICCC 37 (0.053**) showed significant and positive GCA effects, where as ICC 3137 (-0.121*) recorded significant and negative GCA effects.

4.1.6.8 Seed yield per plant

Only Annigeri, the popular cultivar showed significant and positive GCA effects (2.196**). ICC 12479 (-2.236**) recorded highly significant and negative GCA effects.

4.1.6.9 100- seed weight

The GCA effects for 100- seed weight were significant and positive for Annigeri (1.431**), ICC 3137 (4.015**), ICCV 2 (2.114**) and ICCC 37 (1.551**), while rest of five parents showed significant and negative GCA effects for ICC 506 (-1.008**), ICC 12476 (-1.637**), ICC 12477 (-3.344**), ICC 12478 (-1.184**) and ICC 12479 (-1.938**).

4.1.6.10 Total seed yield per plot

The parents Annigeri (61.498**) and ICCC 37 (28.535*) recorded significant and positive GCA effects, while the GCA effects were significantly

Table 9 : Estimates of General combining ability (GCA) effects of nine chickpea parents (ICRISAT, Patancheru, post-rainy season, 2004-05).

parents	Days to initial F	Days to 50% F	Days to maturity	Pod borer damage (%)	pods/ plant	seeds/ plant	seeds/ pod	yield/ plant (g)	100 seed weight	Total plot yield	Yield (kg/ha)
ICC 506 ®	0.862	-1.12**	-0.72**	-3.02**	2.812	4.144	0.013	0.001	-1.008**	19.739	164.49
ICC 12476	7.23**	5.01**	0.65*	0.36	0.474	3.696	0.048**	-0.684	-1.637**	-31.337*	-261.138*
ICC 12477	3.05**	0.62	-1.24**	-0.99*	23.46**	25.163**	0.012	-0.054	-3.344**	-46.716**	-389.303**
ICC 12478	-0.045	0.33	-0.37	-1.66**	6.234	3.811	-0.013	-0.60	-1.184**	22.084	184.033
ICC 12479	3.34**	2.01**	-0.63*	-2.53**	-1.503	-2.3	0.00	-2.236**	-1.938**	11.056	92.137
Annigeri	-5.21**	-2.18**	-0.72**	1.11*	1.519	3.633	0.009	2.196**	1.431**	61.498**	512.479**
ICC 3137	0.566	4.69**	3.37**	7.02**	-11.44**	-22.389**	-0.121*	-0.227	4.015**	-61.947**	-516.221**
ICCV 2	-6.68**	-7.45**	0.30	-1.68**	-9.963**	-9.652**	-0.001	0.816	2.114**	-2.913	-24.272
ICCC 37(S)	-3.12**	-1.92**	-0.65*	1.39**	-11.592**	-6.104	0.053**	0.788	1.551**	28.535*	237.794*
S.E g(I)	0.767	0.381	0.267	0.454	3.182	3.233	0.009	0.561	0.163	12.29	102.44

*, ** = SCA effects significant at P = 0.05 and P = 0.01 respectively.

R= Resistant check; S= Susceptible check.

F = Flowering

negative for ICC 12476 (-31.337*), ICC 12477 (-46.716**) and ICC 3137 (-61.947**).

4.1.6.11 Yield (kg ha^{-1})

The GCA effects for yield (kg ha^{-1}) were highly significant and positive for Annigeri (512.479**) and ICCC 37 (237.794*), while the parents ICC 12476 (-261.138*), ICC 12477 (-389.303**) and ICC 3137 (-516.221**) showed highly significant and negative GCA effects (Table 9).

4.1.7 Specific combining ability (SCA) effects

4.1.7.1 Straight crosses

4.1.7.1.1 Days to initial flowering

The SCA effects for the hybrid ICC 12478 × ICC 3137 (-7.51**) was highly significant and negative, while such effects for ICC 12476 × ICC 12478 (4.656*) and ICC 3137 × ICCV 2 (5.286*) were significant and positive (Tables: 10 & 11).

4.1.7.1.2 Days to 50 % flowering

The SCA effects for days to 50 % flowering was significant and negative for the hybrids ICC 12476 × ICC 3137 (-3.714**), ICC 12479 × ICC 3137 (-2.714*) and ICC 4918 × ICCC 37 (-2.251*), while SCA effects were highly significant and positive for the hybrids *viz.*, ICC 506 × ICCV 2 (3.564**), ICC 12476 × ICCC 37 (3.397**), ICC 12478 × ICCV 2 (3.453**) and ICC 4918 × ICCV 2 (3.286**).

4.1.7.1.3 Days to maturity

Three of 36 crosses ICC 12476 × ICCV 2 (-1.558*), ICC 12479 × ICCC 37 (-1.835*) and ICC 3137 × ICCV 2 (-1.78*) showed significantly negative SCA effects, while the SCA effects were significantly positive for the hybrids of ICC 506

× ICC 4918 (1.665*), ICC 12477 × ICCV 2 (1.998**), ICC 12478 × ICCV 2 (1.794*) and ICC 4918 × ICCV 2 (1.646*).

4.1.7.1.4 Pod borer damage (%)

The SCA effects for the hybrids ICC 506 × ICC 3137 (-4.405**), ICC 12476 × ICC 3137 (-3.462**), ICC 12477 × ICC 4918 (-2.793*), ICC 12479 × ICC 3137 (-3.364**) and ICC 3137 × ICCV 2 (-4.032**) were highly significant and negative, while such effects for the hybrid ICC 4918 × ICC 3137 (2.98*) was significant and positive.

4.1.7.1.5 Pods per plant

Among the 36 hybrids significant and positive SCA effects were recorded by three hybrids, ICC 12477 × ICC 4918 (19.188*), ICC 12477 × ICCC 37 (19.766*) and ICC 12478 × ICC 12479 (26.303**).

4.1.7.1.6 Seeds plant^{-1}

The SCA effects for seeds plant^{-1} were significant and positive for five hybrids, *viz.*, ICC 12476 × ICCC 37 (23.174*), ICC 12477 × ICC 4918 (27.037**), ICC 12477 × ICCC 37 (21.741*), ICC 12478 × ICC 12479 (24.789**) and ICC 3137 × ICCV 2 (20.274*).

4.1.7.1.7 Seeds per pod

Out of 36 straight crosses, six crosses ICC 506 × ICCV 2 (0.057*), ICC 12476 × ICC 12478 (0.057*), ICC 12476 × ICC 4918 (0.055*), ICC 12476 × ICCC 37 (0.117**), ICC 12479 × ICCC 37 (0.083**) and ICC 3137 × ICCV 2 (0.078**) showed significant and positive SCA effects. While such effects were significant and negative for the hybrid ICC 3137 × ICCC 37 (-0.06*).

4.1.7.1.8 Seed yield plant^{-1}

The SCA effects for ICC 12476 × ICCC 37 (3.342*), ICC 12477 × ICC 4918 (3.22*) and ICC 12478 × ICC 12479 (3.823*) hybrids were significant and positive, while such effects for the hybrid ICC 4918 × ICCC 37 (-3.295*) was significant and negative.

4.1.7.1.9 100- seed weight

The SCA effects due to 100- seed weight was significant and positive for only one of 36 hybrids, ICC 506 × ICC 12478 (0.914*).

4.1.7.1.10 Total seed yield per plot

Significantly positive SCA effects due to total plot yield were recorded in the hybrids ICC 506 × ICCV 2 (79.71*) and ICC 12477 × ICCC 37 (137.472**). Significant and negative SCA effects were recorded in the hybrids ICC 506 × ICC 12477 (-73.302*), ICC 12476 × ICC 12477 (-94.986**), ICC 12476 × ICC 12478 (-72.508*) and ICC 3137 × ICCC 37 (-71.736*).

4.1.7.1.11 Yield (kg ha^{-1})

The SCA effects due to yield (kg ha^{-1}) in the hybrids ICC 506 × ICCV 2 (664.247*) and ICC 12477 × ICCC 37 (1145.599**) were significant and positive, while such effects in the hybrids ICC 506 × ICC 12477 (-610.847*), ICC 12476 × ICC 12477 (-791.552**), ICC 12476 × ICC 12478 (-604.236*) and ICC 3137 × ICCC 37 (-597.802*) were significant and negative (Tables 10 and 11).

Table 10 : Estimates of specific combining ability (SCA) effects on straight crosses of F_1s, 9x9 full diallel, Griffing (1956).

Pedigree	Days to initial F	Days to 50% F	Days to maturity	Pod borer damage (%)	pods/ plant	seeds/ plant	seeds/ pod	yield/ plant (g)	100 seed weight	Total plot yield	Yield (kg/ha)
ICC 506 X ICC 12476	-0.251	-1.233	-0.372	1.93	-7.886	-11.907	-0.043	-2.243	-0.34	-1.648	-13.734
ICC 506 X ICC 12477	1.101	-0.344	-1.484	-0.41	9.729	13.026	0.006	0.837	-0.071	-73.302*	-610.847*
ICC 506 X ICC 12478	-3.807	-1.214	-0.521	-1.115	-8.012	-8.622	-0.011	0.005	0.914*	67.458	562.15
ICC 506 X ICC 12479	2.471	-0.733	0.239	0.501	12.326	9.456	-0.015	1.502	0.193	48.521	404.338
ICC 506 X ICC 4918	-2.973	0.453	1.665*	-0.805	-3.197	-0.377	0.031	0.123	0.224	-10.559	-87.99
ICC 506 X ICC 3137	0.249	-0.084	-1.095	-4.405**	9.863	12.112	0.039	2.145	-0.652	65.04	542.002
ICC 506 X ICCV 2	0.49	3.564**	-0.354	1.002	-1.515	4.041	0.057*	0.459	-0.215	79.71*	664.247*
ICC 506 X ICCC 37	2.601	0.693	1.424	-0.604	5.948	2.993	-0.028	1.31	0.47	-30.03	-250.249
ICC 12476 X ICC 12477	0.397	0.36	0.313	0.806	-13.1	-17.826	-0.033	-3.107	-0.209	-94.986**	-791.552**
ICC 12476 X ICC 12478	4.656*	0.49	-0.224	1.898	0.192	-2.407	0.057*	-0.932	-0.214	-72.508*	-604.236*
ICC 12476 X ICC 12479	1.767	-1.362	-0.132	-0.343	6.896	3.904	-0.037	-0.017	-0.024	-29.584	-246.533
ICC 12476 X ICC 4918	-2.177	-1.01	-1.039	-0.606	4.274	13.171	0.055*	2.262	0.238	49.217	410.138
ICC 12476 X ICC 3137	-4.121	-3.714**	0.202	-3.462**	-5.034	-1.207	0.048	0.594	0.199	61.812	515.102
ICC 12476 X ICCV 2	-2.714	-0.899	-1.558*	-1.9	15.588	14.856	-0.01	2.91	-0.302	-0.435	-3.624
ICC 12476 X ICCC 37	0.397	3.397**	0.72	0.054	9.385	23.174*	0.117**	3.342*	-0.376	3.869	32.24
ICC 12477 X ICC 12478	1.675	-1.121	0.831	-1.003	0.74	0.726	-0.01	0.1	0.181	34.6	288.332
ICC 12477 X ICC 12479	2.786	-0.307	-0.909	0.307	-10.589	-8.896	0.013	-2.585	-0.777	-57.361	-478.007
ICC 12477 X ICC 4918	0.842	1.712	-0.984	-2.793*	19.188*	27.037**	0.047	3.22*	-0.509	52.511	437.595
ICC 12477 X ICC 3137	-2.936	-0.492	0.424	0.538	6.148	-1.54	-0.017	1.01	-0.36	21.809	181.74
ICC 12477 X ICCV 2	-1.029	1.156	1.998**	0.521	-17.13	-17.377	0.008	-2.393	0	60.843	507.027

Contd----

Contd----- table 10

Pedigree	Days to initial F	Days to 50% F	Days to maturity	Pod borer damage (%)	pods/ plant	seeds/ plant	seeds/ pod	yield/ plant (g)	100 seed weight	Total plot yield	Yield (kg/ha)
ICC 12477 X ICCC 37	2.416	-1.047	-0.724	1.57	19.766*	21.741*	-0.009	5.14	0.839	137.472**	1145.599**
ICC 12478 X ICC 12479	-0.788	0.656	-0.78	0.768	26.303**	24.789**	-0.023	3.823*	0.164	40.114	334.281
ICC 12478 X ICC 4918	4.267	0.008	-0.687	-0.866	-10.552	-9.677	-0.003	-1.281	-0.009	-50.136	-417.797
ICC 12478 X ICC 3137	-7.51**	0.471	0.387	0.488	-5.926	-5.088	-0.003	-0.321	0.191	32.277	268.973
ICC 12478 X ICCV 2	-0.436	3.453**	1.794*	-0.264	0.629	0.041	-0.015	-0.246	-0.341	10.85	90.413
ICC 12478 X ICCC 37	1.675	-0.418	0.072	1.976	-11.141	-10.707	-0.006	-1.121	0.39	-11.817	-98.473
ICC 12479 X ICC 4918	-0.121	-1.177	-0.761	1.335	-4.649	-6.066	-0.001	-0.435	0.429	-17.128	-142.734
ICC 12479 X ICC 3137	-1.566	-2.714*	0.979	-3.364**	5.511	6.989	0.02	1.443	-0.348	17.398	144.98
ICC 12479 X ICCV 2	-3.325	-0.233	1.22	-0.69	2.133	0.886	-0.016	-0.395	-0.472	19.67	163.92
ICC 12479 X ICCC 37	-1.381	-2.103	-1.835*	-1.881	-8.304	-0.963	0.083**	-0.404	-0.366	27.899	232.493
ICC 4918 X ICC 3137	-3.177	-0.029	-0.095	2.98*	15.955	9.156	-0.03	2.982	0.858	-29.208	-243.404
ICC 4918 X ICCV 2	2.064	3.286**	1.646*	2.159	-0.523	-4.714	-0.042	-0.564	0.45	-41.307	-344.228
ICC 4918 X ICCC 37	0.008	-2.251*	0.757	-2.109	-10.493	-16.696	-0.044	-3.295*	-0.4	36.798	306.65
ICC 3137 X ICCV 2	5.286*	-0.418	-1.78*	-4.032**	13.337	20.274*	0.078**	3.096	-0.911	66.425	553.542
ICC 3137 X ICCC 37	-3.936	-0.621	0.998	0.073	-0.967	-5.907	-0.06*	-1.521	-0.038	-71.736*	-597.802*
ICCV 2 X ICCC 37	-1.529	-1.807	-1.095	-0.338	-0.545	-4.877	-0.029	-0.9	0.343	-5.115	-42.626
SE S(i,j)	2.188	1.086	0.761	1.293	9.07	9.216	0.026	1.599	0.465	35.041	292
SE S(i,j)-S(l,k)	3.257	1.616	1.133	1.924	13.49	13.717	0.038	2.38	0.692	52.155	434.6
SE S(i,j)-S(k,l)	3.047	1.512	1.059	1.799	12.628	12.832	0.036	2.226	0.648	48.786	406.5

*, ** = SCA effects significant at P = 0.05 and P = 0.01 respectively.

F = Flowering

Table 11 : Significant specific combining ability effects (SCA) on straight crosses

Pedigree	Days to initial F	Days to 50% F	Days to maturity	Pod borer damage (%)	pods/ plant	seeds/ plant	seeds/ pod	yield/ plant (g)	100 seed weight	Total plot yield	Yield (kg/ha)
ICC 506 X ICC 12477										-73.302*	-610.847*
ICC 506 X ICC 12478									0.914*		
ICC 506 X ICC 4918			1.665*								
ICC 506 X ICC 3137				-4.405**							
ICC 506 X ICCV 2		3.564**					0.057*			79.71*	664.247*
ICC 12476 X ICC 12477										-94.986**	-791.552**
ICC 12476 X ICC 12478	4.656*						0.057*			-72.508*	-604.236*
ICC 12476 X ICC 4918							0.055*				
ICC 12476 X ICC 3137		-3.714**		-3.462**							
ICC 12476 X ICCV 2			-1.558*								
ICC 12476 X ICCC 37		3.397**				23.174*	0.117**	3.342*			
ICC 12477 X ICC 4918				-2.793*	19.188*	27.037**		3.22*			
ICC 12477 X ICCV 2			1.998**								
ICC 12477 X ICCC 37					19.766*	21.741*				137.472**	1145.599**
ICC 12478 X ICC 12479					26.303**	24.789**		3.823*			
ICC 12478 X ICC 3137	-7.51**										
ICC 12478 X ICCV 2		3.453**	1.794*								
ICC 12479 X ICC 3137		-2.714*		-3.364**							
ICC 12479 X ICCC 37			-1.835*				0.083**				
ICC 4918 X ICC 3137				2.98*							
ICC 4918 X ICCV 2		3.286**	1.646*								
ICC 4918 X ICCC 37		-2.251*						-3.295*			
ICC 3137 X ICCV 2	5.286*		-1.78*	-4.032**		20.274*	0.078**				
ICC 3137 X ICCC 37							-0.06*			-71.736*	-597.802*

*, ** = SCA effects significant at P = 0.05 and P = 0.01 respectively.

F = Flowering

4.1.8 Specific combining ability (SCA) effects

4.1.8.1 Reciprocal crosses

4.1.8.1.1 Days to initial flowering

The SCA effects were highly significant and negative for the hybrids ICCC 37 × ICC 12476 (-5.667*), ICC 4918 × ICC 12477 (-8.5**) and ICCV 2 × ICC 3137 (-11.333**) (Tables 12 & 13).

4.1.8.1.2 Days to 50 % flowering

The SCA effects were significant and negative for the hybrids ICCV 2 × ICC 12476 (-3*), ICCV 2 × ICC 12477 (-3.667**), ICCV 2 × ICC 12478 (-4.333**), ICCV 2 × ICC 4918 (-3*) and ICCV 2 × ICC 3137 (-9.5**), while such effects were significant and positive for the hybrids of ICC 3137 × ICC 506 (5.167**) and ICCC 37 × ICC 3137 (3.833**) (Tables 12 & 13).

4.1.8.1.3 Days to maturity

Out of 36 reciprocal crosses, five parents showed positive SCA effects, while two parents showed significant and negative SCA effects. The SCA effects of ICCC 37 × ICC 4918 (-1.667*) and ICCV 2 × ICC 3137 (-2.167*) were significantly negative, while such effects were significantly positive for the hybrids of ICC 3137 × ICC 506 (3.167**), ICCV 2 × ICC 12476 (2.667**), ICC 3137 × ICC 12477 (1.833*), ICC 3137 × ICC 12478 (1.667*) and ICCV 2 × ICC 4918 (2.167*).

4.1.8.1.4 Pod borer damage (%)

Among 36 crosses, the SCA effects for the hybrid, ICCV 2 × ICC 3137 (-3.457*) was significant and negative, while such effects for the hybrids ICCC 37 ×

ICC 12478 (4.141**) and ICC 4918 × ICC 12479 (3.57*) were significant and positive.

4.1.8.1.5 Total number of pods per plant

The SCA effects for the hybrids ICC 12477 × ICC 506 (46.233**), ICC 3137 × ICC 506 (26.133**) and ICCC 37 × ICC 506 (30**) were significant and positive, while such effects for hybrids ICC 12478 × ICC 12476 (-22.867*) and ICC 4918 × ICC 12477 (-26.133**) were significant and negative.

4.1.8.1.6 Seeds plant^{-1}

The SCA effects for the hybrids, ICC 12477 × ICC 506 (49.367**), ICC 3137 × ICC 506 (26.167*), ICCC 37 × ICC 506 (32.2**) were significant and positive, while such effects for the hybrids ICC 12478 × ICC 12476 (-21.133*) and ICC 4918 × ICC 12477 (-25.933*) were significant and negative.

4.1.8.1.7 Total number of seeds per pod

The SCA effects for the hybrids ICCC 37 × ICC 12476 (-0.059*) and ICC 3137 × ICC 4918 (-0.067*) were significant and negative.

4.1.8.1.8 Seed yield plant^{-1}

Five of 36 crosses, ICC 12477 × ICC 506 (5.679**), ICC 3137 × ICC 506 (5.606**), ICCC 37 × ICC 506 (7.289**), ICCV 2 × ICC 12476 (3.96*) and ICCC 37 × ICC 3137 (4.957**) showed significant and positive specific combining ability effects.

Table 12 : Estimates of specific combining ability (SCA) effects on reciprocal crosses for F_1s, in 9x9 full diallel, Griffing (1956).

Pedigree	Days to initial F	Days to 50% F	Days to maturity	Pod borer damage (%)	pods/ plant	seeds/ plant	seeds/ pod	yield/ plant (g)	100 seed weight	Total plot yield	Yield (kg/ha)
ICC 12477 X ICC 506	3.5	0.833	0.167	0.185	46.233**	49.367**	0.005	5.679**	-0.431	-4.573	-38.111
ICC 12478 X ICC 506	-2.833	1	0.333	-1.757	14.6	15.833	0.012	0.78	-0.987	-48.417	-403.472
ICC 12479 X ICC 506	0.167	0.833	0.5	-0.003	7.4	3.333	-0.015	0.65	0.248	-14.225	-118.542
Annigeri X ICC 506	-1.5	1.167	-0.167	0.786	7.433	8.167	-0.003	1.063	-0.18*	28.77	239.75
ICC 3137 X ICC 506	1.167	5.167**	3.167**	-0.468	26.133**	26.167*	0.019	5.606**	0.37	-17.272	-143.931
ICCV 2 X ICC 506	2.167	-0.333	1.5	-0.073	10.233	7.633	-0.043	0.874	-0.488	-18.182	-151.514
ICCC 37 X ICC 506	-3.5	-1.333	-1	2.755	30**	32.2**	0.005	7.289**	1.186*	46.827	390.222
ICC 12477 X ICC 12476	-0.5	0.667	0.667	2.548	6.6	5.667	0.002	-0.382	-0.927	-4.127	-34.389
ICC 12478 X ICC 12476	-3.333	-0.833	-0.333	1.412	-22.867*	-21.133*	0.129	-3.119	0.027	18.688	155.736
ICC 12479 X ICC 12476	-1.167	-0.667	-0.167	0.203	-7.1	-7.533	-0.006	-1.597	-0.501	-8.202	-68.347
Annigeri X ICC 12476	-4.333	-0.833	-0.5	-0.056	12.7	15.4	0.004	2.383	-0.056	13.043	108.694
ICC 3137 X ICC 12476	1.833	1	0.833	2.444	8.7	6.067	-0.037	2.069	1.016	-19.598	-163.319
ICCV 2 X ICC 12476	-4.667	-3*	2.667**	-0.969	12.067	9.933	-0.032	3.96*	1.764**	65.268	543.903
ICCC 37 X ICC 12476	-5.667*	0.833	0	0.082	-11.7	-18.8	-0.059*	-1.617	1.066	9.783	81.528
ICC 12478 X ICC 12477	-0.167	-0.5	0.5	-1.509	-11.933	-8.733	0.024	-1.039	-0.042	-52.53	-437.75
ICC 12479 X ICC 12477	-2.333	-2.333	0.833	-2.404	3.733	0.8	-0.03	1.602	1.146*	102.662**	855.514**
Annigeri X ICC 12477	-8.5**	0.167	0	1.121	-26.133**	-25.933*	0.012	-2.509	0.767	60.005	500.042
ICC 3137 X ICC 12477	1.833	0.833	1.833*	-2.376	-16.6	-11.667	0.018	-0.768	1.595**	-18.378	-153.153
ICCV 2 X ICC 12477	-4.5	-3.667**	1	0.542	8.333	12.5	0.04	2.025	0.468	-14.91	-124.25
ICCC 37 X ICC 12477	-2.5	-2.333	-0.333	1.509	-4.467	-6.7	-0.01	-0.054	0.69	-36.353	-302.944

Contd-----

Contd---- table 12

Pedigree	Days to initial F	Days to 50% F	Days to maturity	Pod borer damage (%)	pods/ plant	seeds/ plant	seeds/ pod	yield/ plant (g)	100 seed weight	Total plot yield	Yield (kg/ha)
ICC 12479 X ICC 12478	-0.333	-0.333	-0.167	-0.085	1.533	0.933	-0.005	-0.117	-0.132	25.997	216.639
Annigeri X ICC 12478	-2.167	2.5	1.167	1.294	1.567	-2.267	-0.033	0.703	0.981	-56.752	-472.931
ICC 3137 X ICC 12478	-0.833	0.167	1.667*	0.112	6.433	4.3	-0.027	1.22	0.818	8.35	69.583
ICCV 2 X ICC 12478	-4.667	-4.333**	0	-0.487	2.8	3.433	0.008	0.637	0.095	-17.15	-142.917
ICCC 37 X ICC 12478	3.333	0.333	1	4.141**	-2.733	-3.433	-0.002	0.156	0.965	47.878	398.986
Annigeri X ICC 12479	-0.833	0.333	0.833	3.57*	7.6	3.633	-0.041	1.398	0.759	-69.308	-577.569
ICC 3137 X ICC 12479	2.167	2	1.333	-0.496	-2.733	-1.2	0.006	0.785	1.006	14.363	119.694
ICCV 2 X ICC 12479	-2.833	0	0.5	0.283	5.967	5.633	-0.001	1.047	0.026	-36.283	-302.361
ICCC 37 X ICC 12479	1.667	-1	-0.167	-0.021	-10.567	-11.8	-0.002	-1.869	0.243	-24.693	-205.778
ICC 3137 X ICC 4918	0	1.833	0.167	2.641	-2.067	-8.567	-0.067*	-0.726	1.63**	12.718	105.986
ICCV 2 X ICC 4918	-1.667	-3*	2.167*	-0.64	-10.333	-17.1	-0.057	-2.269	1.164*	-12.377	-103.139
ICCC 37 X ICC 4918	0.5	1	-1.667*	0.222	10.933	14.733	0.042	2.657	-0.372	-77.83	-648.583*
ICCV 2 X ICC 3137	-11.333**	-9.5**	-2.167*	-3.457*	1.633	3.8	0.026	0.472	-0.321	67.625	563.542
ICCC 37 X ICC 3137	2.667	3.833**	1.333	-1.946	16.033	19.167	0.056	4.957**	0.505	-17.765	-148.042
ICCC 37 X ICCV 2	-0.167	1.167	-0.833	0.421	-9.6	-7.133	0.023	-1.898	-0.008	30.16	251.333
SE r(I,j)	2.44	1.21	0.849	1.443	10.125	10.288	0.029	1.785	0.519	39.116	325.96
SE (r (I,j) -r (k,l))	3.45	1.71	1.202	2.041	14.318	14.55	0.041	2.525	0.735	55.318	460.9

*, ** = SCA effects on reciprocal crosses significant at P = 0.05 and P = 0.01 respectively.

F = Flowering

Table 13 : Significant specific combining ability (SCA) effects on reciprocal crosses

Pedigree	Days to initial F	Days to 50% F	Days to maturity	Pod borer damage (%)	pods/ plant	seeds/ plant	seeds/ pod	yield/ plant (g)	100 seed weight	Total plot yield	Yield (kg/ha)
ICC 12477 X ICC 506					46.233**	49.367**		5.679**			
Annigeri X ICC 506									-0.18*		
ICC 3137 X ICC 506		5.167**	3.167**		26.133**	26.167*		5.606**			
ICCC 37 X ICC 506					30**	32.2**		7.289**	1.186*		
ICC 12478 X ICC 12476					-22.867*	-21.133*					
ICCV 2 X ICC 12476		-3*	2.667**					3.96*	1.764**		
ICCC 37 X ICC 12476	-5.667*						-0.059*				
ICC 12479 X ICC 12477									1.146*	102.662**	855.514**
Annigeri X ICC 12477	-8.5**				-26.133**	-25.933*					
ICC 3137 X ICC 12477			1.833*						1.595**		
ICCV 2 X ICC 12477		-3.667**									
ICC 3137 X ICC 12478			1.667*								
ICCV 2 X ICC 12478		-4.333**									
ICCC 37 X ICC 12478				4.141**							
Annigeri X ICC 12479				3.57*							
ICC 3137 X ICC 4918							-0.067*		1.63**		
ICCV 2 X ICC 4918		-3*	2.167*						1.164*		
ICCC 37 X ICC 4918			-1.667*								-648.583*
ICCV 2 X ICC 3137	-11.333**	-9.5**	-2.167*	-3.457*							
ICCC 37 X ICC 3137		3.833**						4.957**			

*, ** = SCA effects on reciprocal crosses significant at P = 0.05 and P = 0.01 respectively.

F = Flowering

4.1.8.1.9 100- seed weight

Out of 36 reciprocal crosses, six crosses showed positive SCA effects, while only one hybrid showed negative SCA effect. The SCA effects due to 100- seed weight for the hybrids, ICCC 37 × ICC 506 (1.186*), ICCV 2 × ICC 12476 (1.764**), ICC 12479 × ICC 12477 (1.146*), ICC 3137 × ICC 12477 (1.595**), ICC 3137 × ICC 4918 (1.63**) and ICCV 2 × ICC 4918 (1.164*) were significant and positive, while such effects for the hybrid ICC 4918 × ICC 506 (-0.18*) was significant and negative.

4.1.8.1.10 Total seed yield per plot

Significantly positive SCA effects due to total plot yield were recorded in the hybrid ICC 12479 × ICC 12477 (102.662**).

4.1.8.1.11 Yield (kg ha^{-1})

The SCA effects due to yield (kg ha^{-1}) in the hybrid ICC 12479 × ICC 12477 (855.514**) was significant and positive, while such effects were significant and negative in the hybrid ICCC 37 × ICC 4918 (-648.583*) (Tables 12 & 13).

4.2 THE MECHANISMS AND INHERITANCE OF DIFFERENT COMPONENTS OF RESISTANCE

The different resistance mechanisms include preference and non- preference for oviposition, antibiosis and tolerance. The results of different experiments conducted under this objective are presented below.

4.2.1 Non- preference for oviposition or Antixenosis

4.2.1.1 No-choice conditions

Under no choice conditions, lowest number of eggs were laid on the resistant check, ICC 12475 (713 eggs female^{-1} week^{-1}) followed by ICC 12476 (855 eggs female^{-1} week^{-1}), ICC 12477 (879 eggs female^{-1} week^{-1}), ICC 12478 (912.4 eggs female^{-1} week^{-1}). The highest oviposition was recorded on the susceptible checks, ICC 12426 (1366.6 eggs female^{-1} week^{-1}) and ICC 4918 (1340 eggs female^{-1} week^{-1}). A female laid on an average of 1052.5 eggs. The relative oviposition preference with respect to the susceptible check ICCC 37 was lowest for the resistant check, ICC 12475 (-27.7), ICC 12476 (-20.9), ICC 12477 (-19.8), ICC 12478 (-18.3) and ICC 12479 (-17.9) and highest for Annigeri (-1.0), ICC 3137 (-4.5) and ICCV 2 (-4.7) (Table 14).

4.2.1.2 Dual-choice conditions

Under dual-choice conditions, significantly lower number of eggs were recorded on ICC 12475, ICC 12477, ICC 12476, ICC 12478, ICCV 2 and ICC 12479 as compared to the susceptible check ICCC 37. The differences in the number of eggs laid on the test genotype and susceptible check were not significant for ICC 4918 and ICC 3137 (Table: 14). A female laid on an average of 204.9 and 268.8 eggs day^{-1} on test genotype and susceptible check respectively. Highest oviposition per cent was recorded on ICC 3137 (49.7 %), ICC 4918 (47.4 %), ICC 12476 (43.3 %), ICC 12477 (42.4 %), ICC 12479 (41.9 %), ICC 12478 (41.7 %) and ICCV 2 (40.9 %) compared to the resistant check, ICC 12475 (37.7 %) (Table 15).

During 2004-05 post-rainy season, a set of 72 hybrids and nine parents were compared for their relative oviposition preference in relation to ICCC 37. Significantly lower number of eggs were recorded on all the parents compared to the susceptible check ICCC 37. Eggs laid by the female ranged between 154 eggs day^{-1} (ICC 12475) to 360 eggs day^{-1} on ICC 4918. A female laid on an average of 240 and

Table 14 : Oviposition preference of *H.armigera* females towards nine chickpea genotypes under no- choice conditions (ICRISAT,Patancheru, post-rainy season 2003-04).

Genotype	Mean no. of eggs	($\sqrt{x}$ + 0.05)*	ROP
ICC 3137	1245.2	35.33	-4.5
ICC 12476	855.0	29.29	-20.9
ICC 12477	879.0	29.69	-19.8
ICC 12478	912.4	30.25	-18.3
ICC 12479	921.4	30.40	-17.9
ICCV 2	1240.0	35.26	-4.7
ICC 4918	1340.0	36.65	-1.0
Controls			
ICC 12475 ®	713.0	26.75	-27.7
ICC 12426(S)	1366.6	37.01	
Mean	1052.5	32.29	
Fp	< 0.001		
SE	25.89		
LSD (5%)	74.59		
CV (%)	5.5		

R= Resistant check; S= Susceptible check.

ROP = Relative oviposition preference in relation to ICCC 37.

* Square root transformed values.

Table 15 : Oviposition preference of *H.armigera* females towards nine chickpea genotypes under dual choice conditions (ICRISAT, Patancheru, 2003-04).

Genotype	Mean no.of eggs			Percent
	Test genotype	ICCC37	t' value	oviposition
ICC 3137	197	199	-0.13	49.7
ICC 12476	196[a]	256.5[b]	-3.36*	43.3
ICC 12477	182.5[a]	247.5[b]	-8.76**	42.4
ICC 12478	200.5[a]	280.5[b]	-4.9*	41.7
ICC 12479	206.5[a]	286.5[b]	-8.14**	41.9
ICCV 2	204.5[a]	295[b]	-6.87**	40.9
ICC 4918	300.5	334	-2.09	47.4
Controls				
ICC 12475 ®	152[a]	251.5[b]	-8.27**	37.7
Mean	204.9	268.8		

R= Resistant check.

*, ** significantly different at P= 0.05 and 0.01 respectively.

376.6 eggs day^{-1} on each parent and susceptible check respectively. On comparing the hybrids of each parent, significantly lower number of eggs were recorded on all the hybrids compared to the susceptible check ICCC 37. Eggs laid by the female ranged between 131.5 eggs day^{-1} on ICC 506 × ICC 12476 to 284 eggs day^{-1} on ICCC 37 × ICC 4918. The hybrids, ICC 12477 × ICC 12479, ICC 12477 × ICCV 2, ICC 12478 × ICC 506, ICC 506 × ICC 12476 and ICC 506 × ICC 12477 recorded < 160 eggs, while ICC 3137 × ICC 4918, ICCC 37 × ICC 4918, ICC 4918 × ICC 3137 and ICCV 2 × ICC 12477 recorded > 250 eggs female^{-1} day^{-1}. Average number of eggs laid by the female on hybrids of each parent were significantly lower compared to the parents. There was significant difference between the number of eggs laid on the test genotype and susceptible check among the nine parents and 72 F_1s except in the hybrid ICC 12479 × ICC 12477. A female laid on an average of 189.1, 171.9, 174.4, 177.1, 175.4, 212.7, 223.8, 220.6 and 202.4 eggs day^{-1} on the hybrids of ICC 12476, ICC 12477, ICC 12478, ICC 12479, ICC 506, ICC 3137, ICCC 37, ICC 4918 and ICCV 2 respectively.

Among parents ICC 12478 (42.7%) and ICC 4918 (45.2%) recorded the highest oviposition per cent, while lowest was recorded by ICC 506 (33%), ICCV 2 (35.6%) and ICC 12477 (36.4%). Average percent ovipsition by the female was 40.3, 38.9, 37.5, 41.6, 40.7, 39.8, 36.2, 40.3 and 35.7 on the hybrids of ICC 12476, ICC 12477, ICC 12478, ICC 12479, ICC 506, ICC 3137, ICCC 37, ICC 4918 and ICCV 2 respectively (Table 16).

4.2.1.3 Multi choice conditions

Under multichoice conditions, highest number of eggs were recorded on the susceptible check, ICC 12426 (1127 eggs female^{-1} week^{-1}) followed by ICCV 2

Table 16 : Oviposition by the *H. armigera* females on nine parents and their F_1 hybrids under dual-choice conditions (ICRISAT, Patancheru, 2004-05).

	Mean no.of eggs			Percent
	Test genotype	ICCC 37	t' value	oviposition
Parents				
ICC 506 ®	154[a]	313[b]	-9.93**	33.0
ICC 12476	200.5[a]	313.5[b]	-8.22**	39.0
ICC 12477	200.5[a]	351[b]	-11.44**	36.4
ICC 12479	225.5[a]	360[b]	-39.9**	38.5
ICC 3137	254.2[a]	427.4[b]	-13.78**	37.3
ICC 12478	295[a]	395.5[b]	-9**	42.7
ICC 4918	360[a]	436[b]	-9.43**	45.2
ICCV 2	230.5[a]	416.5[b]	-13.32**	35.6
Mean	240.0	376.6		38.5
F_1s				
ICC 12476 X ICC 506	179.5[a]	291.5[b]	-6.15**	38.1
ICC 12476 X ICC 12477	195[a]	281[b]	-8.14**	41.0
ICC 12476 X ICC 12478	195[a]	273.5[b]	-6.93**	41.6
ICC 12476 X ICC 12479	199[a]	283[b]	-5.22**	41.3
ICC 12476 X ICC 4918	192[a]	273[b]	-7.91**	41.3
ICC 12476 X ICC 3137	179.5[a]	272[b]	-15.99**	39.8
ICC 12476 X ICCV 2	176.5[a]	271.5[b]	-8.82**	39.4
ICC 12476 X ICCC 37	196[a]	290[b]	-14.68**	40.3
Mean	189.1	279.4		40.3
ICC 12477 X ICC 506	178[a]	280[b]	-6.19**	38.9
ICC 12477 X ICC 12476	188[a]	263[b]	-7.54**	41.7
ICC 12477 X ICC 12478	177[a]	239.5[b]	-3.94**	42.5
ICC 12477 X ICC 12479	158.5[a]	279.5[b]	-15.29**	36.2
ICC 12477 X ICC 4918	169.5[a]	269.5[b]	-5.81**	38.6
ICC 12477 X ICC 3137	173.5[a]	298[b]	-5.92**	36.8
ICC 12477 X ICCV 2	154.5[a]	260[b]	-8.31**	37.3
ICC 12477 X ICCC 37	176[a]	274[b]	-6.72**	39.1
Mean	171.9	270.4		38.9
ICC 12478 X ICC 506	157.5[a]	284[b]	-6.62**	35.7
ICC 12478 X ICC 12476	175[a]	338[b]	-14.61**	34.1
ICC 12478 X ICC 12477	186[a]	308[b]	-9.87**	37.7
ICC 12478 X ICC 12479	197.5[a]	260[b]	-10.23**	43.2
ICC 12478 X ICC 4918	162[a]	310[b]	-20.79**	34.3
ICC 12478 X ICC 3137	150.5[a]	280[b]	-53.75**	35.0
ICC 12478 X ICCV 2	169.5[a]	267[b]	-14.69**	38.8
ICC 12478 X ICCC 37	197[a]	281.5[b]	-9.93**	41.2
Mean	174.4	291.1		37.5
ICC 12479 X ICC 506	170[a]	221[b]	-3.36*	43.5
ICC 12479 X ICC 12476	188.5[a]	267[b]	-28.1**	41.4
ICC 12479 X ICC 12477	207.6	238.5	-1.8	46.5
ICC 12479 X ICC 12478	167[a]	219.5[b]	-5.28**	43.2
ICC 12479 X ICC 4918	164[a]	266[b]	-9.72**	38.1
ICC 12479 X ICC 3137	174[a]	280[b]	-13.45**	38.3
ICC 12479 X ICCV 2	176[a]	240[b]	-8.73**	42.3
ICC 12479 X ICCC 37	169.5[a]	260.5[b]	-34.12**	39.4
Mean	177.1	249.1		41.6

Contd----

Contd---- table 16

	Mean no.of eggs			Percent
	Test genotype	ICCC 37	t' value	oviposition
ICC 506 X ICC 12476	131.5[a]	199[b]	-9.43**	39.8
ICC 506 X ICC 12477	152[a]	260[b]	-16.94**	36.9
ICC 506 X ICC 12478	160[a]	241[b]	-8.22**	39.9
ICC 506 X ICC 12479	172[a]	264[b]	-17.78**	39.4
ICC 506 X ICC 4918	174.5[a]	260.5[b]	-10.72**	40.1
ICC 506 X ICC 3137	196.5[a]	243[b]	-43.57**	44.7
ICC 506 X ICCV 2	209.5[a]	271[b]	-17.57**	43.6
ICC 506 X ICCC 37	207.5[a]	293.5[b]	-86**	41.4
Mean	175.4	254.0		40.7
ICC 3137 X 506	214.5[a]	311.5[b]	-57.07**	40.8
ICC 3137 X ICC 12476	204[a]	340[b]	-10.42**	37.5
ICC 3137 X ICC 12477	209[a]	343[b]	-15.43**	37.9
ICC 3137 X ICC 12478	209.5[a]	312[b]	-4.94**	40.2
ICC 3137 X ICC 12479	186[a]	292[b]	-5.74**	38.9
ICC 3137 X ICC 4918	255[a]	312[b]	-4.73**	45.0
ICC 3137 X ICCV 2	222[a]	318[b]	-23.21**	41.1
ICC 3137 X ICCC 37	202[a]	337[b]	-14.06**	37.5
Mean	212.7	320.7		39.8
ICCC 37 X ICC 506	204.5[a]	384.5[b]	-22.62**	34.7
ICCC 37 X ICC 12476	222[a]	361[b]	-13.43**	38.1
ICCC 37 X ICC 12477	214[a]	372.5[b]	-15.72**	36.5
ICCC 37 X ICC 12478	228[a]	399.7[b]	-15.64**	36.3
ICCC 37 X ICC 12479	187.5[a]	400[b]	-14.86**	31.9
ICCC 37 X ICC 4918	284[a]	411.5[b]	-8.3**	40.8
ICCC 37 X ICC 3137	216.5[a]	407[b]	-52.78**	34.7
ICCC 37 X ICCV 2	234[a]	404.5[b]	-53.26**	36.6
Mean	223.8	392.6		36.2
ICC 4918 X ICC 506	175[a]	261.5[b]	-7.79**	40.1
ICC 4918 X ICC 12476	201.5[a]	296.5[b]	-24.09**	40.5
ICC 4918 X ICC 12477	199.5[a]	295[b]	-29.05**	40.3
ICC 4918 X ICC 12478	219.5[a]	357[b]	-26.56**	38.1
ICC 4918 X ICC 12479	218.5[a]	361.5[b]	-8.51**	37.7
ICC 4918 X ICC 3137	259[a]	309.5[b]	-3.85**	45.6
ICC 4918 X ICCV 2	247.5[a]	386.5[b]	-10.3**	39.0
ICC 4918 X ICCC 37	244[a]	354[b]	-18.59**	40.8
Mean	220.6	327.7		40.3
ICCV 2 X ICC 506	178.5[a]	357[b]	-37.38**	33.3
ICCV 2 X ICC 12476	205.5[a]	362[b]	-27.1**	36.2
ICCV 2 X ICC 12477	254[a]	383[b]	-11.06**	39.9
ICCV 2 X ICC 12478	203.5[a]	375[b]	-49**	35.2
ICCV 2 X ICC 12479	182.5[a]	346.5[b]	-12.38**	34.5
ICCV 2 X ICC 4918	200.5[a]	348[b]	-25.93**	36.6
ICCV 2 X ICC 3137	187.4[a]	365.5[b]	-16.36**	33.9
ICCV 2 X ICCC 37	207[a]	362[b]	-30.66**	36.4
Mean	202.4	362.4		35.7

R = resistant check

*, ** significantly different at P= 0.05 and 0.01 respectively.

(1076 eggs female^{-1} week^{-1}) and ICC 4918 (1050 eggs female^{-1} week^{-1}). Lowest number of eggs were laid on the resistant check ICC 12475 (692 eggs female^{-1} week^{-1}) followed by ICC 12476 (758 eggs female^{-1} week^{-1}). The genotypes ICCV 2, ICC 4918 and ICC 12478 were highly preferred by the *H. armigera* females compared to ICC 12475, ICC 12476, ICC 3137, ICC 12479 and ICC 12477 (Table 17).

Under field conditions, oviposition rate (No. of eggs plant^{-1}) of *H. armigera* females on nine chickpea genotypes was higher under un-protected conditions compared to protected conditions. Greater oviposition was recorded on ICC 3137, ICC 12476, ICC 12479, ICCV 2, ICC 12475 and ICC 12426 under un-protected conditions compared to protected conditions during vegetative stage, while ICC 12477, ICC 12478 and ICC 4918 did not differ significantly both under protected and un-protected conditions. Mean oviposition rate of 3.47 and 4.75 during vegetative stage, 1.7 and 2.79 during flowering stage and 1.67 and 2.8 during podding stage of the crop was observed under protected and un-protected conditions respectively (Table 18).

In the F_1 trial an average oviposition of 2.3, 1.25 and 1.21 (No. of eggs plant^{-1}) was recorded during vegetative, flowering and pod formation stage of the crop on parents, while the mean oviposition of 1.87, 1.34 and 1.1; 1.85, 1.31 and 0.97; 2.32, 1.41 and 1.24; 2.23, 1.29 and 1.07; 1.62, 1.32 and 1.03; 1.82, 1.38 and 1.04; 2.31, 1.3 and 1.03; 1.42, 1.37 and 0.88 and 1.88, 1.56 and 1.11 was recorded on hybrids of ICC 12476, ICC 12477, ICC 12478, ICC 12479, ICC 506, ICC 3137, ICCC 37, ICC 4918 and ICCV2 during vegetative, flowering and podding stage respectively (Table 19).

Table 17 : Oviposition preference of *H.armigera* females towards nine chickpea genotypes under multi choice conditions (ICRISAT,Patancheru, 2003-04).

Genotype	Mean no. of eggs	(√x + 0.05)*	ROP
ICC 3137	825	28.77	-14.4
ICC 12476	758	27.58	-18.0
ICC 12477	885	29.80	-11.4
ICC 12478	925	30.46	-9.4
ICC 12479	869	29.51	-12.2
ICCV 2	1076	32.85	-2.3
ICC 4918	1050	32.45	-3.5
Controls			
ICC 12475®	692	26.35	-21.6
ICC 12426(S)	1127	33.62	
Mean	912	30.15	
Fp	< 0.001		
SE	42.8		
LSD (5%)	128.2		
CV (%)	8.1		

R= Resistant check; S= Susceptible check.

ROP = Relative oviposition preference in relation to ICCC 37.

* Square root transformed values.

Table 18 : Oviposition rate (Eggs per plant) of *H.armigera* females on nine chickpea genotypes under protected and unprotected conditions ICRISAT, Patancheru, post-rainy season 2003/04 to 2004/05.

Genotype	Vegatative stage						Flowering stage						Poding stage					
	2003/04		2004/05		Mean		2003/04		2004/05		Mean		2003/04		2004/05		Mean	
	Prot	Unprot	Prot	Unprot	Prot	Unprot	Prot	Unprot	Prot	Unprot	Prot	Unprot	Prot	Unprot	Prot	Unprot	Prot	Unprot
ICC 3137	2.10	6.80	3.20	6.80	2.65	6.80	1.70	2.60	1.70	2.90	1.70	2.75	3.20	3.17	1.20	3.17	2.20	3.17
ICC 12476	2.20	4.40	4.40	4.40	3.30	4.40	2.77	2.60	1.77	2.60	2.27	2.60	1.57	2.93	1.57	2.93	1.57	2.93
ICC 12477	3.70	3.70	3.70	3.70	3.70	3.70	1.60	2.13	1.60	2.13	1.60	2.13	1.43	2.43	1.43	2.43	1.43	2.43
ICC 12478	2.93	2.93	3.23	3.23	3.08	3.08	1.53	2.70	1.53	2.70	1.53	2.70	1.13	3.07	1.13	3.07	1.13	3.07
ICC 12479	3.12	5.00	3.20	5.00	3.16	5.00	1.53	2.33	1.53	2.33	1.53	2.33	1.40	2.64	1.40	1.67	1.40	2.16
ICCV 2	4.60	4.60	3.20	5.00	3.90	4.80	2.12	2.77	1.00	2.77	1.56	2.77	2.27	3.17	2.27	3.17	2.27	3.17
ICC 4918	4.50	4.50	4.67	4.67	4.59	4.59	1.50	3.43	1.50	3.43	1.50	3.43	1.70	3.00	1.70	3.00	1.70	3.00
Controls																		
ICC 12475 ®	1.20	2.80	2.60	2.60	1.90	2.70	1.80	2.77	1.80	2.77	1.80	2.77	1.10	3.21	1.10	2.00	1.10	2.61
ICC 12426(S)	4.50	7.70	5.40	7.70	4.95	7.70	1.77	3.60	1.77	3.60	1.77	3.60	3.23	2.70	1.23	2.70	2.23	2.70
Mean	3.21	4.71	3.73	4.79	3.47	4.75	1.81	2.77	1.58	2.80	1.70	2.79	1.89	2.92	1.45	2.68	1.67	2.80
F-prob	<0.001	<0.001	<0.001	<0.001			0.02	0.13	0.02	0.13			<0.001	0.07	0.00	0.07		
SEM	0.319	0.271	0.319	0.271			0.224	0.339	0.137	0.339			0.156	0.421	0.156	0.351		
LSD(5%)	0.956	0.812	0.956	0.812			0.401	1.020	0.401	1.020			0.468	1.052	0.468	1.052		
CV%	11.2	4.6	12.0	9.8			9.5	11.3	14.7	21.0			8.2	14.5	18.7	22.7		

R = Resistant check, S = Susceptible check

Prot = Protected crop; Unprot = Unprotected crop.

Table 19 : Oviposition rate (Eggs per plant) of *H.armigera* females on 81 entries of chickpea under unprotected conditions (ICRISAT, Patancheru, 2004-05).

	OVIPOSITION RATE			
	Vegetative stage	Flowering stage	Poding stage	Total
Parents				
ICC 3137	3.13	1.40	1.27	5.80
ICC 12476	1.80	1.20	0.93	3.93
ICC 12477	2.93	1.20	0.87	5.00
ICC 12478	2.93	1.20	1.80	5.93
ICC 12479	1.73	1.13	1.13	4.00
ICCV 2	1.67	1.00	1.80	4.47
ICC 4918	2.60	1.67	1.00	5.27
ICC 506 ®	1.40	1.33	0.93	3.66
ICCC 37 (S)	2.47	1.13	1.20	4.80
Mean	2.30	1.25	1.21	4.76
F_1s				
ICC 12476 X ICC 506	1.60	1.40	1.07	4.07
ICC 12476 X ICC 12477	1.67	1.53	1.13	4.33
ICC 12476 X ICC 12478	1.93	1.00	1.13	4.07
ICC 12476 X ICC 12479	2.20	1.33	1.13	4.67
ICC 12476 X ICC 4918	2.33	1.27	1.13	4.73
ICC 12476 X ICC 3137	1.53	1.73	0.93	4.20
ICC 12476 X ICCV 2	2.40	1.27	1.13	4.80
ICC 12476 X ICCC 37	1.27	1.20	1.13	3.60
Mean	1.87	1.34	1.10	4.31
ICC 12477 X ICC 506	2.93	1.53	1.13	5.60
ICC 12477 X ICC 12476	1.40	0.93	0.47	2.80
ICC 12477 X ICC 12478	1.93	1.27	1.13	4.33
ICC 12477 X ICC 12479	2.20	0.73	1.27	4.20
ICC 12477 X ICC 4918	1.80	1.40	0.47	3.67
ICC 12477 X ICC 3137	1.47	1.93	1.13	4.53
ICC 12477 X ICCV 2	1.73	1.47	1.07	4.27
ICC 12477 X ICCC 37	1.33	1.20	1.07	3.60
Mean	1.85	1.31	0.97	4.12
ICC 12478 X ICC 506	2.40	1.93	1.07	5.40
ICC 12478 X ICC 12476	2.87	1.27	1.73	5.87
ICC 12478 X ICC 12477	3.13	1.60	1.53	6.27
ICC 12478 X ICC 12479	1.67	1.20	1.07	3.93
ICC 12478 X ICC 4918	2.13	1.33	1.20	4.67
ICC 12478 X ICC 3137	2.40	1.20	1.00	4.60
ICC 12478 X ICCV 2	1.47	1.53	1.27	4.27
ICC 12478 X ICCC 37	2.47	1.20	1.07	4.73
Mean	2.32	1.41	1.24	4.97
ICC 12479 X ICC 506	1.80	1.20	1.13	4.13
ICC 12479 X ICC 12476	2.20	1.00	1.13	4.33
ICC 12479 X ICC 12477	1.73	0.80	1.13	3.67
ICC 12479 X ICC 12478	1.47	1.67	0.80	3.93
ICC 12479 X ICC 4918	2.53	1.67	0.93	5.13
ICC 12479 X ICC 3137	2.20	1.07	0.80	4.07
ICC 12479 X ICCV 2	3.07	1.20	1.60	5.87
ICC 12479 X ICCC 37	2.80	1.73	1.07	5.60
Mean	2.23	1.29	1.07	4.59

Contd ----- table 19

F₁s	OVIPOSITION RATE			
	Vegetative stage	Flowering stage	Poding stage	Total
ICC 506 X ICC 12476	1.87	1.07	0.93	3.87
ICC 506 X ICC 12477	2.13	1.40	0.87	4.40
ICC 506 X ICC 12478	0.93	0.93	1.13	3.00
ICC 506 X ICC 12479	1.67	1.53	1.07	4.27
ICC 506 X ICC 4918	1.53	1.20	1.00	3.73
ICC 506 X ICC 3137	2.13	1.53	1.33	5.00
ICC 506 X ICCV 2	1.33	1.33	1.00	3.67
ICC 506 X ICCC 37	1.40	1.53	0.93	3.87
Mean	1.62	1.32	1.03	3.97
ICC 3137 X 506	1.33	0.67	1.00	3.00
ICC 3137 X ICC 12476	1.40	2.00	1.20	4.60
ICC 3137 X ICC 12477	2.07	1.20	0.87	4.13
ICC 3137 X ICC 12478	2.00	1.93	1.13	5.07
ICC 3137 X ICC 12479	1.87	1.47	1.07	4.40
ICC 3137 X ICC 4918	1.60	1.40	1.13	4.13
ICC 3137 X ICCV 2	2.67	1.07	0.87	4.60
ICC 3137 X ICCC 37	1.60	1.27	1.07	3.93
Mean	1.82	1.38	1.04	4.23
ICCC 37 X ICC 506	2.00	1.07	1.00	4.07
ICCC 37 X ICC 12476	2.40	1.47	0.73	4.60
ICCC 37 X ICC 12477	2.47	1.20	1.33	5.00
ICCC 37 X ICC 12478	2.33	1.60	1.13	5.07
ICCC 37 X ICC 12479	2.40	1.27	0.93	4.60
ICCC 37 X ICC 4918	2.13	1.47	1.00	4.60
ICCC 37 X ICC 3137	2.40	1.13	1.07	4.60
ICCC 37 X ICCV 2	2.33	1.20	1.07	4.60
Mean	2.31	1.30	1.03	4.64
ICC 4918 X ICC 506	1.33	1.40	0.87	3.60
ICC 4918 X ICC 12476	1.33	1.47	1.20	4.00
ICC 4918 X ICC 12477	1.07	0.93	0.80	2.80
ICC 4918 X ICC 12478	1.73	1.40	0.73	3.87
ICC 4918 X ICC 12479	1.33	2.00	0.93	4.27
ICC 4918 X ICC 3137	1.40	1.07	0.93	3.40
ICC 4918 X ICCV 2	1.40	1.47	0.73	3.60
ICC 4918 X ICCC 37	1.80	1.20	0.87	3.87
Mean	1.42	1.37	0.88	3.67
ICCV 2 X ICC 506	2.53	1.60	1.13	5.27
ICCV 2 X ICC 12476	2.33	1.73	0.67	4.73
ICCV 2 X ICC 12477	1.73	1.33	1.07	4.13
ICCV 2 X ICC 12478	1.47	1.60	1.13	4.20
ICCV 2 X ICC 12479	1.67	1.07	1.13	3.87
ICCV 2 X ICC 4918	1.13	1.13	0.80	3.07
ICCV 2 X ICC 3137	2.20	1.13	1.73	5.07
ICCV 2 X ICCC 37	2.00	2.87	1.20	6.07
Mean	1.88	1.56	1.11	4.55
Fp	0.245	0.036	0.337	
SE	0.498	0.276	0.236	
LSD (5%)	1.39	0.773	0.66	
CV (%)	43.9	35.5	38.2	

R= Resistant check; S= Susceptible check.

4.2.2 Antibiosis

The results of different experiments conducted under this mechanism *viz.*, detached leaf assay, no-choice cage technique, biology of pod borer on leaf material and biology on artificial diet impregnated with lyophilized leaf and pod powder were presented here.

4.2.2.1 Detached leaf assay

Neonate *H. armigera* larvae when fed on chickpea branches during vegetative stage using detached leaf assay, greater leaf feeding was observed on the susceptible check, ICCC 37 (DR 8.2), followed by ICC 4918 (DR 7.2) and ICCV 2 (DR 7.2). Significantly lower leaf feeding was observed on the resistant check, ICC 12475 (DR 4.2) followed by ICC 12476 (DR 6.2). Larval survival was lower on resistant check ICC 12475 (68 %) followed by ICC 12477 (72 %), ICC 12479 (74 %) and ICC 12476 (78 %). The unit larval weight was ranged between 5.45 mg (ICC 12475) to 8.55 mg (ICC 4918) (Table 20). Larval weight was significantly lower on ICC 12475, ICC 12478 and ICC 12479 as compared to that of the larvae reared on the susceptible check, ICC 12426 (8.44 mg) (Table 20).

During the flowering stage, leaf damage rating was ranged between 5.1 (ICC 12478) to 8.0 (ICC 12426) and ICC 12478, ICC 12479 and ICC 12475 suffered lower leaf damage than the susceptible check, ICC 12426 (DR 8.0). Survival percentage of larvae was 88 % on ICC 12426 compared to 68 % survival on ICC 12475. The genotypes ICC 12475 (68 %), ICC 3137 (74 %), ICC 12478 (78 %) and ICC 12479 (76 %) were less preferred by *H. armigera* larvae compared to susceptible checks, ICC 4918 (90 %) and ICC 12426 (88 %). The genotypes ICC 12475, ICC 12476, ICC 12478, ICC 12479 and ICC 4918 had lower larval weight

Table 20 : Expression of resistance to *H. armigera* in nine chickpea genotypes by using detached leaf assay during vegetative stage (ICRISAT, Patancheru, 2003-04).

Genotype	Damage rating	Larval survival (%)	Larval weight (mg)
ICC 3137	7.0	84	8.11
ICC 12476	6.2	78	7.89
ICC 12477	6.4	72	7.19
ICC 12478	6.8	86	6.66
ICC 12479	6.5	74	6.99
ICCV 2	7.2	86	7.43
ICC 4918	7.2	86	8.55
Controls			
ICC 12475 ®	4.2	68	5.45
ICC 12426 (S)	8.2	90	8.44
Mean	6.6	80.4	7.4
Fp	<0.001	<0.001	<0.001
SE	0.442	4.92	0.642
LSD (5%)	1.27	10.02	1.85
CV (%)	16.4	9.9	23.2

R= Resistant check; S= Susceptible check.

(5.78 to 6.24 mg per larva) as compared to the larvae weighed on the susceptible check, ICC 12426 (8.52 mg per larva) (Table 21).

In another experiment, during 2004-05 post-rainy season, flowering stage significantly lower leaf feeding was observed on the resistant check, ICC 12475 (4.2), but did not differ significantly with other genotypes. Greater number of larvae survived on ICC 4918 (78 %), ICC 12426 (76 %), ICC 12478 (72 %) and ICC 12476 (70 %) and ICC 12479 (70 %). The average weight of the larva was 6.96 mg (Table 22). The larval weights were significantly lower on ICC 12475, ICC 12477 and ICC 12478 as compared to those on the susceptible check, ICC 12426 (10.18 mg per larva) (Table 22).

For F_1s the damage rating ranged between 3.6 (ICC 12475) to 7.8 (ICCC 37) for parents and 3.2 (ICC 12479 × ICC 506) to 7.8 (ICCC 37 × ICC 4918) for the hybrids, indicating considerable variation for susceptibility to neonate larvae of *H.armigera* among the parents and their F_1 hybrids. Significantly greater number of larvae were survived on ICC 12478 (76 %), while the larval survival on the F_1 hybrids ranged between 40 % (ICC 12476 × ICC 12478) to 74 % (ICCC 37 × ICC 4918). The larvae gained maximum weight on susceptible check, ICCC 37 (11.36 mg). In F_1s the weight gain was maximum on ICCC 37 × ICC 4918 (12.04 mg per larva). Each larva weighed on an average of 7.1 mg on parents and 7.97 mg on hybrids. Damage rating, larval survival and/or weight gain were lower on the hybrids crossed with ICC 12475, ICC 12476, ICC 12477, ICC 12478 and ICC 12479 as compared to the hybrids crossed with ICC 3137, ICCC 37, ICC 4918 and ICCV 2. The hybrids ICC 12476 × ICC 12478, ICC 12476 × ICC 506, ICC 12477 × ICC 12479, ICC 12478 × ICC 12477, ICC 12479 × ICC 506, ICC 4918 × ICC 506, ICC 506 × ICC 12476, ICC 506 × ICC 12479 and ICCV 2 × ICC 506 showed

Table 21 : Expression of resistance to *H. armigera* in nine chickpea genotypes by using detached leaf assay during flowering stage (ICRISAT, Patancheru, 2003-04).

Genotype	Damage rating	Larval survival (%)	Larval weight (mg)
ICC 3137	6.3	74	7.64
ICC 12476	6.2	80	6.04
ICC 12477	6.4	82	8.17
ICC 12478	5.1	78	6.23
ICC 12479	5.2	76	6.24
ICCV 2	6.0	86	7.80
ICC 4918	7.4	90	6.15
Controls			
ICC 12475 ®	5.2	68	5.78
ICC 12426 (S)	8.0	88	8.52
Mean	6.2	80.2	6.95
Fp	0.006	<0.001	<0.001
SE	0.656	2.86	0.319
LSD (5%)	1.89	8.23	0.92
CV (%)	24.2	8.1	13.2

R= Resistant check; S= Susceptible check.

Table 22 : Expression of resistance to *H. armigera* in nine chickpea genotypes by using detached leaf assay during flowering stage (ICRISAT, Patancheru, 2004-05).

Genotype	Damage rating	Larval survival (%)	Larval weight (mg)
ICC 3137	5.7	66	7.90
ICC 12476	5.9	70	6.36
ICC 12477	6.0	68	5.90
ICC 12478	4.9	72	5.40
ICC 12479	5.3	70	7.38
ICCV 2	5.2	64	8.12
ICC 4918	6.8	78	7.04
Controls			
ICC 12475 ®	4.2	58	4.40
ICC 12426 (S)	6.7	76	10.18
Mean	5.63	69.1	6.96
Fp	0.006	0.39	< 0.001
SE	0.568	5.81	0.847
LSD (5%)	1.63	16.74	2.43
CV (%)	23	18.8	27.4

R= Resistant check; S= Susceptible check.

less susceptibility to *H. armigera* neonate larvae than the hybrids of ICC 12476 × ICCC 37, ICC 12478 × ICCC 37, ICC 12479 × ICCC 37, ICC 12479 × ICCV 2, ICC 3137 × ICC 12479, ICC 3137 × ICCC 37, ICC 4918 × ICC 12476, ICC 4918 × ICC 3137, ICC 4918 × ICCC 37, ICC 506 × ICCC 37, ICCC 37 × ICC 12476, ICCC 37 × ICC 4918, ICCV 2 × ICC 12478 and ICCV 2 × ICC 3137. Mean damage rating, larval survival and weight gain by the neonate larvae on parents were 6.2, 62 % and 7.1 mg respectively (Table 23).

During the podding stage, when a single third-instar larva was released on chickpea branches with young pods, the number of damaged pods ranged between 3.8 (ICC 12475 and ICC 12477) to 5.4 (ICCC 37) and ICC 3137, ICC 12476, ICC 12478, ICC 12479 and ICCV 2 suffered less pod damage compared to susceptible checks, ICC 4918 (5.2) and ICCC 37 (5.4). Significantly more weight was gained by the larva on ICCC 37 (387.5 mg) followed by ICC 4918 (354.1 mg) and ICC 3137 (353.4 mg). The weight gain by the larva was lowest on ICC 12475 the resistant check (227.2 mg) (Table 24). The larvae recorded lower weight gain on the genotypes ICC 12476, ICC 12477, ICC 12478 and ICCV 2 compared to the susceptible check, ICCC 37 (Table 24).

4.2.2.2 Relative susceptibility of chickpea genotypes to *H. armigera* under no-choice cage conditions

During the 2003/04 post-rainy season vegetative stage, significantly lower leaf feeding was recorded on resistant check, ICC 12475 (DR 3.8), while ICCC 37 showed the highest leaf damage (DR 9.0). Greater number of larvae survived on ICC 4918 (83.3 %) followed by ICC 12426 (83 %) as compared to ICC 12475 (63.3 %). There were no significant differences in weight gain by the larvae on the genotypes tested. The mean unit weight of the larva was 54.6 mg. Recovery rate of the infested

Table 23 : Detached leaf assay for evaluating relative susceptibility of nine parents and their 72 hybrids during the flowering stage (ICRISAT, Patancheru, post-rainy season, 2004-05).

	Damage rating	Larval survival (%)	Larval weight (mg)
Parents			
ICC 3137	7.2	72	7.08
ICC 12476	5.8	56	6.88
ICC 12477	5.8	56	6.48
ICC 12478	5.2	76	5.84
ICC 12479	6.2	58	5.94
ICCV 2	6.6	56	5.06
ICC 4918	7.5	62	9.88
ICC 506 ®	3.6	54	5.36
ICCC 37 (S)	7.8	72	11.36
Mean	6.2	62	7.10
F_1s			
ICC 12476 X ICC 12477	4.8	52	7.74
ICC 12476 X ICC 12478	4.6	40	5.84
ICC 12476 X ICC 12479	5.1	54	7.66
ICC 12476 X ICC 3137	5.5	60	5.28
ICC 12476 X ICC 4918	6.2	56	6.88
ICC 12476 X ICC 506	4.7	54	4.44
ICC 12476 X ICCC 37	5.3	64	8.92
ICC 12476 X ICCV 2	5.9	42	6.3
Mean	5.3	53	6.63
ICC 12477 X ICC 12476	5.6	48	6.88
ICC 12477 X ICC 12478	4.9	44	7.32
ICC 12477 X ICC 12479	4.8	54	5.36
ICC 12477 X ICC 3137	4.2	50	6.68
ICC 12477 X ICC 4918	7.2	62	6.56
ICC 12477 X ICC 506	3.7	44	8.48
ICC 12477 X ICCC 37	4.5	54	8.36
ICC 12477 X ICCV 2	5	54	8.48
Mean	5.0	51	7.27
ICC 12478 X ICC 12476	4.5	50	6.74
ICC 12478 X ICC 12477	4.2	48	5.34
ICC 12478 X ICC 12479	4.5	52	6.12
ICC 12478 X ICC 3137	5.5	56	6.56
ICC 12478 X ICC 4918	7.6	64	7.84
ICC 12478 X ICC 506	4.7	52	8.4
ICC 12478 X ICCC 37	5.1	58	8.72
ICC 12478 X ICCV 2	5.3	60	7.88
Mean	5.2	55	7.20
ICC 12479 X ICC 12476	5.5	68	8.32
ICC 12479 X ICC 12477	4.1	70	7.64
ICC 12479 X ICC 12478	5.3	56	7.84
ICC 12479 X ICC 3137	5.6	52	7.91
ICC 12479 X ICC 4918	6	64	9.5
ICC 12479 X ICC 506	3.2	64	5.52
ICC 12479 X ICCC 37	5	56	8.86
ICC 12479 X ICCV 2	6.2	56	9.04
Mean	5.1	61	8.08
ICC 3137 X 506	6.3	66	6.18
ICC 3137 X ICC 12476	7	56	7.04
ICC 3137 X ICC 12477	5.5	58	8.48
ICC 3137 X ICC 12478	6	60	9.72
ICC 3137 X ICC 12479	6.8	68	13.2

Contd--------

Contd-------- table 23

F_1s	Damage rating	Larval survival (%)	Larval weight (mg)
ICC 3137 X ICC 4918	7.2	62	6.54
ICC 3137 X ICCC 37	6.8	66	12.6
ICC 3137 X ICCV 2	4.6	72	7.26
Mean	6.3	64	8.88
ICC 4918 X ICC 12476	5.4	56	10.28
ICC 4918 X ICC 12477	7.2	58	8.66
ICC 4918 X ICC 12478	6.2	58	8.34
ICC 4918 X ICC 12479	5.3	54	8.80
ICC 4918 X ICC 3137	7.6	52	10.66
ICC 4918 X ICC 506	3.78	52	5.98
ICC 4918 X ICCC 37	6.2	46	12.54
ICC 4918 X ICCV 2	6.4	48	7.56
Mean	6.0	53	9.10
ICC 506 X ICC 12476	4.6	70	4.36
ICC 506 X ICC 12477	5.2	70	5.06
ICC 506 X ICC 12478	4.3	68	7.3
ICC 506 X ICC 12479	5.2	54	4.08
ICC 506 X ICC 3137	4.2	72	4.38
ICC 506 X ICC 4918	7	62	6.42
ICC 506 X ICCC 37	6.1	60	8.88
ICC 506 X ICCV 2	4.8	72	4.12
Mean	5.2	66	5.58
ICCC 37 X ICC 12476	6.2	60	9.7
ICCC 37 X ICC 12477	3.8	70	7.82
ICCC 37 X ICC 12478	6.4	68	6.64
ICCC 37 X ICC 12479	6	62	8.66
ICCC 37 X ICC 3137	6.5	62	8.8
ICCC 37 X ICC 4918	7.8	74	12.04
ICCC 37 X ICC 506	5.9	64	6.56
ICCC 37 X ICCV 2	6.1	58	8.62
Mean	6.1	65	8.61
ICCV 2 X ICC 12476	6.6	56	6.68
ICCV 2 X ICC 12477	4.6	48	7.28
ICCV 2 X ICC 12478	7.1	46	9.12
ICCV 2 X ICC 12479	6.5	58	8.38
ICCV 2 X ICC 3137	4.6	48	11.32
ICCV 2 X ICC 4918	5.2	68	7.08
ICCV 2 X ICC 506	5.6	52	5.4
ICCV 2 X ICCC 37	6.1	52	9.2
Mean	5.8	54	8.06
Mean			
Parents	6.19	62.44	7.10
F_1s	5.54	58.00	7.97
Fp	< 0.001	< 0.001	< 0.001
SE	0.5	5.59	1.302
LSD (5%)	1.4	15.56	3.62
CV (%)	20.6	21.4	29.7

R= Resistant check; S= Susceptible check.

Table 24 : Expression of resistance to *H. armigera* in nine chickpea genotypes by using detached leaf assay during podding stage (ICRISAT, Patancheru, post-rainy season, 2003-04).

Genotype	No. of pods taken	Damaged pods	Initial larval weight (mg)	Final larval weight (mg)	Weight gain by the larva	Weight gain (%)
ICC 3137	8	4.8	32.5	385.9	353.4	1087.4
ICC 12476	8	4	31.1	306.9	275.8	886.8
ICC 12477	8	3.8	33.68	331.8	298.1	885.2
ICC 12478	8	4.4	31.82	268.3	236.5	743.2
ICC 12479	8	4.6	32.8	336.5	303.7	925.9
ICCV 2	8	4.6	30.74	298.2	267.5	870.1
ICC 4918	8	5.2	32.14	386.2	354.1	1101.6
Controls						
ICC 12475 ®	8	3.8	34.28	261.5	227.2	662.8
ICC 12426 (S)	8	5.4	32.4	420.2	387.5	1196.9
Mean	8.0	4.5	32.4	332.8	300.4	928.9
Fp		0.063	0.938	< 0.001	< 0.001	
SE		0.395	0.0019	0.022	0.022	
LSD (5%)		1.14	0.005	0.064	0.063	
CV (%)		19.6	13.2	13.9	15.2	

R= Resistant check; S= Susceptible check.

plant was maximum in the genotype, ICC 12475 (3.29). Lowest recovery rate was recorded in the susceptible checks, ICC 12426 (1.58) and in ICC 4918 (1.98). Under infested conditions, greater grain yield was recorded in case of ICCV 2 (10.7 g), followed by ICC 12475 (8.65 g), ICC 12478 (7.35 g) and ICC 12479 (7.3 g) compared to ICC 3137 (4.1 g), ICC 12476 (6.15 g), ICC 12477 (6.25 g), ICC 4918 (6.55 g) and ICC 12426 (5.5 g). The susceptible genotypes ICC 12426 and ICC 3137 were poor yielders under infested conditions. Under un-infested conditions, significantly higher grain yield was recorded in all the tested genotypes except ICC 3137. The loss in grain yield was highest in case of ICC 12426, ICC 3137, ICC 12476 and ICC 12477 (50.6 to 59.4 %) as compared to 5.7 % in ICCV 2. The resistant check, ICC 12475 recorded the grain loss of 13.9 % (Table 25).

During the 2004/05 post-rainy season, the leaf feeding ranged between 4.0 (ICC 12475) to 8.5 (ICC 12426) and ICC 3137, ICC 12476, ICC 12477, ICC 12478, ICC 12479 and ICCV 2 suffered less damage than the susceptible check, ICC 12426. Larval survival ranged from 63.3 % on ICC 12475 to 86% on ICC 12426. Weight gain by the larva was numerically lower on ICC 12476, ICC 12477 and ICC 12475 compared to that on the susceptible check, ICC 12426 (60.8 mg per larva). Plant recovery following *H. armigera* infestation was better on ICC 12475 (3.29) than in ICC 12426 (1.62). Under infested conditions greater grain yield was recovered in case of ICCV 2 (10.7 g) and ICC 12475 (9.4 g) compared to the susceptible check, ICC 12426 (5.5 g). The un-infested plants of ICC 12478 (13.3 g) and ICC 12426 (13.55 g) yielded better than those of ICC 12475 (10.05 g) and ICCV 2 (11.35 g). ICC 12426, ICC 12476 and ICC 12477 recorded the highest loss in grain yield (50.6 to 59.4 %) as compared to ICCV 2 (5.7%) and ICC 12475 (6.5 %). Mean per cent loss was 39.3 % (Table 26).

Table 25 : Expression of resistance and recovery of nine chickpea genotypes to neonate larvae of *H. armigera* during vegetative stage (ICRISAT, Patancheru, post-rainy season, 2003-04).

Genotype	Damage rating	Larval survival (%)	Larval weight (mg)	Recovery by infested plant	Total Yield (g)		Yield loss (%)
					infested	uninfested	
ICC 3137	7.2	78.0	44.8	2.64	4.10	9.30	55.9
ICC 12476	6.3	71.0	52.9	2.47	6.15	12.45	50.6
ICC 12477	5.9	66.7	69.9	2.89	6.25	12.70	50.8
ICC 12478	6.1	66.7	54.1	2.51	7.35	13.30	44.7
ICC 12479	6.1	70.0	55.3	3.16	7.30	12.10	39.7
ICCV 2	5.9	70.0	55.9	2.36	10.70	11.35	5.7
ICC 4918	8.2	83.3	59.3	1.98	6.55	12.90	49.2
Controls							
ICC 12475 ®	3.8	63.3	49.2	3.29	8.65	10.05	13.9
ICC 12426 (S)	9	83.0	49.8	1.58	5.50	13.55	59.4
Mean	6.5	72.4	54.6	2.54	6.95	11.97	41.1
Fp (0.05)	<0.001	<0.001	0.81	<0.001			
SE	0.427	2.56	9.65	0.228	Treat	SE	0.177
LSD (5%)	1.23	7.38	27.79	0.645	Geno	LSD (5%)	0.501
CV (%)	14.7	8.3	39.5	13	Treat.Geno	CV (%)	12.3

R= Resistant check; S= Susceptible check.

Table 26 : Expression of resistance and recovery of nine chickpea genotypes to neonate larvae of *H. armigera* during vegetative stage (ICRISAT, Patancheru, post-rainy season, 2004-05).

Genotype	Damage rating	Larval survival (%)	Larval weight (mg)	Recovery by infested plant	Total Yield (g)		Yield loss (%)
					infested	uninfested	
ICC 3137	7.2	80.0	54.8	2.64	6.40	12.10	47.1
ICC 12476	5.9	71.0	42.6	2.47	6.15	12.45	50.6
ICC 12477	6.3	63.3	49.1	2.64	6.25	12.70	50.8
ICC 12478	6.1	66.7	54.1	2.51	7.35	13.30	44.7
ICC 12479	6.1	70.0	55.3	2.82	7.30	12.10	39.7
ICCV 2	5.9	72.0	55.9	2.36	10.70	11.35	5.7
ICC 4918	8.2	83.3	59.3	1.99	6.55	12.90	49.2
Controls							
ICC 12475 ®	4.0	63.3	40.9	3.29	9.40	10.05	6.5
ICC 12426 (S)	8.5	86.0	60.8	1.62	5.50	13.55	59.4
Mean	6.5	72.8	52.5	2.48	7.29	12.28	39.3
Fp (0.05)	<0.001	<0.001	0.81	<0.001			
SE	0.427	2.06	8.61	0.228	Treat	SE	0.167
LSD (5%)	1.123	7.38	27.79	0.603	Geno	LSD (5%)	0.395
CV (%)	12.7	7.2	28.3	11.8	Treat.Geno	CV (%)	11.4

R= Resistant check; S= Susceptible check.

In plants infested during the flowering stage, leaf feeding ranged between 5.0 (ICC 12475) to 8.8 (ICC 12426 and ICC 4918). Significantly greater number of larvae survived on ICC 12426 (85 %) and ICC 4918 (83.3 %) than on the ICC 12475 (60.1 %). ICC 12477, ICC 12478 and ICC 12475 had lower larval weight (55.5 – 59.5 mg per larva) as compared to the larva feed on the ICC 4918 (73.5 mg per larva), ICCV 2 (71 mg), ICC 3137 (76 mg) and ICC 12426 (69 mg per larva). The recovery by the infested plant was better in case of ICC 12475, ICC 12476, ICC 12477, ICC 12478, ICC 12479 and ICCV 2 (recovery score 2.05 to 3.63) as compared to ICC 3137, ICC 4918 and ICC 12426 (recovery score 1.86 to 1.95). Grain yield of infested plants was > 5 g in case of ICC 12477, ICC 12478 and ICC 12475 as compared to 2.73 g in the susceptible check, ICC 12426. Under un-infested conditions, ICC 12475, ICC 12426 and ICC 12476 yielded > 5.94 g compared to 2.43 g in ICCV 2. The loss in grain yield was > 23 % in case of ICC 3137, ICC 12476, ICC 4918 and ICC 12426, as compared to 2.0 % in the resistant check, ICC 12475, however the negative yield loss of –4.9 % was recorded in case of ICC 12479 (Table 27).

During the 2004/05 post-rainy season, when plants were infested during the flowering stage, significantly lower leaf feeding was observed on ICC 12475 (DR 4.8) compared to the susceptible check, ICC 12426 (DR 8.6). Larval survival ranged from 60.1 % on ICC 12475 to 85.0 % on ICC 12426. Larval weight was significantly lower on ICC 12475, ICC 12477, ICC 12478 and ICC 12476 compared to ICCV 2, ICC 4918 and ICC 12426. Infested plant recovery was better in ICC 12475 (2.88) compared to ICC 12426 (1.72). Grain yield of infested plants was greater in case of ICC 12475 (5.94 g) and ICC 12477 (5.01 g) as compared to that of ICC 12426 (2.55 g). The un-infested plants of ICC 12475, ICC 12426, ICC 3137,

Table 27 : Expression of resistance and recovery of nine chickpea genotypes to neonate larvae of *H. armigera* during flowering stage (ICRISAT, Patancheru, post-rainy season, 2003-04).

Genotype	Damage rating	Larval survival (%)	Larval weight (mg)	Recovery by infested plant	Total Yield (g) infested	Total Yield (g) uninfested	Yield loss (%)
ICC 3137	7.6	75.0	76.0	1.95	3.87	5.25	26.3
ICC 12476	5.9	63.3	58.0	2.28	4.20	5.94	29.3
ICC 12477	5.8	66.7	55.5	2.36	5.01	5.37	6.7
ICC 12478	6.1	66.7	55.8	2.05	5.04	5.40	6.7
ICC 12479	6.3	70.0	61.1	2.46	3.87	3.69	-4.9
ICCV 2	6.5	70.0	71.0	2.26	2.25	2.43	7.4
ICC 4918	8.8	83.3	73.5	1.86	2.79	3.63	23.1
Controls							
ICC 12475 ®	5.0	60.1	59.5	3.63	5.94	6.06	2.0
ICC 12426 (S)	8.8	85.0	69.0	1.90	2.73	6.42	57.5
Mean	6.8	71.1	64.4	2.31	3.97	4.91	17.1
Fp (0.05)	<0.001	<0.001	0.21	<0.001			
SE	0.52	6.13	6.6	0.172	Treat	SE	0.257
LSD (5%)	1.498	17.66	19.02	0.486	Geno	LSD (5%)	0.728
CV (%)	17.5	20.7	22.9	10.4	Treat.Geno	CV (%)	21.1

R= Resistant check; S= Susceptible check.

ICC 12476, ICC 12477 and ICC 12478 (5.01 to 6.25 g) yielded better than those of ICC 12479, ICCV 2 and ICC 4918 (3.63 to 4.2 g). ICC 3137, ICC 12476, ICCV 2, ICC 4918 and ICC 12426 recorded the highest grain loss of > 22 % as compared to 2.0 % in the resistant check, ICC 12475 (Table 28).

During podding stage of the crop, when the plants were infested with third instar larvae inside the cage, the larval feeding was lowest in resistant check, ICC 12475 (DR 3.6), and highest in susceptible check ICC 12426 (DR 8.2). Survival per cent of larvae was greater on susceptible check (82.6 %) as compared to the resistant check, ICC 12475 (56.7 %). The weight gain by the larva was ranged between 282.2 mg on ICC 12475 to 422.1 mg on ICC 12426 and ICC 4918. The recovery by the infested plant was better in case of ICC 12475, ICC 12476, ICC 12477 and ICC 12479 (recovery score 1.75 to 2.06) as compared to ICC 12426 (recovery score 0.66). Grain yield of infested plants was greater in case of ICC 12475, ICC 12477 and ICC 12478 (4.92 to 5.13 g) as compared to that of ICC 12426 (2.91 g). Under un-infested conditions, ICC 12475, ICC 12426, ICC 12476, ICC 12477, ICC 12478, ICC 12479 and ICC 4918 yielded > 5 g compared to ICCV 2 and ICC 3137 (4.71 – 4.86 g). The loss in grain yield was higher in case of ICC 3137, ICC 12476, ICCV 2, ICC 4918 and ICC 12426 (27.9 to 55.3 %) as compared to 2.4 % in case of ICC 12478 (Table 29).

During the second season, the pod feeding ranged between 4.2 (ICC 12475) to 8.1 (ICC 4918) and ICC 3137, ICC 12476, ICC 12477, ICC 12478, ICC 12479 and ICCV 2 suffered less pod damage than the susceptible check, ICC 12426 (DR 8.0). Larval survival ranged from 56.7 % on IC 12475 to 78.8 % on ICC 12426. Weight gain by the larva was > 350 mg in case of ICC 3137, ICC 12478, ICC 12479, ICCV 2, ICC 4918 and ICC 12426 as compared to 292.2 mg in the resistant

Table 28 : Expression of resistance and recovery of nine chickpea genotypes to neonate larvae of *H. armigera* during flowering stage (ICRISAT, Patancheru, post-rainy season, 2004-05).

Genotype	Damage rating	Larval survival (%)	Larval weight (mg)	Recovery by infested plant	Total Yield (g) infested	Total Yield (g) uninfested	Yield loss (%)
ICC 3137	7.2	76.0	69.0	1.95	3.87	5.01	22.8
ICC 12476	6.2	63.3	58.0	2.05	4.20	6.02	30.2
ICC 12477	5.8	66.7	55.5	2.36	5.01	5.37	6.7
ICC 12478	6.1	66.7	55.8	2.18	4.62	5.40	14.4
ICC 12479	6.3	70.0	61.1	2.46	3.87	3.69	-4.9
ICCV 2	6.5	72.0	71.0	2.26	3.06	4.20	27.1
ICC 4918	8.8	83.3	73.5	1.86	2.79	3.63	23.1
Controls							
ICC 12475 ®	4.8	60.1	55.5	2.88	5.94	6.06	2.0
ICC 12426 (S)	8.6	85.0	76.0	1.72	2.55	6.25	59.2
Mean	6.70	71.5	63.9	2.19	3.99	5.07	20.1
Fp (0.05)	<0.001	<0.001	0.21	<0.001			20.1
SE	1.52	6.13	5.48	0.143	<0.001	SE	0.324
LSD (5%)	1.498	15.64	16.12	0.325	<0.001	LSD (5%)	0.628
CV (%)	15.4	18.6	21.4	10.8	<0.001	CV (%)	18.4

R= Resistant check; S= Susceptible check.

Table 29 : Expression of resistance and recovery of nine chickpea genotypes to third instar larvae of *H. armigera* during podding stage (ICRISAT, Patancheru, post-rainy season, 2003-04).

Genotype	Damage rating	Larval survival (%)	Initial larval weight (mg)	Final larval weight (mg)	Weight gain by the larva	Weight gain (%)	recovery by infested plant	Total Yield (g) infested	Total Yield (g) uninfested	Yield loss (%)
ICC 3137	6.8	66.7	35.68	402.4	366.7	1027.8	0.82	3.12	4.86	35.8
ICC 12476	6.4	73.3	34.6	326.1	291.5	842.5	1.96	3.87	5.37	27.9
ICC 12477	6.8	73.3	32.78	356.4	323.6	987.2	1.86	4.92	5.25	6.3
ICC 12478	6.7	66.7	33.36	395.9	362.6	1086.8	1.54	4.95	5.07	2.4
ICC 12479	6.8	66.7	31.7	401.9	370.2	1167.8	1.75	4.5	5.01	10.2
ICCV 2	6.7	66.7	30.8	391.1	360.3	1169.8	1.56	3.12	4.71	33.8
ICC 4918	8.1	76.7	33.98	456.1	422.1	1242.3	0.85	2.91	5.88	50.5
Controls										
ICC 12475 ®	3.6	56.7	31.52	313.7	282.2	895.2	2.06	5.13	6.09	15.8
ICC 12426 (S)	8.2	82.6	31.84	446.1	422.1	1301.1	0.66	2.91	6.51	55.3
Mean	6.70	69.9	32.9	387.7	355.7	1080.1	1.45	3.94	5.42	26.4
Fp (0.05)	< 0.001	0.004	0.062	0.02	0.016		< 0.001			
SE	0.204	4.8	0.002	0.029	0.029		0.137	Treat	SE	0.244
LSD (5%)	0.58	13.8	0.005	0.085	0.083		0.387	Geno	LSD (5%)	0.69
CV (%)	6.8	15.2	12.5	16.7	17.9		9.4	Treat.Geno	CV (%)	21.8

R= Resistant check; S= Susceptible check.

check, ICC 12475. Recovery of the plants infested during the podding stage was very poor as compared to vegetative and flowering stages, however the resistant check, ICC 12475 (2.08) recovered well compared to all other genotypes. Grain yield of infested plants was > 4 g in case of ICC 12478, ICC 12479 and ICC 12475 as compared to ICC 2.91 g in the susceptible checks, ICC 4918 and ICC 12426. Under un-infested conditions, ICC 12476, ICC 12477, ICC 12478, ICC 12479, ICC 4918, ICC 12475 and ICC 12426 yielded > 5 g compared to 4.71 g in ICCV 2. ICC 12426, ICC 4918, ICC 3137, ICC 12476, ICC 12477 and ICCV 2 recorded the greater yield loss (24.6 to 55.3 %) as compared to 11.4 % in ICC 12479 (Table 30).

4.2.2.3 Survival and development of *H. armigera* on leaf material of different chickpea genotypes

4.2.2.3.1 Larval and pupal weights

Weight of the 10- day old larvae reared on leaves of different genotypes differed significantly and ranged from 298.1 mg on ICC 12475 to 396.3 mg on ICC 4918. The highest larval weight was recorded on ICC 4918 (396.3 mg per larva) followed by those reared on ICC 12426 (382.9 mg) and ICC 12478 (367.5 mg). The lowest weight of the larvae was recorded on resistant check, ICC 12475 (298.1 mg), followed by ICC 12476 (320.5 mg). Larval weight was significantly lower on ICC 12476, ICC 12477, ICC 12478, ICC 12479 and ICCV 2 as compared to susceptible check, ICC 12426 (382.9 mg). Highest weight of one day old pupae was recorded on ICC 3137 (324.5 mg) followed by ICC 4918 (323.9 mg), ICC 12479 (317.8 mg) and ICC 12426 (316.6 mg). ICC 12476, ICC 12478 and ICC 12475 recorded the lowest pupal weight (274.2 to 286.2 mg) compared to susceptible check, ICC 12426 (316.6 mg) (Table 31).

Table 30 : Expression of resistance and recovery of nine chickpea genotypes to third instar larvae of *H.armigera* during podding stage (ICRISAT, Patancheru, post-rainy season, 2004-05).

Genotype	Damage rating	Larval survival (%)	Initial larval weight (mg)	Final larval weight (mg)	Weight gain by the larva	Weight gain (%)	recovery by infested plant	Total Yield (g)		Yield loss (%)
								infested	uninfested	
ICC 3137	6.9	70.3	34.6	402.4	367.8	1063.0	0.84	3.12	4.86	35.8
ICC 12476	6.4	73.3	35.68	346.5	310.8	871.1	1.64	3.87	5.37	27.9
ICC 12477	6.8	73.3	32.78	356.4	323.6	987.2	1.55	3.96	5.25	24.6
ICC 12478	6.7	66.7	33.36	401.9	368.5	1104.7	1.54	4.32	5.07	14.8
ICC 12479	6.8	66.7	31.7	395.9	364.2	1148.9	1.75	4.44	5.01	11.4
ICCV 2	6.2	63.3	33.36	391.1	357.7	1072.4	1.56	3.12	4.71	33.8
ICC 4918	8.1	76.7	33.98	456.1	422.1	1242.3	0.88	2.91	5.88	50.5
Controls										
ICC 12475 ®	4.2	56.7	31.52	323.7	292.2	927.0	2.08	5.22	6.09	14.3
ICC 12426 (S)	8	78.8	31.84	456.1	424.3	1332.5	0.72	2.91	6.51	55.3
Mean	6.68	69.53	33.20	392.23	359.0	1083.2	1.40	3.76	5.42	29.8
Fp	< 0.001	0.004	0.062	0.02	0.016		< 0.001			
SE	0.204	4.8	0.102	0.029	0.029		0.214	Treat	SE	0.184
LSD (5%)	0.412	13.8	0.005	0.126	0.083		0.387	Geno	LSD (5%)	0.69
CV (%)	6.8	16.2	12.5	16.7	15.8		9.4	Treat.Geno	CV (%)	18.5

R= Resistant check; S= Susceptible check.

Table 31 : Survival and development of *H.armigera* on leaves of nine chickpea genotypes, ICRISAT, Patancheru, 2003-04

Genotype	Larval weight 10th day (mg)	Larval period (days)	Pupal period (days)	Pupal weight (mg)	LarvalSurvival 10th day (%)	Pupation (%)	Adult emergence (%)
ICC 3137	361.8	16.4	10.6	324.5	88	84	84
ICC 12476	320.5	16.2	11.8	274.2	76	66	60
ICC 12477	340.8	16.4	11.8	302.6	74	70	60
ICC 12478	367.5	16.5	11.0	292.3	78	74	62
ICC 12479	359.8	16.5	11.1	317.8	78	72	60
ICCV 2	329.7	16.5	12.0	300.0	84	76	70
ICC 4918	396.3	15.5	10.9	323.9	86	84	84
Controls							
ICC 12475 ®	298.1	17.8	11.7	286.2	66	64	62
ICC 12426 (S)	382.9	15.5	8.8	316.6	88	86	86
Mean	350.8	16.4	11.1	304.2	79.8	75.1	69.8
Fp (0.05)	< 0.001	< 0.001	< 0.001	< 0.001			
SE	0.0104	0.096	0.097	0.005			
LSD (5%)	0.029	0.268	0.27	0.016			
CV (%)	19.6	3.9	5.9	12.6			

R= Resistant check; S= Susceptible check.

4.2.2.3.2 Larval and pupal periods

Larval period was longer on ICC 12475 (17.8 days) than on ICCC 37 (15.5 days). There were no significant difference in larval period of ICC 3137, ICC 12476, ICC 12477, ICC 12478, ICC 12479 and ICCV 2.

The pupal period was longer on ICC 12477 (11.8 days), ICC 12476 (11.8 d), ICC 12475 (11.7 d), ICC 12479 (11.1 d) and ICC 12478 (11 days) as compared to the insects reared on ICC 12426 (8.8 days).

4.2.2.3.3 Larval survival, pupation and adult emergence (%)

Larval survival on 10^{th} day after release of the larvae was lowest on resistant check, ICC 12475 (66 %), and highest on ICC 12426 (88 %) and ICC 3137 (88 %). ICC 3137, ICCV 2, ICC 4918 and ICC 12426 recorded > 80 % larval survival as compared to 66 % in the resistant check, ICC 12475. Greater number of pupae were survived when the larvae reared on ICC 12426 (86 %), ICC 4918 (84 %) and ICC 3137 (84 %). Pupation was lowest in insects reared on the resistant check, ICC 12475 (64 %) and on ICC 12476 (66 %). Highest adult emergence rate was observed in ICCC 37 (86 %), ICC 4918 (84 %) and ICC 3137 (84 %) as compared to the emergence recorded on ICC 12476 (60 %), ICC 12477 (60 %), ICC 12478 (62 %) and ICC 12479 (60 %) and ICC 12475 (62 %) (Table 31).

The male female sex ratio and mean adult longevity of insects reared on different genotypes did not differ significantly (Table 32).

The fecundity of insects reared on ICC 12426 (1291.2 eggs $female^{-1}$) and ICC 4918 (1270.7 eggs) did not differ significantly. Reduced fecundity was observed in insects reared on ICC 12476, ICC 12477, ICC 12478, ICC 12479 and ICC 12475 as compared to the susceptible check, ICC 12476 (1291.2 eggs $female^{-1}$ $week^{-1}$). A female laid on an average of 1012.7 eggs. Egg viability of > 80 % was

Table 32 : Antibiotic influence of nine chickpea genotypes on sex ratio,fecundity, egg viability,adult longevity, growth index, adult index, ovipositional index and pupal index of *Helicoverpa armigera*, ICRISAT,Patancheru, 2003-04.

Genotype	Sex ratio		No.of eggs	Viability of	Adult longevity(days)		Growth	Adult	Oviposition	Pupal
	Male	Female	laid/female	eggs(%)	Male	Female	index	index	index	index
ICC 3137	1.0	0.9	1066.5	78.5	10.0	12.0	5.13	0.83	0.83	1.02
ICC 12476	1.0	0.8	839.5	72.5	9.5	11.5	4.06	0.79	0.65	0.87
ICC 12477	1.0	0.9	882.9[a]	76.0	10.5	11.5	4.26	0.88	0.68	0.96
ICC 12478	1.0	0.9	907.1[a]	80.0	9.5	12.0	4.47	0.79	0.70	0.92
ICC 12479	0.9	1.0	901.3[a]	75.5	10.0	12.5	4.37	0.83	0.70	1.00
ICCV 2	1.0	1.1	1170.1	82.5	11.0	13.0	4.60	0.92	0.91	0.95
ICC 4918	1.1	0.9	1270.7[b]	84.0	11.5	12.5	5.44	0.96	0.98	1.02
Controls										
ICC 12475 ®	0.9	1.0	785	69.0	9.0	10.5	3.61	0.75	0.46	0.90
ICC 12426 (S)	1.0	1.1	1291.2[b]	85.0	12.0	13.5	5.54	1.00	1.00	1.00
Mean	N.S	N.S	1012.7	N.S	N.S	N.S	-	-	-	-
Fp (0.05)			<0.001							
SE			12.84							
LSD (5%)			20.8							
CV (%)			4.7							

R= Resistant check; S= Susceptible check.

Means followed by same letter did not differ significantly at P= 0.05.

observed in ICC 12478, ICCV 2, ICC 4918 and ICC 12426. Egg viability was lower in insects reared on ICC 12476, ICC 12479 and ICC 12475 as compared to the insects reared on ICC 12426. Highest and lowest longevity of adults was recorded on resistant check, ICC 12475 and ICC 12426, susceptible check respectively.

The susceptible checks, ICC 12426 and ICC 4918 recorded highest growth index, adult index, ovipositional index and pupal index, while lowest indices were observed on the resistant check, ICC 12475 (Table 32).

4.2.2.4 Survival and development of *H. armigera* on artificial diet impregnated with lyophilized leaf and pod powder of different chickpea genotypes

4.2.2.4.1 Larval and pupal weights

Mean weight of the 10 day old larvae was highest on the standard diet (422.7 mg per larva) followed by ICC 4918 (405.4 mg) and ICCC 37 (396.6 mg). Lowest larval weight was recorded on the resistant check, ICC 12475 (257.7 mg). Highest and lowest weight of one day old pupae was recorded on the standard artificial diet (380.1 mg), while the lowest weight was recorded in insects reared on artificial diet impregnated with leaf powder of ICC 12475 (283.7 mg per pupa) (Table 33).

During the 2004-05 post-rainy season, significantly higher larval weight was recorded on standard artificial diet (468.9 mg per larva) followed by ICC 12426 (434.6 mg), ICC 4918 (429.6 mg) and ICC 3137 (410.4 mg). Lowest larval weight of 313.7 mg was recorded on ICC 12476. Larval weight on diets with ICC 12477, ICC 12478 and ICC 12475 leaf powder did not differ significantly. The pupae of the insects reared on artificial diet impregnated with lyophilized leaf powder of ICC 12476 (293.7 mg per pupa) and ICC 12477 (278.1 mg) weighed significantly lower than the insects reared on ICC 4918 (352 mg), Standard diet (351.5 mg), ICC 12426 (345.6 mg) and ICC 12479 (340.1 mg per pupa) (Table 34).

Table 33 : Survival and development of *H.armigera* on artificial diet impregnated with lyophilised leaf powder of nine chickpea genotypes (ICRISAT, Patancheru, post-rainy season, 2003-04).

Genotype	Larval weight 10thday (mg)	Larval period	Pupal period	Pupal weight (mg)	LarvalSurvival 10th day (%)	Pupation (%)	Adult emergence (%)
ICC 3137	357.1	15.5	9.7	326.6	86.0	83.3	80.0
ICC 12476	329.8	16.7	10.3	304.0	76.6	73.3	66.6
ICC 12477	380.1	16.3	11.1	322.2	73.3	66.6	66.6
ICC 12478	352.7	16.5	10.8	293.5	76.6	72.0	70.0
ICC 12479	357.6	16.9	11.7	344.8	76.6	73.3	73.3
ICCV 2	355.3	17.6	10.5	300.4	80.0	76.6	76.6
ICC 4918	405.4	16.7	10.1	359.4	90.0	86.6	86.6
Controls							
ICC 12475 ®	257.7	18.0	11.0	283.7	70.0	63.3	63.3
ICC 12426 (S)	396.6	16.5	9.1	339.7	90.0	88.0	86.0
S.D	422.7	14.8	9.0	380.1	98.0	96.0	94.0
Mean	361.5	16.5	10.3	325.4	81.7	77.9	76.3
Fp (0.05)	< 0.001	< 0.001	< 0.001	< 0.001			
SE	0.011	0.132	0.124	0.063			
LSD (5%)	0.261	0.312	0.295	0.015			
CV (%)	14	3.7	5.6	8.9			

R= Resistant check; S= Susceptible check.

S.D = Standard diet

Table 34 : Survival and development of *H.armigera* on artificial diet impregnated with lyophilised leaf powder of nine chickpea genotypes (ICRISAT, Patancheru, post-rainy season, 2004-05).

Genotype	Larval weight 10[th]day (mg)	Larval period	Pupal period	Pupal weight (mg)	LarvalSurvival 10[th] day (%)	Pupation (%)	Adult emergence (%)
ICC 3137	410.4	16.8	8.8	331.4	88.0	83.3	80.0
ICC 12476	313.7	15.6	10.6	293.7	73.3	70.0	66.6
ICC 12477	353.7	16.2	9.0	278.1	76.6	66.6	66.6
ICC 12478	358.5	16.5	10.8	301.0	76.6	70.0	70.0
ICC 12479	394.0	16.4	11.5	340.1	73.3	73.3	70.0
ICCV 2	402.0	16.3	10.9	333.6	80.0	76.6	76.6
ICC 4918	429.6	15.8	10.8	352.0	88.0	86.6	86.6
Controls							
ICC 12475 ®	356.6	16.8	11.9	338.6	70.0	63.3	63.3
ICC 12426 (S)	434.6	15.5	9.0	345.6	93.3	90.0	88.0
S.D	468.9	15.1	8.9	351.5	98.0	98.0	96.0
Mean	392.2	16.1	10.2	326.6	81.7	77.8	76.4
Fp (0.05)	< 0.001	< 0.001	< 0.001	< 0.001			
SE	0.008	0.093	0.092	0.005			
LSD (5%)	0.023	0.259	0.258	0.014			
CV (%)	11.4	3.1	4.9	8.3			

R= Resistant check; S= Susceptible check.

S.D = Standard diet

Larval survival in diet impregnated with leaf powder of F_1 hybrids, ranged between 54 % (ICC 12476 × ICC 506) to 90 % (ICC 4918 × ICCC 37). Larval survival of < 65 % was recorded in the hybrids of ICC 12476 × ICC 12479, ICC 12476 × ICC 506, ICC 12476 × ICCV 2, ICC 12477 × ICC 3137, ICC 12477 × ICC 4918, ICC 12477 × ICCV 2, ICC 12478 × ICC 12476, ICC 12478 × ICC 12479, ICC 12478 × ICC 3137, ICC 12478 × ICC 506, ICC 12478 × ICCC 37, ICC 12478 × ICCV 2, ICC 12479 × ICC 12476, ICC 12479 × ICC 12477, ICC 12479 × ICC 12478, ICC 3137 × ICC 506, ICC 3137 × ICC 12478, ICC 506 × ICC 12477, ICC 506 × ICC 12479 and ICCV 2 × ICC 506. The lowest weight of 7 day old larva was recorded in ICC 12477 × ICC 12476 (2.93 mg), while the hybrids, ICC 12476 × ICC 12477, ICC 12476 × ICC 12479, ICC 12476 × ICC 506, ICCC 37 × ICC 12478, ICCC 37 × ICC 3137, ICCV 2 × ICC 12478, ICCV 2 × ICC 3137, ICCV 2 × ICC 506 and ICCV 2 × ICCC 37 recorded the larval weight of < 4 mg (Table 35).

Weight of the 10-day old larva on artificial diet with lyophilized leaf powder of different hybrids differed significantly and ranged from 252 mg on ICC 12478 × ICC 12477 to 452.4 mg on ICC 12478 × ICCC 37. Mean weight of one day old pupa was ranged between 245.8 mg on ICC 12478 × ICC 12476 to 341.9 mg on ICC 12476 × ICC 12478. The hybrids, ICC 12476 × ICC 12478, ICC 12477 × ICC 506, ICC 12477 × ICCV 2, ICC 12478 × ICC 12477, ICC 12478 × ICC 506, ICC 12479 × ICC 12478, ICC 12479 × ICC 12476, ICC 12479 × ICC 12477, ICC 12479 × ICC 506, ICC 12479 × ICCV 2, ICC 3137 × ICC 506, ICC 3137 × ICC 12476, ICC 3137 × ICC 12477, ICC 3137 × ICC 12478, ICC 3137 × ICC 12479, ICC 4918 × ICC 12476, ICC 4918 × ICC 12477, ICC 4918 × ICC 12478, ICC 4918 × ICCV 2, ICC 506 × ICC 12476, ICC 506 × ICC 12477, ICC 506 × ICC 12478, ICC 506 × ICC 4918, ICC 506 × ICC 12479, ICC 506 × ICCV 2, ICCC 37 × ICC 12477, ICCC 37 ×

Table 35 : Larval survival and larval weight of *H.armigera* on artificial diet impregnated with lyophilised leaf powder of 72 F_1 hybrids (ICRISAT, Patancheru, post-rainy season, 2004-05).

pedigree	Larval survival (%)	Larval weight (mg)
ICC 12476 X ICC 12477	70	3.70
ICC 12476 X ICC 12478	68	4.21
ICC 12476 X ICC 12479	58	3.99
ICC 12476 X ICC 3137	70	5.30
ICC 12476 X ICC 4918	72	4.18
ICC 12476 X ICC 506	54	3.40
ICC 12476 X ICCC 37	74	4.44
ICC 12476 X ICCV 2	64	4.80
Mean	66	4.25
ICC 12477 X ICC 12476	80	2.93
ICC 12477 X ICC 12478	66	6.47
ICC 12477 X ICC 12479	66	6.29
ICC 12477 X ICC 3137	62	7.69
ICC 12477 X ICC 4918	60	8.29
ICC 12477 X ICC 506	68	4.16
ICC 12477 X ICCC 37	68	7.19
ICC 12477 X ICCV 2	56	7.79
Mean	66	6.35
ICC 12478 X ICC 12476	60	8.26
ICC 12478 X ICC 12477	66	7.06
ICC 12478 X ICC 12479	62	6.62
ICC 12478 X ICC 3137	64	7.99
ICC 12478 X ICC 4918	68	8.42
ICC 12478 X ICC 506	58	7.99
ICC 12478 X ICCC 37	58	8.61
ICC 12478 X ICCV 2	60	7.53
Mean	62	7.81
ICC 12479 X ICC 12476	64	7.47
ICC 12479 X ICC 12477	60	7.82
ICC 12479 X ICC 12478	62	6.27
ICC 12479 X ICC 3137	68	8.05
ICC 12479 X ICC 4918	70	8.99
ICC 12479 X ICC 506	72	6.28
ICC 12479 X ICCC 37	68	6.81
ICC 12479 X ICCV 2	74	7.45
Mean	67	7.39
ICC 3137 X 506	64	8.95
ICC 3137 X ICC 12476	70	7.70
ICC 3137 X ICC 12477	72	6.71
ICC 3137 X ICC 12478	64	8.65
ICC 3137 X ICC 12479	68	5.19
ICC 3137 X ICC 4918	66	7.86

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pedigree	Larval survival (%)	Larval weight (mg)
ICC 3137 X ICCC 37	76	7.46
ICC 3137 X ICCV 2	70	7.75
Mean	69	7.53
ICC 4918 X ICC 12476	68	5.62
ICC 4918 X ICC 12477	68	4.91
ICC 4918 X ICC 12478	80	5.99
ICC 4918 X ICC 12479	76	4.27
ICC 4918 X ICC 3137	82	4.03
ICC 4918 X ICC 506	70	4.62
ICC 4918 X ICCC 37	90	6.67
ICC 4918 X ICCV 2	74	4.93
Mean	76	5.13
ICC 506 X ICC 12476	72	4.00
ICC 506 X ICC 12477	60	5.09
ICC 506 X ICC 12478	66	4.66
ICC 506 X ICC 12479	64	9.41
ICC 506 X ICC 3137	76	4.02
ICC 506 X ICC 4918	72	4.28
ICC 506 X ICCC 37	70	4.63
ICC 506 X ICCV 2	66	4.50
Mean	68	5.07
ICCC 37 X ICC 12476	74	4.75
ICCC 37 X ICC 12477	72	4.86
ICCC 37 X ICC 12478	76	3.38
ICCC 37 X ICC 12479	78	4.09
ICCC 37 X ICC 3137	80	3.95
ICCC 37 X ICC 4918	82	2.94
ICCC 37 X ICC 506	68	5.05
ICCC 37 X ICCV 2	76	4.59
Mean	76	4.20
ICCV 2 X ICC 12476	72	4.10
ICCV 2 X ICC 12477	72	4.41
ICCV 2 X ICC 12478	70	3.54
ICCV 2 X ICC 12479	72	4.46
ICCV 2 X ICC 3137	68	3.74
ICCV 2 X ICC 4918	76	4.31
ICCV 2 X ICC 506	64	3.51
ICCV 2 X ICCC 37	70	3.77
Mean	71	3.98
Fp	< 0.006	< 0.001
SE	5.42	1.05
LSD (5%)	15.1	2.95
CV (%)	17.6	41.2

ICC 12476, ICCC 37 × ICC 506, ICCC 37 × ICCV 2, ICCV 2 × ICC 12476, ICCV 2 × ICC 12478, ICCV 2 × ICC 4918 and ICCV 2 × ICC 506 with larval weight of < 330 mg, and the hybrids ICC 12476 × ICC 12477, ICC 12477 × ICC 506, ICC 12477 × ICCV 2, ICC 12478 × ICC 12476, ICC 12478 × ICC 3137, ICC 12478 × ICC 4918, ICC 12478 × ICC 506, ICC 12478 × ICCV 2, ICC 12479 × ICC 12476, ICC 12479 × ICC 12477, ICC 12479 × ICC 12478, ICC 12479 × ICC 3137, ICC 12479 × ICC 3137, ICC 12479 × ICC 506, ICC 3137 × ICC 12478, ICC 3137 × ICC 12479, ICC 3137 × ICC 4918, ICC 3137 × ICCV 2, ICC 3137 × ICC 506, ICC 4918 × ICC 12476, ICC 4918 × ICC 12477, ICC 4918 × ICC 12479, ICC 4918 × ICC 3137, ICC 4918 × ICC 506, ICC 4918 × ICCV 2, ICC 506 × ICC 12476, ICC 506 × ICC 12477, ICC 506 × ICC 12478, ICC 506 × ICC 12479, ICC 506 × ICC 3137, ICC 506 × ICCC 37, ICC 506 × ICCV 2, ICCC 37 × ICC 12476, ICCC 37 × ICC 12479, ICCC 37 × ICCV 2 and ICCV 2 × ICC 12476 with pupal weight of < 300 mg, showed evidence for antibiosis mechanism of resistance as compared to 434.6 mg larval weight and 345.6 mg pupal weight on the susceptible check, ICC 12426. Average larval and pupal weights was 394.3 mg and 317.9 mg, 369.4 mg and 317.7 mg, 353.8 mg and 294.1 mg, 319.8 mg and 300.4 mg, 319.9 mg and 287.1 mg, 329 mg and 285 mg, 318.9 mg and 279.5 mg, 333.5 mg and 305.6 mg and 326.2 mg and 318 mg on the hybrids of ICC 12476, ICC 12477, ICC 12478, ICC 12479, ICC 3137, ICC 4918, ICC 506, ICCC 37 and ICCV 2 respectively (Table 36).

Larvae fed on diet with lyophilized pod powder of ICC 12475 (253.3 mg), ICC 12476 (285.4 mg) and ICC 12479 (288.3 mg) weighed significantly lower than those fed on standard diet (468.8 mg per larva), ICC 12426 (443.8 mg), ICC 3137 (424.1 mg) and ICCV 2 (420.2 mg). Larval weight on diet with pod powder of ICC

Table 36 : Survival and development of *H.armigera* on artificial diet impregnated with lyophilised leaf powder of 72 chickpea hybrids (ICRISAT, Patancheru, post-rainy season, 2004-05).

Pedigree	Larval weight 10thday (mg)	Larval period	Pupal period	Pupal weight (mg)	LarvalSurvival 10th day (%)	Pupation (%)	Adult emergence (%)
ICC 12476 X ICC 12477	361.2	15.8	9.8	297.9	80	70	60
ICC 12476 X ICC 12478	296.5	15.2	10.4	341.9	80	80	70
ICC 12476 X ICC 12479	345.7	15.9	9.8	325.0	70	70	60
ICC 12476 X ICC 3137	443.7	15.1	9.4	330.6	70	60	60
ICC 12476 X ICC 4918	402.6	15.7	9.5	315.7	80	70	70
ICC 12476 X ICC 506	389.3	15.8	10.2	312.3	70	70	60
ICC 12476 X ICCC 37	476.2	15.8	8.6	307.9	80	70	60
ICC 12476 X ICCV 2	439.2	14.9	10.2	312.2	80	80	70
Mean	394.3	15.5	9.7	317.9	76	71	64
ICC 12477 X ICC 12476	394.7	15.8	10.3	317.2	70	60	60
ICC 12477 X ICC 12478	414.2	16.2	10.3	316.7	60	60	50
ICC 12477 X ICC 12479	366.7	16.0	10.5	316.6	70	70	60
ICC 12477 X ICC 3137	410.0	16.0	10.8	332.1	80	60	60
ICC 12477 X ICC 4918	343.7	15.8	10.2	319.7	80	80	60
ICC 12477 X ICC 506	290.6	15.8	9.1	283.8	80	70	70
ICC 12477 X ICCC 37	406.2	15.2	10.3	359.0	70	60	60
ICC 12477 X ICCV 2	328.9	15.6	9.5	296.6	80	70	70
Mean	369.4	15.8	10.1	317.7	74	66	61
ICC 12478 X ICC 12476	354.2	15.9	10.6	245.8	60	60	60
ICC 12478 X ICC 12477	252.0	15.4	11.4	309.6	70	70	60
ICC 12478 X ICC 12479	403.4	16.1	10.4	324.0	80	70	70
ICC 12478 X ICC 3137	341.6	15.5	10.6	295.9	70	70	60
ICC 12478 X ICC 4918	369.3	16.5	11.3	280.6	80	80	70
ICC 12478 X ICC 506	325.9	16.6	9.1	288.0	80	70	60
ICC 12478 X ICCC 37	452.4	15.8	8.5	317.1	80	70	60
ICC 12478 X ICCV 2	332.1	15.7	8.7	291.8	90	80	80
Mean	353.8	15.9	10.1	294.1	76	71	65
ICC 12479 X ICC 12476	294.4	16.3	9.2	282.8	60	60	60
ICC 12479 X ICC 12477	285.0	16.1	9.3	296.6	70	60	60
ICC 12479 X ICC 12478	320.5	15.9	9.3	298.8	70	70	60

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Pedigree	Larval weight 10thday (mg)	Larval period	Pupal period	Pupal weight (mg)	LarvalSurvival 10th day (%)	Pupation (%)	Adult emergence (%)
ICC 12479 X ICC 3137	336.4	16.0	9.1	299.7	80	70	60
ICC 12479 X ICC 4918	341.1	15.0	8.9	309.4	80	70	60
ICC 12479 X ICC 506	314.1	16.0	9.8	295.1	70	60	60
ICC 12479 X ICCC 37	343.1	16.8	10.9	313.0	80	70	70
ICC 12479 X ICCV 2	324.1	15.9	8.5	307.7	80	70	60
Mean	319.8	16.0	9.4	300.4	74	66	61
ICC 3137 X 506	279.7	16.3	10.2	250.3	60	60	60
ICC 3137 X ICC 12476	253.8	16.4	9.9	321.7	80	80	60
ICC 3137 X ICC 12477	323.9	16.1	9.8	318.1	80	70	60
ICC 3137 X ICC 12478	309.0	16.4	10.3	290.7	80	80	60
ICC 3137 X ICC 12479	302.1	16.1	10.7	266.2	80	70	60
ICC 3137 X ICC 4918	363.5	15.1	10.3	284.7	80	70	70
ICC 3137 X ICCC 37	350.5	15.5	9.0	312.6	80	70	60
ICC 3137 X ICCV 2	376.3	15.8	10.2	252.9	70	70	60
Mean	319.9	16.0	10.1	287.1	76	71	61
ICC 4918 X ICC 12476	310.3	16.6	10.5	291.3	80	80	70
ICC 4918 X ICC 12477	325.9	15.7	9.6	274.7	70	70	70
ICC 4918 X ICC 12478	279.5	16.1	10.5	325.8	60	60	50
ICC 4918 X ICC 12479	359.7	15.9	10.0	278.5	80	80	70
ICC 4918 X ICC 3137	377.2	16.1	10.0	262.4	70	70	60
ICC 4918 X ICC 506	338.3	16.1	9.1	245.2	90	80	80
ICC 4918 X ICCC 37	338.1	14.9	9.8	323.5	80	80	70
ICC 4918 X ICCV 2	303.3	16.1	9.1	282.1	90	80	70
Mean	329	16	10	285	78	75	68
ICC 506 X ICC 12476	307.9	16.1	9.9	255.0	60	60	50
ICC 506 X ICC 12477	289.7	15.6	9.9	258.4	80	60	70
ICC 506 X ICC 12478	300.3	15.6	10.4	276.4	80	60	50
ICC 506 X ICC 12479	302.0	15.4	10.4	290.4	80	60	50
ICC 506 X ICC 3137	345.2	16.0	10.3	278.0	70	70	60
ICC 506 X ICC 4918	317.7	15.8	10.1	302.7	80	60	60
ICC 506 X ICCC 37	372.7	15.4	8.7	298.6	70	60	60
ICC 506 X ICCV 2	316.1	16.0	8.8	276.7	80	60	50
Mean	318.9	15.8	9.8	279.5	75	61	56

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Pedigree	Larval weight 10thday (mg)	Larval period	Pupal period	Pupal weight (mg)	LarvalSurvival 10th day (%)	Pupation (%)	Adult emergence (%)
ICCC 37 X ICC 12476	292.0	15.9	9.6	257.7	70	70	60
ICCC 37 X ICC 12477	299.8	16.1	10.1	316.0	80	70	70
ICCC 37 X ICC 12478	340.6	15.9	10.0	310.8	70	70	70
ICCC 37 X ICC 12479	362.3	16.2	9.4	257.5	80	80	60
ICCC 37 X ICC 3137	343.8	15.4	10.3	342.9	80	80	80
ICCC 37 X ICC 4918	445.9	15.8	9.9	330.2	90	80	80
ICCC 37 X ICC 506	292.2	15.4	9.6	338.8	90	80	80
ICCC 37 X ICCV 2	291.5	16.4	10.3	290.8	80	80	80
Mean	333.5	15.9	9.9	305.6	80	76	73
ICCV 2 X ICC 12476	279.6	15.8	10.0	279.8	60	60	60
ICCV 2 X ICC 12477	379.3	15.8	10.1	326.0	70	60	60
ICCV 2 X ICC 12478	307.9	15.8	9.1	333.0	80	80	80
ICCV 2 X ICC 12479	368.7	15.6	9.6	315.5	80	80	60
ICCV 2 X ICC 3137	269.7	16.4	10.6	329.1	70	70	70
ICCV 2 X ICC 4918	312.2	15.9	9.6	316.7	80	70	60
ICCV 2 X ICC 506	293.0	15.6	10.0	305.4	80	70	70
ICCV 2 X ICCC 37	399.5	15.7	10.3	338.3	70	60	60
Mean	326.2	15.8	9.9	318.0	74	69	65
Controls							
ICC12475 ®	356.6	16.8	11.93	338.6	70	63.3	63.3
ICC12426 (S)	434.6	15.5	9.02	345.6	93.3	90	88
S.D	468.9	15.07	8.9	351.5	98	98	96
Fp (0.05)	<0.001	<0.001	<0.001	<0.001			
SE	0.029	0.234	0.295	0.014			
LSD (5%)	0.082	0.649	0.820	0.039			
CV (%)	27.2	4.7	9.5	14.8			

R= Resistant check; S= Susceptible check.
S.D = Standard diet

12476 and ICC 12479 and ICC 3137 and ICCV 2 did not differ significantly (Table 37).

Pupal weight of one day old pupae differed significantly on different genotypes. When the larvae were reared on artificial diet with lyophilized pod powder, highest pupal weight was recorded on diet with pod powder of ICC 12426 (351.4 mg) followed by standard diet (342.1 mg) and ICC 4918 (327.9 mg). Lowest pupal weights were recorded on diet with pod powder of ICC 12475 (244.1 mg), ICC 12478 (245.7 mg) and ICC 12476 (249.5 mg) and were on par with one another.

4.2.2.4.2 Larval and pupal periods

When the larvae were reared on artificial diet with lyophilized leaf powder, longest and shortest larval periods were recorded on ICC 12475 (18 days) and ICC 3137 (15.5 days) respectively. The pupal period ranged between 9.1 days on ICC 12426 to 11.7 days on ICC 12479. The differences in pupal period between the genotypes tested were not large (Table 33).

During 2004-05 post-rainy season, differences in duration of larval and pupal development were significant. Longest and shortest larval and pupal periods was recorded in ICC 12475 (16.8 days) and ICC 12426 (15.5 days) and ICC 12475 (11.9 days) and ICC 3137 (8.8 days) respectively (Table 34).

Larval period in diet impregnated with lyophilized leaf powder of F_1 hybrids was ≤ 15.5 days on ICC 12476 × ICC 12478, ICC 12476 × ICC 3137, ICC 12476 × ICCV 2, ICC 12477 × ICCC 37, ICC 12478 × ICC 12477, ICC 12478 × ICC 3137, ICC 12479 × ICC 4918, ICC 3137 × ICC 4918, ICC 3137 × ICCC 37, ICC 4918 × ICCC 37, ICC 506 × ICC 12479, ICC 506 × ICCC 37, ICCC 37 × ICC 3137 and ICCC 37 × ICC 506. The pupal period was ranged from 8.5 days on ICC 12478 ×

ICCC 37 and ICC 12479 × ICCV 2 to 11.4 days on ICC 12478 × ICC 12477. The hybrids ICC 12476 × ICCC 37, ICC 12478 × ICCV 2, ICC 12479 × ICC 4918, ICC 506 × ICCC 37 and ICC 506 × ICCV 2 with pupal period of < 9 days did not differ significantly. The mean larval and pupal periods was 15.5 and 9.7 days, 15.8 and 10.1 days, 15.9 and 10.1 days, 16 and 9.4 days, 16 and 10.1 days, 16 and 10 days, 15.8 and 9.8 days, 15.9 and 9.9 days and 15.8 and 9.9 days on the hybrids of ICC 12476, ICC 12477, ICC 12478, ICC 12479, ICC 3137, ICC 4918, ICC 506, ICCC 37 and ICCV 2 respectively (Table 36).

Duration of the larval period of the insects reared on diet with lyophilized pod powder of different genotypes did not differ significantly. Longest and shortest pupal periods were recorded on ICC 12475 (12.03 days) and ICC 3137 (8.5 days) respectively. ICC 12477, ICCV 2, ICC 4918 and ICC 12426 recorded the lowest pupal period as compared to the resistant check, ICC 12475 (12.03 days) (Table 37).

4.2.2.4.3 Larval survival, pupation and adult emergence (%)

Larval survival on 10th day after release of the larvae was lowest on resistant check, ICC 12475 (70 %) and highest on standard diet (98 %). ICC 3137, ICCV 2, ICC 4918, ICC 12426 and standard diet recorded > 80 % larval survival as compared to resistant check, ICC 12475. The genotypes ICC 12476, ICC 12478 and ICC 12479 recorded 76.6 % larval survival and were on par with one another (Table 33).

During 2004-05 post-rainy season, ICC 3137, ICCV 2, ICC 4918, ICC 12426 and standard diet recorded higher larval survival as compared to ICC 12476, ICC 12477, ICC 12478 and ICC 12479 (Table 34). In diet with leaf powder of F_1 larval survival was ranged from 60 % on ICC 12477 × ICC 12478, ICC 12478 × ICC 12476, ICC 12479 × ICC 12476, ICC 3137 × ICC 506, ICC 4918 × ICC 12478,

Table 37 : Survival and development of *H.armigera* on artificial diet impregnated with lyophilised pod powder of nine chickpea genotypes (ICRISAT, Patancheru, post-rainy season, 2003-04).

Genotype	Larval weight 10thday (mg)	Larval period	Pupal period	Pupal weight (mg)	LarvalSurvival 10th day (%)	Pupation (%)	Adult emergence (%)
ICC 3137	424.1^{b}	16.6^{a}	8.5	315.8	86.6	80.0	70.0
ICC 12476	285.4^{a}	15.6^{a}	10.5	249.5^{b}	76.6	70.0	60.0
ICC 12477	359.1	16.2^{a}	8.9	262.4	80.0	73.3	63.3
ICC 12478	334.9	16.5^{a}	10.7	245.7^{ab}	76.6	70.0	60.0
ICC 12479	288.3^{a}	17.6^{a}	11.6	233.8	80.0	76.6	66.6
ICCV 2	420.2^{b}	17.6^{a}	9.5	274.7	83.3	80.0	66.6
ICC 4918	413.9	16.9^{a}	9.3	327.9	90.0	86.6	80.0
Controls							
ICC 12475 ®	253.3	18.3^{a}	12.03	244.1^{a}	76.0	63.3	60.0
ICC 12426 (S)	443.8	15.4^{a}	9.2	351.4	93.3	86.6	83.3
S.D	468.8	14.8^{a}	8.8	342.1	100	100	100
Mean	369.2	16.6	9.9	284.7	84.2	78.6	71.0
Fp (0.05)	< 0.001	< 0.001	< 0.001	< 0.001			
SE	2.22	0.148	0.145	2.24			
LSD (5%)	3.65	0.348	0.259	4.08			
CV (%)	1.9	3.5	5.3	2.5			

R= Resistant check; S= Susceptible check.

Means followed by same letter donot differ significantly at P= 0.05.

S.D = Standard diet

ICC 506 × ICC 12476 and ICCV 2 × ICC 12476 to 90 % on ICC 12478 × ICCV 2, ICC 4918 × ICC 506, ICC 4918 × ICCV 2, ICCC 37 × ICC 4918 and ICCC 37 × ICC 506. Average larval survival was 76 %, 74 %, 76 %, 74 %, 76 %, 78 %, 75 %, 80 % and 74 % on the hybrids of ICC 12476, ICC 12477, ICC 12478, ICC 12479, ICC 3137, ICC 4918, ICC 506, ICCC 37 and ICCV 2 respectively (Table 36).

When the larvae reared on artificial diet with lyophilized pod powder of the genotypes ICC 3137, ICC 12477, ICC 12479, ICCV 2, ICC 4918, ICC 12426 and standard diet recorded ≥ 80 % larval survival as compared to 76 % on the resistant check, ICC 12475 (Table 37).

Greater number of pupae survived when the larvae reared on standard diet (96 %) followed by ICC 12426 (88 %) and ICC 4918 (86.6 %) as compared to 63.3 % on resistant check, ICC 12475. During the second season > 80 % pupal survival was recorded on ICC 3137, ICC 4918, ICC 12426 and standard diet as compared to 63.3 % on resistant check, ICC 12475. In F_1 hybrids the pupation (%) ranged from 60 % on ICC 12476 × ICC 3137, ICC 12477 × ICC 12476, ICC 12477 × ICC 12478, ICC 12477 × ICC 3137, ICC 12477 × ICCC 37, ICC 12478 × ICC 12476, ICC 12479 × ICC 12476, ICC 12479 × ICC 12477, ICC 12479 × ICC 506, ICC 3137 × ICC 506, ICC 4918 × ICC 12478, ICC 506 × ICC 12476, ICC 506 × ICC 12477, ICC 506 × ICC 12478, ICC 506 × ICC 12479, ICC 506 × ICC 4918, ICC 506 × ICCC 37, ICC 506 × ICCV 2, ICCV 2 × ICC 12476, ICCV 2 × ICC 12477 and ICCV 2 × ICCC 37 to 80 % on ICC 12476 × ICC 12478, ICC 12476 × ICCV 2, ICC 12477 × ICC 4918, ICC 12478 × ICC 4918, ICC 12478 × ICCV2, ICC 3137 × ICC 12476, ICC 3137 × ICC 12478, ICC 4918 × ICC 12476, ICC 4918 × ICC 12479, ICC 4918 × ICC 506, ICC 4918 × ICCC 37, ICC 4918 × ICCV 2, ICCC 37 × ICC 12479, ICCC 37 × ICC 3137, ICCC 37 × ICC 4918, ICCC 37 × ICC 506, ICCC

37 × ICCV 2, ICCV 2 × ICC 12478 and ICCV 2 × ICC 12479. The average pupal survival of 71 %, 66 %, 71 %, 66 %, 71 %, 75 %, 61 %, 76 % and 69 % on the hybrids of ICC 12476, ICC 12477, ICC 12478, ICC 12479, ICC 3137, ICC 4918, ICC 506, ICCC 37 and ICCV 2 respectively (Table 36).

Highest and lowest pupal survival was recorded in insects reared on artificial diet impregnated with lyophilized pod powder on standard diet (100 %) and resistant check, ICC 12475 (63.3 %) respectively.

Highest adult emergence was observed on standard diet (94 %) followed by ICC 4918 (86.6 %), ICC 12426 (86 %) and ICC 3137 (80 %) as compared to the emergence on ICC 12479 (73.3 %) and ICCV 2 (76.6 %). During 2004-05 post-rainy season, ICC 3137, ICC 4918, ICC 12426 and standard diet recorded higher adult emergence (≥ 80 %) compared to 63.3 % on resistant check, ICC 12475. In F_1 hybrids the adult emergence ranged between 50 % on ICC 12477 × ICC 12478, ICC 4918 × ICC 12478, ICC 506 × ICC 12476, ICC 506 × ICC 12478, ICC 506 × ICC 12479 and ICC 506 × ICCV 2 to 80 % on ICC 12478 × ICCV 2, ICC 4918 × ICC 506, ICCC 37 × ICC 3137, ICCC 37 × ICC 4918, ICCC 37 × ICC 506, ICCC 37 × ICCV 2 and ICCV 2 × ICC 12478. Hybrids of ICC 12476, ICC 12477, ICC 12478, ICC 12479, ICC 3137, ICC 4918, ICC 506, ICCC 37 and ICCV 2 recorded average adult emergence of 64 %, 61 %, 65 %, 61 %, 61 %, 68 %, 56 %, 73 % and 65 % respectively (Table 36). Highest and lowest adult emergence was recorded in insects reared on artificial diet impregnated with lyophilized pod powder on standard diet (100 %) and resistant check, ICC 12475 (60 %) respectively (Table 37).

On diet with lyophilized leaf powder, highest and lowest fecundity was recorded on standard diet (1225 eggs female^{-1}) and ICC 12476 (630.7 eggs female^{-1}) respectively (Table 38). During 2004-05 post-rainy season, standard diet and ICC

Table 38 : Antibiotic influence of artificial diet impregnated with lyophilised leaf powder on sex ratio,fecundity,egg viability, adult longevity, growth index, adult index, oviposition index and pupal index of *H. armigera,* ICRISAT,Patancheru, 2003-04.

Genotype	Sex ratio		No.of eggs	Viability of	Adult longevity(days)		Growth	Adult	Oviposition	Pupal
	Male	Female	laid/female	eggs(%)	Male	Female	index	index	index	index
ICC 3137	1.0	0.9	1025	80.5	10.5	12.0	5.37	0.95	0.83	0.96
ICC 12476	0.8	1.0	630.7	76.5	9.5	12.1	4.39	0.86	0.51	0.89
ICC 12477	1.0	0.9	839.8[a]	78.5	10.5	11.5	4.09	0.95	0.68	0.95
ICC 12478	1.0	0.9	899.7	80.0	10.0	12.0	4.36	0.91	0.73	0.86
ICC 12479	0.9	1.0	854.5[a]	77.5	10.0	12.5	4.33	0.91	0.69	1.02
ICCV 2	1.0	1.1	975.7	82.5	11.0	13.0	4.35	1.00	0.79	0.88
ICC 4918	1.1	0.9	1001.7	84.0	11.5	12.5	5.19	1.05	0.81	1.06
Controls										
ICC 12475 ®	0.8	1.0	650	65.0	8.5	10.5	3.53	0.77	0.32	0.84
ICC 12426 (S)	1.0	1.1	1150	86.5	11.0	12.5	5.33	1.00	1.00	1.00
S.D	1.0	0.9	1225	91.5	11.5	12.0	6.50	1.05	1.05	1.12
Mean	N.S	N.S	925.2	N.S	N.S	N.S	-	-	-	
Fp (0.05)			<0.001							
SE			12.08							
LSD (5%)			18.99							
CV (%)			3.9							

R= Resistant check; S= Susceptible check.

Means followed by same letter donot differ significantly at P= 0.05.

S.D = Standard diet

Table 39 : Antibiotic influence of artificial diet impregnated with lyophilised leaf powder on sex ratio,fecundity,egg viability, adult longevity, growth index, adult index, oviposition index and pupal index of *Helicoverpa armigera*, ICRISAT,Patancheru, 2004-05.

Genotype	Sex ratio		No.of eggs	Viability of	Adult longevity(days)		Growth	Adult	Oviposition	Pupal
	Male	Female	laid/female	eggs (%)	Male	Female	index	index	index	index
ICC 3137	1.0	0.9	1025	80.5	10.5	12.0	4.96	0.95	0.89	0.96
ICC 12476	0.8	1.0	730.7	76.5	9.5	12.1	4.49	0.86	0.64	0.85
ICC 12477	1.0	0.9	839.8	78.5	10.5	11.5	4.11	0.95	0.73	0.80
ICC 12478	1.0	0.9	899.7	80.0	10.0	12.0	4.24	0.91	0.78	0.87
ICC 12479	0.9	1.0	854.5	77.5	10.0	12.5	4.47	0.91	0.74	0.98
ICCV 2	1.0	1.1	975.7	82.5	11.0	13.0	4.70	1.00	0.85	0.97
ICC 4918	1.1	0.9	1015	84.0	10.0	12.5	5.48	0.91	0.88	1.02
Controls										
ICC 12475 ®	0.8	1.0	675	65.0	9.0	10.5	3.77	0.82	0.59	0.98
ICC 12426 (S)	1.0	1.1	1150	86.5	11.0	12.5	5.81	1.00	1.00	1.00
S.D	1.0	0.9	1220	91.5	11.5	12.0	6.50	1.05	1.06	1.02
Mean	N.S	N.S	938.5	N.S	N.S	N.S	-	-	-	-
Fp			<0.001							
SE			11.08							
LSD (5%)			18.91							
CV (%)			3.9							

R= Resistant check; S= Susceptible check.

S.D = Standard diet

12475 recorded the highest and lowest fecundity of 1220 eggs female^{-1} and 675 eggs female^{-1} (Table 39). In diet with leaf powder of F_1, the fecundity of < 750 eggs female^{-1} was recorded on ICC 12476 × ICC 12478, ICC 12476 × ICC 12479, ICC 12476 × ICC 4918, ICC 3137 × ICC 506, ICC 3137 × ICC 12476, ICC 3137 × ICC 12477, ICC 4918 × ICC 506, ICC 506 × ICC 12476, ICC 506 × ICC 12477, ICC 506 × ICC 12479 and ICC 506 × ICC 4918 as compared to 1150 eggs female^{-1} on the susceptible check, ICC 12426. Higher fecundity was recorded on ICCC 37 × ICC 4918 (1209.8 eggs female^{-1}) followed by ICC 4918 × ICCC 37 (1199.8 eggs female^{-1}), ICCC 37 × ICC 12477 (1036.6 eggs female^{-1}), ICCC 37 × ICC 3137 (1033.2 eggs female^{-1}), ICCC 37 × ICCV 2 (1026.6 eggs female^{-1}), ICCC 37 × ICC 12479 (1019.9 eggs female^{-1}), ICCC 37 × ICC 12478 (1016.6 eggs female^{-1}), and ICCV 2 × ICCC 37 (1013.3 eggs female^{-1}) (Table 40).

Egg viability was lower on insects reared on leaf powder of ICC 12477 × ICC 12476, ICC 12478 × ICC 506, ICC 12479 × ICCV 2, ICC 506 × ICC 12476, ICC 506 × ICC 12478 and ICCC 37 × ICCV 2 (65 %) as compared to 86.5 % on the susceptible check, ICC 12426.

Mean growth indices of 4.6, 4.19, 4.47, 4.15, 3.76, 4.8, 4.84, 4.8 and 4.35 were recorded on the hybrids of ICC 12476, ICC 12477, ICC 12478, ICC 12479, ICC 3137, ICC 4918, ICC 506, ICCC 37 and ICCV 2 respectively (Table 40). On diet with lyophilized pod powder, highest and lowest fecundity was recorded on standard diet (1290.2 eggs female-1) and ICC 12475 (632.8). A female laid on an average of 978.3 eggs (Table 41). The susceptible checks, ICC 12426 and ICC 4918 recorded highest growth index, adult index, oviposition index and pupal index, while lowest indices were observed on the resistant check, ICC 12475 (Table 41).

Table 40 : Antibiotic influence of artificial diet impregnated with lyophilised leaf powder of F_1s on sex ratio,fecundity,egg viability, adult longevity, growth index, adult index, oviposition index and pupal index of *Helicoverpa armigera*, ICRISAT,Patancheru, 2004-05.

Pedigree	Sex ratio		No.of eggs laid/female	Viability of eggs(%)	Adult longevity(days)		Growth index	Adult index	Oviposition index	Pupal index
	Male	Female			Male	Female				
ICC 12476 X ICC 12477	1.0	0.9	776.7	80.5	10.5	12.0	4.44	0.95	0.68	0.86
ICC 12476 X ICC 12478	0.8	1.0	746.8	76.5	9.5	12.1	5.27	0.86	0.65	0.99
ICC 12476 X ICC 12479	1.0	0.9	733.4	78.5	10.5	11.5	4.39	0.95	0.64	0.94
ICC 12476 X ICC 3137	1.0	0.9	750.1	80.0	10.0	12.0	3.98	0.91	0.65	0.96
ICC 12476 X ICC 4918	0.9	1.0	723.4	77.5	10.0	12.5	4.46	0.91	0.63	0.91
ICC 12476 X ICC 506	1.0	1.1	883.3	82.5	11.0	13.0	4.43	1.00	0.77	0.90
ICC 12476 X ICCC 37	1.1	0.9	836.7	84.0	10.0	12.5	4.44	0.91	0.73	0.89
ICC 12476 X ICCV 2	1.0	1.1	823.4	82.5	11.0	13.0	5.38	1.00	0.72	0.90
Mean	1.0	1.0	784.2	80.3	10.3	12.3	4.6	0.94	0.68	0.92
ICC 12477 X ICC 12476	0.8	1.0	780.1	65.0	9.0	10.5	3.80	0.82	0.68	0.92
ICC 12477 X ICC 12478	1.0	1.1	826.7	86.5	11.0	12.5	3.71	1.00	0.72	0.92
ICC 12477 X ICC 12479	1.0	0.9	806.7	75.5	11.5	12.0	4.38	1.05	0.70	0.92
ICC 12477 X ICC 3137	1.0	0.9	816.7	80.5	10.5	12.0	3.75	0.95	0.71	0.96
ICC 12477 X ICC 4918	0.8	1.0	896.7	76.5	9.5	12.1	5.06	0.86	0.78	0.92
ICC 12477 X ICC 506	1.0	0.9	843.4	78.5	10.5	11.5	4.43	0.95	0.73	1.04
ICC 12477 X ICCC 37	1.0	0.9	863.4	80.0	10.0	12.0	3.94	0.91	0.75	0.82
ICC 12477 X ICCV 2	0.9	1.0	850.0	77.5	10.0	12.5	4.48	0.91	0.74	0.86
Mean	0.9	1.0	835.5	77.5	10.3	11.9	4.19	0.93	0.73	0.92
ICC 12478 X ICC 12476	1.0	1.1	696.8	82.5	11.0	13.0	3.77	1.00	0.61	0.71
ICC 12478 X ICC 12477	1.1	0.9	756.8	84.0	10.0	12.5	4.53	0.91	0.66	0.90
ICC 12478 X ICC 12479	1.0	1.1	756.8	82.5	11.0	13.0	4.36	1.00	0.66	0.94
ICC 12478 X ICC 3137	0.8	1.0	783.4	65.0	9.0	10.5	4.52	0.82	0.68	0.86
ICC 12478 X ICC 4918	1.0	1.1	833.4	86.5	11.0	12.5	4.85	1.00	0.72	0.81
ICC 12478 X ICC 506	1.0	0.9	863.4	75.5	11.5	12.0	4.21	1.05	0.75	0.83
ICC 12478 X ICCC 37	1.0	0.9	830.0	80.5	10.5	12.0	4.43	0.95	0.72	0.92
ICC 12478 X ICCV 2	0.8	1.0	890.0	76.5	9.5	12.1	5.11	0.86	0.77	0.84
Mean	1.0	1.0	801.3	79.1	10.4	12.2	4.47	0.95	0.70	0.85
ICC 12479 X ICC 12476	1.0	0.9	683.5	78.5	10.5	11.5	3.67	0.95	0.59	0.82
ICC 12479 X ICC 12477	1.0	0.9	763.4	80.0	10.0	12.0	3.73	0.91	0.66	0.86

Contd -----

Contd---- table 40

Pedigree	Sex ratio		No.of eggs	Viability of	Adult longevity(days)		Growth	Adult	Oviposition	Pupal
	Male	Female	laid/female	eggs(%)	Male	Female	index	index	index	index
ICC 12479 X ICC 12478	0.9	1.0	780.1	77.5	10.0	12.5	4.39	0.91	0.68	0.86
ICC 12479 X ICC 3137	1.0	1.1	820.0	82.5	11.0	13.0	4.38	1.00	0.71	0.87
ICC 12479 X ICC 4918	1.1	0.9	883.3	84.0	10.0	12.5	4.67	0.91	0.77	0.90
ICC 12479 X ICC 506	1.0	1.1	916.7	82.5	11.0	13.0	3.75	1.00	0.80	0.91
ICC 12479 X ICCC 37	0.8	1.0	883.3	65.0	9.0	10.5	4.16	0.82	0.77	0.85
ICC 12479 X ICCV 2	1.0	1.1	946.6	86.5	11.0	12.5	4.41	1.00	0.82	0.89
Mean	1.0	1.0	834.6	79.6	10.3	12.2	4.15	0.94	0.73	0.87
ICC 3137 X 506	1.0	0.9	710.1	75.5	11.5	12.0	3.67	1.05	0.62	0.90
ICC 3137 X ICC 12476	1.0	0.9	730.1	80.5	10.5	12.0	3.65	0.95	0.63	0.93
ICC 3137 X ICC 12477	0.8	1.0	736.8	76.5	9.5	12.1	3.73	0.86	0.64	0.92
ICC 3137 X ICC 12478	1.0	0.9	753.4	78.5	10.5	11.5	3.66	0.95	0.66	0.84
ICC 3137 X ICC 12479	1.0	0.9	820.0	80.0	10.0	12.0	3.73	0.91	0.71	0.77
ICC 3137 X ICC 4918	0.9	1.0	863.4	77.5	10.0	12.5	3.96	0.91	0.75	0.82
ICC 3137 X ICCC 37	1.0	1.1	876.7	82.5	11.0	13.0	3.87	1.00	0.76	0.72
ICC 3137 X ICCV 2	1.1	0.9	810.1	84.0	10.0	12.5	3.80	0.91	0.70	0.73
Mean	1.0	1.0	787.6	79.4	10.4	12.20	3.76	0.94	0.68	0.83
ICC 4918 X ICC 12476	1.0	1.1	976.6	82.5	11.0	13.0	4.81	1.00	0.85	0.84
ICC 4918 X ICC 12477	0.8	1.0	950.0	65.0	9.0	10.5	4.45	0.82	0.83	0.79
ICC 4918 X ICC 12478	1.0	1.1	970.0	86.5	11.0	12.5	3.73	1.00	0.84	0.94
ICC 4918 X ICC 12479	1.0	0.9	970.0	75.5	11.5	12.0	5.04	1.05	0.84	0.81
ICC 4918 X ICC 3137	1.0	0.9	946.6	80.5	10.5	12.0	4.36	0.95	0.82	0.76
ICC 4918 X ICC 506	0.8	1.0	733.2	76.5	9.5	12.1	5.61	0.86	0.64	0.71
ICC 4918 X ICCC 37	1.0	0.9	1199.8	78.5	10.5	11.5	5.38	0.95	1.04	0.94
ICC 4918 X ICCV 2	1.0	0.9	993.3	80.0	10.0	12.0	4.96	0.91	0.86	0.82
Mean	1.0	1.0	967.4	78.1	10.4	12.0	4.8	0.9	0.8	0.8
ICC 506 X ICC 12476	0.9	1.0	626.8	77.5	10.0	12.5	4.96	0.91	0.55	0.74
ICC 506 X ICC 12477	1.0	1.1	710.5	82.5	11.0	13.0	5.12	1.00	0.62	0.75
ICC 506 X ICC 12478	1.1	0.9	770.6	84.0	10.0	12.5	4.48	0.91	0.67	0.80
ICC 506 X ICC 12479	1.0	1.1	689.5	82.5	11.0	13.0	4.53	1.00	0.60	0.84
ICC 506 X ICC 3137	0.8	1.0	843.2	65.0	9.0	10.5	4.38	0.82	0.73	0.80
ICC 506 X ICC 4918	1.0	1.1	748.1	86.5	11.0	12.5	5.07	1.00	0.65	0.88
ICC 506 X ICCC 37	1.0	0.9	765.8	75.5	11.5	12.0	5.18	1.05	0.67	0.86

Contd -----

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Pedigree	Sex ratio		No.of eggs laid/female	Viability of eggs(%)	Adult longevity(days)		Growth index	Adult index	Oviposition index	Pupal index
	Male	Female			Male	Female				
ICC 506 X ICCV 2	1.0	0.9	789.6	80.5	10.5	12.0	5.00	0.95	0.69	0.80
Mean	1.0	1.0	743.0	79.3	10.5	12.3	4.84	0.95	0.65	0.81
ICCC 37 X ICC 12476	0.8	1.0	943.3	76.5	9.5	12.1	4.41	0.86	0.82	0.75
ICCC 37 X ICC 12477	1.0	0.9	1036.6	78.5	10.5	11.5	4.36	0.95	0.90	0.91
ICCC 37 X ICC 12478	1.0	0.9	1016.6	80.0	10.0	12.0	4.39	0.91	0.88	0.90
ICCC 37 X ICC 12479	0.9	1.0	1019.9	77.5	10.0	12.5	4.94	0.91	0.89	0.75
ICCC 37 X ICC 3137	1.0	1.1	1033.2	82.5	11.0	13.0	5.18	1.00	0.90	0.99
ICCC 37 X ICC 4918	1.1	0.9	1209.8	84.0	10.0	12.5	5.07	0.91	1.05	0.96
ICCC 37 X ICC 506	1.0	1.1	776.9	82.5	11.0	13.0	5.18	1.00	0.68	0.98
ICCC 37 X ICCV 2	0.8	1.0	1026.6	65.0	9.0	10.5	4.89	0.82	0.89	0.84
Mean	1.0	1.0	1007.9	78.3	10.1	12.1	4.80	0.92	0.88	0.88
ICCV 2 X ICC 12476	1.0	1.1	900.0	86.5	11.0	12.5	3.81	1.00	0.78	0.81
ICCV 2 X ICC 12477	1.0	0.9	903.3	75.5	11.5	12.0	3.80	1.05	0.79	0.94
ICCV 2 X ICC 12478	1.0	0.9	776.7	75.5	11.5	12.0	5.06	1.05	0.68	0.96
ICCV 2 X ICC 12479	0.8	1.0	796.7	80.5	10.5	12.0	5.12	0.95	0.69	0.91
ICCV 2 X ICC 3137	1.0	0.9	840.0	76.5	9.5	12.1	4.26	0.86	0.73	0.95
ICCV 2 X ICC 4918	1.0	0.9	853.4	78.5	10.5	11.5	4.41	0.95	0.74	0.92
ICCV 2 X ICC 506	0.9	1.0	906.7	80.0	10.0	12.0	4.50	0.91	0.79	0.88
ICCV 2 X ICCC 37	1.0	1.1	1013.3	77.5	10.0	12.5	3.82	0.91	0.88	0.98
Mean	1.0	1.0	873.8	78.8	10.6	12.1	4.35	0.96	0.76	0.92
Controls										
ICC12475 ®	0.8	1.0	675	65.0	9.0	10.5	3.77	0.82	0.59	0.98
ICC12426 (S)	1.0	1.1	1150	86.5	11.0	12.5	5.81	1.00	1.00	1.00
S.D	1.0	0.9	1220	91.5	11.5	12.0	6.50	1.05	1.06	1.02
Mean	N.S	N.S	855.0	N.S	N.S	N.S	-	-	-	-
Fp (0.05)			<0.001							
SE			20.130							
LSD (5%)			56.290							
CV (%)			7.1							

R= Resistant check; S= Susceptible check.
S.D = Standard diet

Table 41 : Antibiotic influence of artificial diet impregnated with lyophilised pod powder on sex ratio,fecundity,egg viability, adult longevity, growth index, adult index, oviposition index and pupal index of *Helicoverpa armigera* , ICRISAT,Ptancheru,2003-04.

Genotype	Sex ratio		No.of eggs	Viability of	Adult longevity(days)		Growth	Adult	Oviposition	Pupal
	Male	Female	laid/female	eggs(%)	Male	Female	index	index	index	index
ICC 3137	1.0	0.9	1092.9	82.5	9.5	11.5	4.82	0.92	0.88	0.90
ICC 12476	0.8	1.0	672.5	75.6	10.5	12.0	4.49	0.96	0.54	0.71
ICC 12477	0.8	0.9	860.5	78.5	11.0	11.2	4.52	0.90	0.69	0.75
ICC 12478	1.0	0.9	901.6	81.8	9.5	12.0	4.24	0.96	0.73	0.70
ICC 12479	0.9	1.0	842.0	76.3	10.0	12.5	4.35	1.00	0.68	0.67
ICCV 2	1.0	1.1	1051.5	82.5	10.5	12.8	4.55	1.02	0.85	0.78
ICC 4918	1.1	0.9	1198.1	84.0	11.5	12.5	5.12	1.00	0.97	0.93
Controls										
ICC 12475 ®	0.9	1.1	632.8	62.0	8.5	11.0	3.46	0.88	0.44	0.69
ICC 12426 (S)	1.1	1.0	1241.2	88.5	11.5	12.5	5.62	1.04	1.00	1.00
S.D	1.0	0.9	1290.2	90.5	11.5	12.0	6.76	0.96	1.04	0.97
Mean	N.S	N.S	978.3	N.S	N.S	N.S	-	-	-	
Fp (0.05)			< 0.001							
SE			6.31							
LSD (5%)			12.4							
CV (%)			2.4							

R= Resistant check; S= Susceptible check.

S.D = Standard diet

4.2.2.5 The HPLC profiles of leaf exudates

The HPLC analysis of leaf samples for acid exudates collection revealed the following results.

Among the parents, greater number of peaks were recorded on ICC 12476 and ICC 12477 (13) followed by ICC 506, ICC 12478, ICC 3137 and ICCV 2 (12). The lowest number of peaks (6) were observed in the susceptible parent, ICCC 37. Among hybrids, the highest number of (14) peaks were observed in the crosses, ICC 12476 × ICC 506, ICC 12476 × ICC 3137, ICC 12479 × ICC 12477, ICC 12479 × ICC 12478, ICC 12479 × ICC 4918, ICC 12479 × ICC 3137, ICC 12479 × ICCC 37, ICC 506 × ICC 12476, ICC 506 × ICC 12477, ICC 506 × ICC 12478, ICC 506 × ICC 4918, ICC 506 × ICC 3137, ICC 506 × ICCV 2, ICC 506 × ICCC 37, ICCC 37 × ICC 12479, ICCC 37 × ICC 4918, ICCC 37 × ICC 3137, ICC 4918 × ICC 12476, and ICC 12477 × ICC 12478 (Table 42).

The peaks at retension times, 3.51, 3.71, 3.92, 5.82, 6.77 and 16.2 were observed in all the 81 entries. The peak at RT 6.77 was absent only in ICC 12479 × ICC 506. The peak at RT 4.7 was observed in all the parents except in ICC 12478 and ICCC 37. Peak at RT 4.9 was observed in all the parents except in Annigeri and ICCC 37. The parent ICC 12478 showed the peak at RT 3.7 and 6.2. Peak 8 at RT 9.4 was observed in ICC 12476 and ICC 12479. Peak at RT 12.8 was observed in all the parents, except ICCC 37. ICC 506 had one peak at RT 15.5.

In the hybrids, peak at RT 3.7 was observed in ICC 4918 × ICC 12476, ICC 4918 × ICC 12477, ICC 4918 × ICC 3137, ICC 4918 × ICCV 2, ICC 4918 × ICCC 37, ICCC 37 × ICC 506, ICCC 37 × ICC 12476, ICCC 37 × ICC 12477, ICCC 37 × ICC 12478, ICCC 37 × ICC 12479, ICCC 37 × ICC 4918, ICCC 37 × ICCV 2, ICC 3137 × ICC 506, ICC 3137 × ICC 12477, ICC 3137 × ICCC 37, ICC 12478 × ICC

Table 42 : Number of peaks for leaf samples of nine chickpea parents and their 72 hybrids based on HPLC analysis.

Pedigree	No. of peaks
ICC 12476 X ICC 506	14
ICC 12476 X ICC 12477	10
ICC 12476 X ICC 12478	12
ICC 12476 X ICC 12479	13
ICC 12476 X ICC 4918	12
ICC 12476 X ICC 3137	14
ICC 12476 X ICCV 2	11
ICC 12476 X ICCC 37	10
ICC 12477 X ICC 506	9
ICC 12477 X ICC 12476	9
ICC 12477 X ICC 12478	7
ICC 12477 X ICC 12479	9
ICC 12477 X ICC 4918	12
ICC 12477 X ICC 3137	9
ICC 12477 X ICCV 2	9
ICC 12477 X ICCC 37	12
ICC 12478 X ICC 506	11
ICC 12478 X ICC 12476	12
ICC 12478 X ICC 12477	12
ICC 12478 X ICC 12479	12
ICC 12478 X ICC 4918	11
ICC 12478 X ICC 3137	12
ICC 12478 X ICCV 2	10
ICC 12478 X ICCC 37	12
ICC 12479 X ICC 506	12
ICC 12479 X ICC 12476	12
ICC 12479 X ICC 12477	14
ICC 12479 X ICC 12478	14
ICC 12479 X ICC 4918	14
ICC 12479 X ICC 3137	14
ICC 12479 X ICCV 2	13
ICC 12479 X ICCC 37	14
ICC 506 X ICC 12476	14
ICC 506 X ICC 12477	14
ICC 506 X ICC 12478	14
ICC 506 X ICC 12479	13
ICC 506 X ICC 4918	14
ICC 506 X ICC 3137	14
ICC 506 X ICCV 2	14

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ICC 506 X ICCC 37	14
ICC 3137 X ICC 506	11
ICC 3137 X ICC 12476	12
ICC 3137 X ICC 12477	10
ICC 3137 X ICC 12478	12
ICC 3137 X ICC 12479	11
ICC 3137 X ICC 4918	12
ICC 3137 X ICCC 37	10
ICC 3137 X ICCV 2	10
ICCC 37 X ICC 506	12
ICCC 37 X ICC 12476	12
ICCC 37 X ICC 12477	13
ICCC 37 X ICC 12478	13
ICCC 37 X ICC 12479	14
ICCC 37 X ICC 4918	14
ICCC 37 X ICC 3137	14
ICCC 37 X ICCV 2	13
ICC 4918 X ICC 506	13
ICC 4918 X ICC 12476	14
ICC 4918 X ICC 12477	13
ICC 4918 X ICC 12478	13
ICC 4918 X ICC 12479	13
ICC 4918 X ICC 3137	14
ICC 4918 X ICCV 2	12
ICC 4918 X ICCC 37	13
ICCV 2 X ICC 506	9
ICCV 2 X ICC 12476	10
ICCV 2 X ICC 12477	8
ICCV 2 X ICC 12478	8
ICCV 2 X ICC 12479	11
ICCV 2 X ICC 3137	8
ICCV 2 X ICC 4918	9
ICCV 2 X ICCC 37	12
ICC 506	12
ICC 12476	13
ICC 12477	13
ICC 12478	12
ICC 12479	11
ICC 3137	12
ICC 4918	10
ICCC 37	6
ICCV 2	12

12477, ICC 12478 × ICC 3137, ICC 12479 × ICC 12478, ICC 12479 × ICC 3137, ICC 12479 × ICCV 2, ICC 12479 × ICCC 37, ICC 506 × ICC 12476, ICC 506 × ICC 12477, ICC 506 × ICC 12478, ICC 506 × ICC 3137, ICC 506 × ICCC 37, ICC 506 × ICCV 2, ICC 12476 × ICC 506, ICC 12476 × ICC 12479, ICC 12476 × ICC 3137 and ICC 12476 × ICCV 2. The peak at RT 4.7 was observed in all the hybrids except ICC 4918 × ICC 12476, ICC 4918 × ICC 12477, ICC 4918 × ICC 3137, ICC 4918 × ICCV 2, ICC 4918 × ICCC 37, ICCC 37 × ICC 506, ICCC 37 × ICC 12476, ICCC 37 × ICC 12478, ICCC 37 × ICC 12479, ICCC 37 × ICCV 2, ICC 3137 × ICC 506, ICC 3137 × ICC 12477, ICC 3137 × ICCC 37, ICC 12478 × ICC 12477, ICC 12478 × ICC 3137, ICC 12479 × ICC 12478, ICC 12479 × ICC 3137, ICC 12479 × ICCV 2, ICC 12479 × ICCC 37, ICC 506 × ICC 12476, ICC 506 × ICC 12477, ICC 506 × ICC 12478, ICC 506 × ICC 3137, ICC 506 × ICC 3137, ICC 506 × ICCV 2, ICC 12476 × ICC 12479, ICC 12476× ICC 3137, ICC 12476 × ICCV 2 and ICC 12477 × ICC 12478. Out of 72 hybrids, only 41 hybrids recorded the peak 7 at RT 6.1. The peak at RT 4.9 was absent in 35 hybrids. The peak at RT 10.1 was observed in ICC 4918 × ICC 506, ICC 4918 × ICC 12476, ICC 4918 × ICC 12477, ICC 4918 × ICC 12478, ICC 4918× ICC 12479, ICC 4918 × ICC 3137, ICC 4918× ICCC 37, ICCC 37 × ICC 12477, ICCC 37 × ICC 12478, ICCC 37 × ICC 12479, ICCC 37 × ICC 3137, ICCC 37× ICCV 2, ICC 3137 × ICC 12476, ICC 12478 × ICC 3137, ICC 12479 × ICC 12477, ICC 12479 × ICC 12478, ICC 12479× ICC 4918, ICC 12479 × ICC 3137, ICC 12479 × ICCV 2, ICC 506 × ICC 12479, ICC 506 × ICC 4918, ICC 506 × ICCC 37, ICC 12476 × ICC 12479 and ICC 12476 × ICC 3137. None of the hybrids recorded the peak at RT 16.7. ICC 4918 × ICC 12476 and ICCC 37 × ICC 4918 recorded the peak at RT 17.1.

4.2.2.5.1 HPLC finger prints of the parents for acid exudates

4.2.2.5.1.1 ICC 506

ICC 506 had five major peaks at RT 3.89 (23.24 % area and 245558 peak height), RT 5.86 (24.2 % and 128619), RT 6.77 (12.39 % and 76486), RT 12.47 (9.07 % and 35452) and RT 15.55 (8.75 % and 32729). Less than 5 % of total area was observed in peaks at RT 3.5, 3.7, 4.7, 4.9, 9.4 and 9.7 (Table 43) (Fig 1).

4.2.2.5.1.2 ICC 12476

It had 4 major peaks at RT 3.9 (12.74 % and 121887 peak ht), RT 5.84 (25.83 % and 133731), RT 6.73 (16.77 % and 107426) and RT 15.4 (9.34 % and 33019). Out of 14 peaks, 8 peaks had < 5 % area, including citric and fumaric acids (Table 44) (Fig 2).

4.2.2.5.1.3 ICC 12477

It had 4 major peaks at RT 3.5 (15.04 % and 102183), RT 3.89 (28.43 % and 291518), RT 5.87 (20.9 % and 108983) and RT 6.82 (11.48 % and 57781). Peaks 2, 4, 5, 6, 9, 10 and peaks for citric acid and fumaric acid accounted for < 5 % area (Table 45) (Fig 3).

4.2.2.5.1.4 ICC 12478

Oxalic acid (22.01 % and 150982) at RT 3.9, malic acid (33.7 % and 133490) at RT 5.9 and acetic acid (16.59 % and 65430) at RT 6.8 were the major peaks in ICC 12478. Less than 5 % peak area was accounted for the parents at RT 3.15, 3.7, 4.3, 4.9, 9.5 and 12.8 (Table 46) (Fig 4).

4.2.2.5.1.5 ICC 12479

Oxalic acid (17.87 % and 200791) at RT 3.9, malic acid (25.41 % and 166588) at RT 5.9, acetic acid (24.45 % and 162781) at RT 6.89 and fumaric acid (12.03 % and 46980) at RT 15.9 were the major peaks in the leaf sample of ICC

Individual Sample Report

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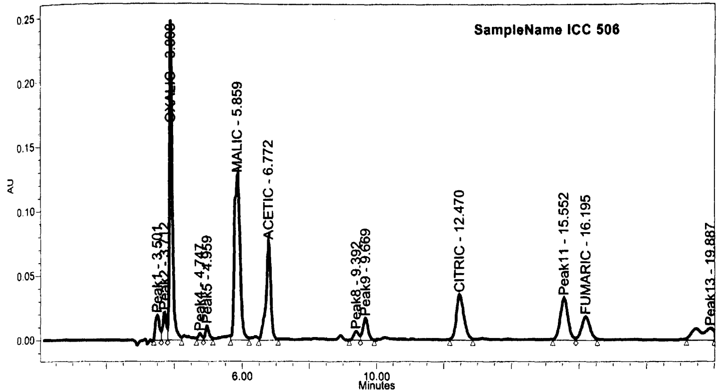

	Peak Name	RT	Area	% Area	Height
1	Peak1	3.501	162911	2.68	19055
2	Peak2	3.712	151862	2.50	21165
3	OXALIC	3.898	1414178	23.24	245558
4	Peak4	4.747	38834	0.64	4883
5	Peak5	4.959	84544	1.39	10883
6	MALIC	5.859	1472468	24.20	128619
7	ACETIC	6.772	753775	12.39	76486
8	Peak8	9.392	75964	1.25	6924
9	Peak9	9.669	186874	3.07	17154
10	CITRIC	12.470	551806	9.07	35452
11	Peak11	15.552	532425	8.75	32729
12	FUMARIC	16.195	324472	5.33	18200
13	Peak13	19.887	335218	5.51	9308

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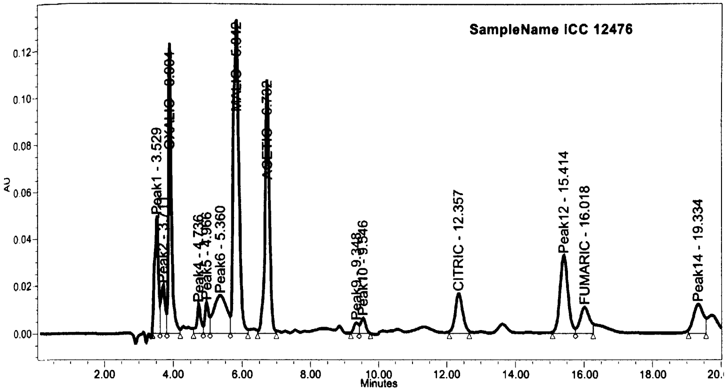

	Peak Name	RT	Area	% Area	Height
1	Peak1	3.529	382228	6.66	49218
2	Peak2	3.711	176539	3.08	20134
3	OXALIC	3.904	731093	12.74	121887
4	Peak4	4.736	96593	1.68	12132
5	Peak5	4.966	101997	1.78	12994
6	Peak6	5.360	418052	7.29	15928
7	MALIC	5.842	1481796	25.83	133731
8	ACETIC	6.732	962248	16.77	107426
9	Peak9	9.348	47444	0.83	4756
10	Peak10	9.546	71060	1.24	6601
11	CITRIC	12.357	262854	4.58	16911
12	Peak12	15.414	535752	9.34	33019
13	FUMARIC	16.018	216902	3.78	11226
14	Peak14	19.334	252613	4.40	12420

Individual Sample Report

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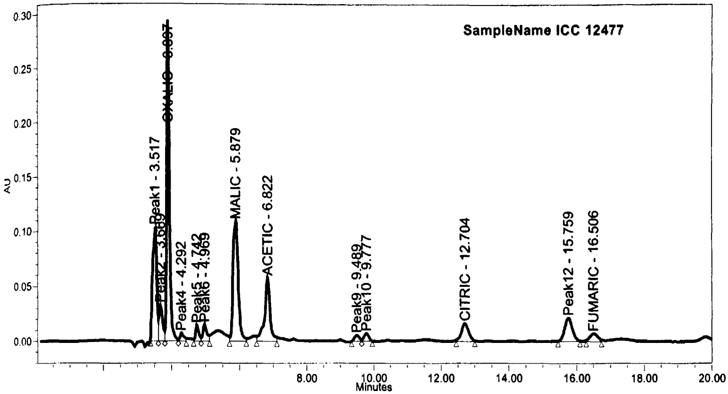
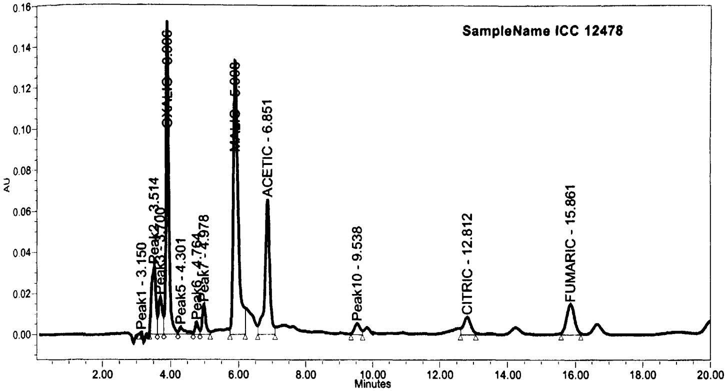


	Peak Name	RT	Area	% Area	Height
1	Peak1	3.517	851728	15.04	102183
2	Peak2	3.669	242281	4.28	32764
3	OXALIC	3.897	1610067	28.43	291518
4	Peak4	4.292	58161	1.03	7223
5	Peak5	4.742	97412	1.72	14669
6	Peak6	4.969	123403	2.18	15136
7	MALIC	5.879	1183700	20.90	108983
8	ACETIC	6.822	650210	11.48	57781
9	Peak9	9.489	59323	1.05	5592
10	Peak10	9.777	75366	1.33	7333
11	CITRIC	12.704	245859	4.34	16252
12	Peak12	15.759	343797	6.07	21552
13	FUMARIC	16.506	121104	2.14	7302

Individual Sample Report

Reported by User: System

Project Name: OrganicacidsEstimation



	Peak Name	RT	Area	% Area	Height
1	Peak1	3.150	2942	0.08	966
2	Peak2	3.514	282441	7.29	32917
3	Peak3	3.700	147430	3.80	17952
4	OXALIC	3.906	853087	22.01	150982
5	Peak5	4.301	45336	1.17	3386
6	Peak6	4.764	40448	1.04	5861
7	Peak7	4.978	106937	2.76	14592
8	MALIC	5.908	1306453	33.71	133490
9	ACETIC	6.851	642947	16.59	65430
10	Peak10	9.538	68083	1.76	5422
11	CITRIC	12.812	135076	3.49	8608
12	FUMARIC	15.861	244656	6.31	14957

12479. Peak 2, 4, 5, 8, 9, citric acid and peak 12 were the minor peaks with < 3 % peak area (Table 47) (Fig 5).

4.2.2.5.1.6 ICC 3137

Out of five organic acids, 4 organic acids i.e. oxalic acid, malic acid, acetic acid and fumaric acid occupied the major area. Less than 15 % area was occupied by oxalic acid with peak height of 120348 at RT 3.9. Malic acid at RT 5.9 occupied 17.95 % area with peak height of 93713. Peak area of ≥ 25 % was observed in acetic acid and fumaric acid at RT 6.89 and 16.0, respectively (Table 48) (Fig 6).

4.2.2.5.1.7 ICC 4918

Oxalic acid with peak area of 47.02 % was the major peak followed by fumaric acid with 12.53 % area and 50217 peak height at RT 16.03. Peaks 2,4,7 and 10 were the minor peaks (Table 49) (Fig 7).

4.2.2.5.1.8 ICCC 37

This genotype had the lowest number of peaks (6). Except citric acid, all the acids occupied the major area. Oxalic acid peak with RT 3.9 (46.28 % area and 248336 ht) was the major peak, followed by malic acid at RT 5.9 (30.4 % and 39064 ht), acetic acid at RT 6.86 (14.33 % area and 39064 ht), and fumaric acid with RT 15.9 (154413 peak area, 5.93 % area and 13740 peak ht). Peak 2 was minor with < 0.5 % area (Table 50) (Fig 8).

4.2.2.5.1.9 ICCV 2

ICCV 2 had 4 mjor peaks at RT 3.5 (20.4 % area and 219763 ht), oxalic acid at RT 3.9 (16.35 % area and 214244 ht), malic acid at RT 5.96 (21.06 % area and 188465 ht) and acetic acid at RT 6.95 (12.44 % area and 94152 ht). Peak 4, 5, 9 and 10 were minor with < 1 % area (Table 51) (Fig 9).

Individual Sample Report

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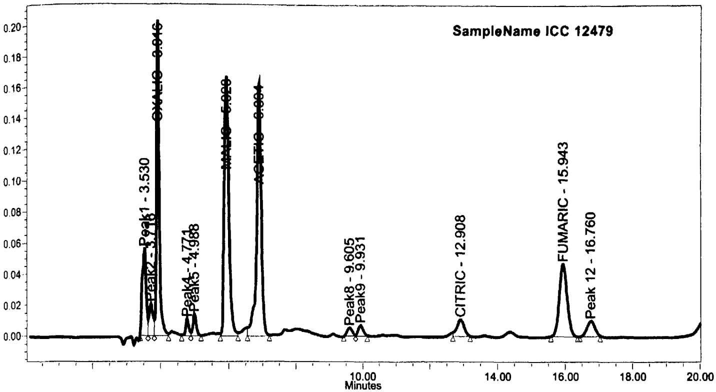

	Peak Name	RT	Area	% Area	Height
1	Peak1	3.530	450203	7.16	56012
2	Peak2	3.716	169555	2.69	20660
3	OXALIC	3.916	1124451	17.87	200791
4	Peak4	4.771	71869	1.14	11144
5	Peak5	4.988	96158	1.53	14226
6	MALIC	5.928	1598969	25.41	166588
7	ACETIC	6.894	1538461	24.45	162781
8	Peak8	9.605	63975	1.02	5575
9	Peak9	9.931	78112	1.24	7185
10	CITRIC	12.908	172450	2.74	11117
11	FUMARIC	15.943	757148	12.03	46980
12	Peak 12	16.760	170716	2.71	10193

Individual Sample Report

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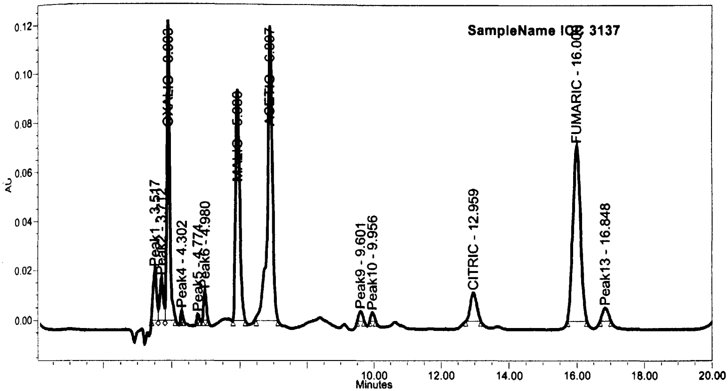

	Peak Name	RT	Area	% Area	Height
1	Peak1	3.517	143654	3.27	20522
2	Peak2	3.712	122339	2.79	17292
3	OXALIC	3.903	668756	15.23	120348
4	Peak4	4.302	14102	0.32	4044
5	Peak5	4.774	10086	0.23	2608
6	Peak6	4.980	61393	1.40	11849
7	MALIC	5.930	788242	17.95	93713
8	ACETIC	6.897	1219989	27.78	119817
9	Peak9	9.601	31904	0.73	3964
10	Peak10	9.956	23150	0.53	3429
11	CITRIC	12.959	148633	3.38	11412
12	FUMARIC	16.000	1096952	24.98	71430
13	Peak13	16.848	62839	1.43	5324

Individual Sample Report

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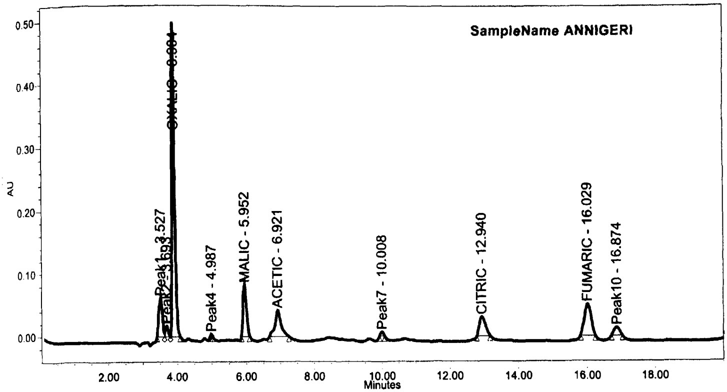

	Peak Name	RT	Area	% Area	Height
1	Peak1	3.527	443515	8.14	61826
2	Peak2	3.693	98576	1.81	17098
3	OXALIC	3.904	2560263	47.02	492088
4	Peak4	4.987	10677	0.20	3893
5	MALIC	5.952	571576	10.50	82915
6	ACETIC	6.921	516208	9.48	41727
7	Peak7	10.008	41961	0.77	7159
8	CITRIC	12.940	376509	6.91	30482
9	FUMARIC	16.029	682558	12.53	50217
10	Peak10	16.874	143777	2.64	12753

Individual Sample Report

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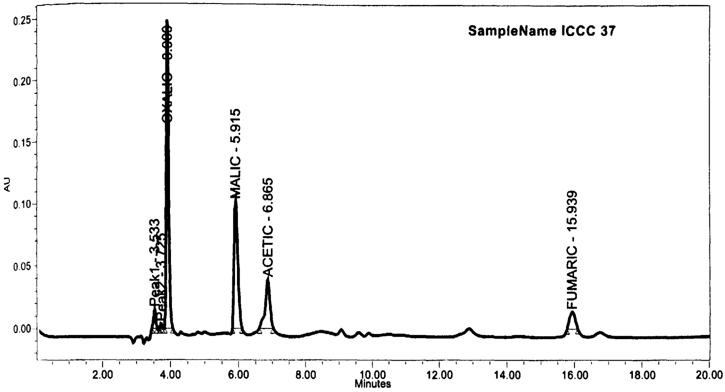

	Peak Name	RT	Area	% Area	Height
1	Peak1	3.533	66931	2.57	14780
2	Peak2	3.725	12531	0.48	3804
3	OXALIC	3.909	1204621	46.28	248336
4	MALIC	5.915	791207	30.40	101533
5	ACETIC	6.865	373108	14.33	39064
6	FUMARIC	15.939	154413	5.93	13740

Individual Sample Report

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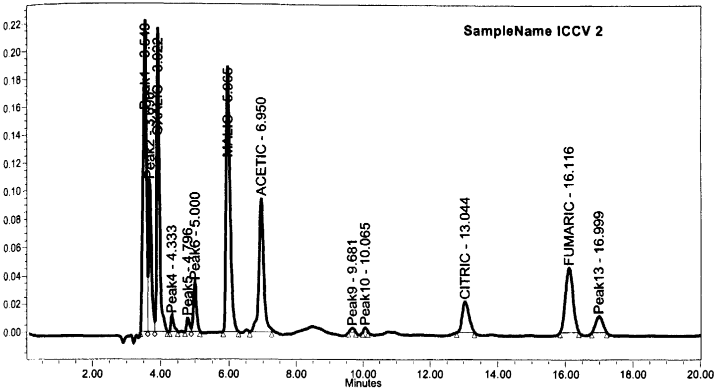


	Peak Name	RT	Area	% Area	Height
1	Peak1	3.549	1487461	20.42	219763
2	Peak2	3.690	591938	8.12	105982
3	OXALIC	3.922	1191479	16.35	214244
4	Peak4	4.333	70754	0.97	11532
5	Peak5	4.796	60071	0.82	9682
6	Peak6	5.000	215460	2.96	34512
7	MALIC	5.965	1534254	21.06	188465
8	ACETIC	6.950	906021	12.44	94152
9	Peak9	9.681	24064	0.33	2874
10	Peak10	10.065	21132	0.29	3269
11	CITRIC	13.044	304103	4.17	22048
12	FUMARIC	16.116	708724	9.73	46233
13	Peak13	16.999	170195	2.34	11690

4.2.2.5.2 Correlations

4.2.2.5.2.1 Correlation between peak area at different retension times and insect damage

Correlations between peak area at different retension times and insect damage in chickpea genotypes showed the following results.

Peak at RT 3.52 showed negative and significant correlation with larval weight (-0.255*). Peak at RT 3.72 was negatively and significantly correlated with larval weight (-0.216*) and total number of larvae (-0.238*). The correlation co-efficient was significant and positive with larval survival (0.225*). Peak at RT 5.3 showed significantly positive correlation with damage rating (0.285**). Malic acid at RT 6.76 the peak area showed significantly negative correlation with damage rating at flowering (-0.275*), damage rating at maturity (-0.321**) and pod borer damage (%) (-0.218*). Peak area at RT 6.82 showed negatively significant correlation with damage rating at flowering (-0.229*) and at maturity (-0.275**). Peak area at RT 10.3 showed positive and significant correlation with larval survival (%) (0.253*) and negative correlation with damage rating at flowering (-0.221*). Significant and positive correlation was also recorded between the peak at RT 10.33 and larval survival (0.415**), and a negative with larval weight (-0.241*). Citric acid showed positive significant correlation with larval survival (0.251*) and negative significant with larval weight (-0.225*). Peak at RT 16.76, showed positive correlation with damage rating at vegetative stage (0.234*), and at maturity (0.231*) and pod damage (0.339**) (Table 52).

Table 52 : Correlations between peak area and insect damage parameters in chickpea

Retension time	Damage rating	Larval survival	Larval weight	Total eggs	Total larvae	DR		Pod damage (%)
						Flowering	Maturity	
RT 3.52	-0.12	-0.04	-0.26*	-0.14	-0.07	0.02	-0.05	-0.16
RT 3.69	-0.06	0.21	-0.08	-0.03	-0.17	-0.20	0.02	0.01
RT 3.72	-0.10	0.23*	-0.22*	-0.05	-0.24	-0.12	0.01	-0.06
Oxalic acid	-0.19	0.20	-0.18	-0.06	-0.20	-0.19	-0.12	-0.08
RT 4.76	0.12	0.16	0.17	0.03	0.12	-0.03	-0.19	0.00
RT 4.95	0.20	0.17	0.02	-0.01	0.07	0.08	-0.02	0.02
RT 4.98	-0.02	0.08	-0.02	-0.20	0.05	-0.07	-0.01	0.09
RT 5.92	0.29**	0.03	0.14	-0.05	-0.13	0.10	0.16	0.16
Malic acid	-0.13	-0.13	-0.03	0.19	-0.08	-0.28*	-0.32**	-0.22*
Acetic acid	0.18	0.07	0.07	0.07	0.06	-0.09	0.06	0.12
RT 6.82	-0.07	0.07	-0.08	-0.19	0.01	-0.23*	-0.28**	-0.15
RT 9.95	0.03	0.08	-0.12	-0.08	-0.01	-0.09	0.02	0.01
RT 10.3	-0.02	0.25*	-0.13	-0.01	-0.18	-0.22*	-0.09	-0.12
RT 10.33	-0.11	0.42**	-0.24*	-0.03	0.01	-0.08	-0.02	-0.08
Citric acid	-0.13	0.25*	-0.23*	0.04	0.12	-0.03	0.09	-0.09
Fumaric acid	0.17	0.00	0.11	-0.15	0.01	-0.16	-0.07	0.01
RT 16.76	0.23*	0.07	0.05	-0.05	0.01	0.04	0.23*	0.34**

4.2.2.5.2.2 Correlation between peak height at different retension times and insect damage

At RT 3.52 the peak height showed a significant and negative correlation with larval weight (-0.258*). Peak height at RT 3.68 showed a negative correlation with larval weight (-0.224*). Oxalic acid showed a negatively significant correlation with damage rating (-0.217*). At RT 4.2, the peak height showed positive and significant correlation with larval survival (%) (0.254*) and a negative correlation with larval weight (-0.295*). Acetic acid showed negatively significant correlation with larval weight (-0.451**), damage rating at flowering (-0.329**) and at maturity (-0.257*). At RT 7.3 the peak height showed positively significant correlation with larval survival (%) (0.252*). Pod damage showed significantly positive correlation with peak height at RT 9.4. Citric acid showed positive correlation with larval survival (0.25*). At RT 15.5 the peak height showed a significant positive correlation with total eggs (0.224*), damage rating at maturity (0.296**) and pod damage (0.28**) (Table 53).

4.2.2.5.3 Organic acid amounts on fresh weight (mg/g) basis

4.2.2.5.3.1 **Oxalic acid**

High amounts of oxalic acid were recorded in ICC 4918 (66.33), followed by ICC 12477 (47.38), ICC 506 (36.9), ICCC 37 (32.58) and ICCV 2 (31.55). The genotype ICC 3137 had lowest amount of oxalic acid (15.04 mg/g) (Table 54) (Fig 10).

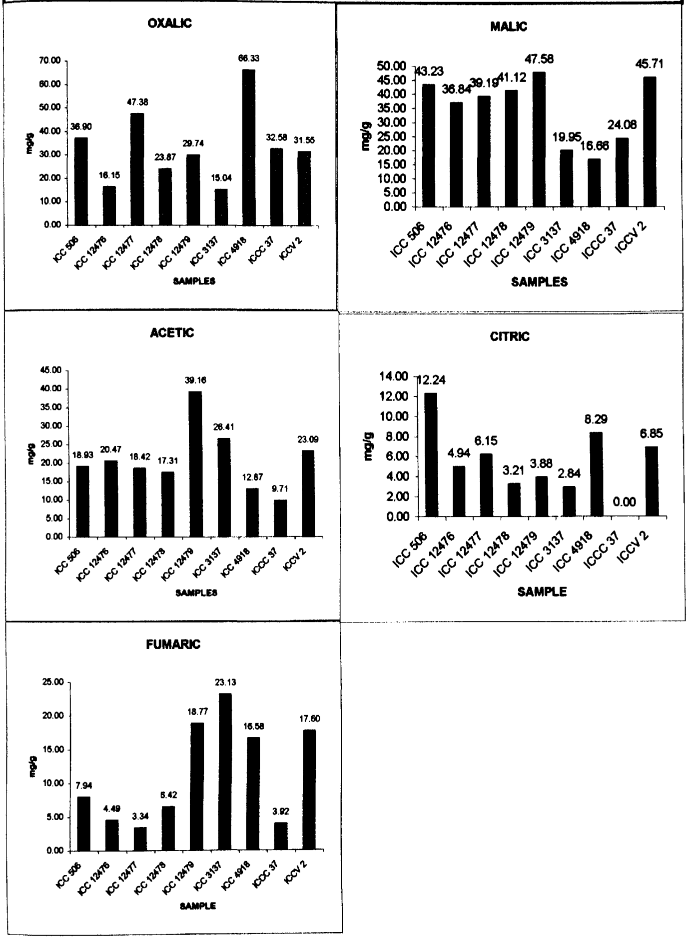
4.2.2.5.3.2 Malic acid

Highest amounts of malic acid were observed in ICC 12479 (47.58) followed by ICCV 2 (45.71), ICC 506 (43.23), and ICC 12478 (41.12). Lowest amount of 16.66 mg/g malic acid was recorded in ICC 4918.

Table 53 : Correlation between peak height and insect damage parameters in chickpea

Retension time	Damage rating	Larval survival	Larval weight	Total eggs	Total larvae	DR		Pod damage (%)
						Flowering	Maturity	
RT_3_2	0.09	0.15	0.10	0.01	-0.12	-0.04	-0.02	0.11
RT_3_52	-0.12	0.17	-0.26*	-0.08	-0.20	-0.10	-0.09	-0.14
RT_3_68	-0.02	0.18	-0.22*	-0.08	-0.21	-0.05	-0.01	-0.11
Oxalic acid	-0.22	0.17	-0.19	-0.07	-0.19	-0.20	-0.14	-0.09
RT_4_2	-0.15	0.25*	-0.30**	0.00	-0.12	-0.02	0.05	-0.06
RT_4_76	-0.12	0.15	-0.14	-0.10	-0.12	-0.19	-0.14	-0.13
RT_4_95	0.18	0.10	0.02	-0.12	-0.12	0.20	0.21	0.15
RT_5_3	0.02	-0.04	-0.04	-0.07	-0.05	-0.17	-0.17	0.05
Malic acid	0.19	-0.04	0.04	-0.14	-0.10	-0.05	0.06	0.05
Acetic acid	-0.20	0.17	-0.45**	0.04	0.05	-0.33**	-0.26*	-0.20
RT_6_82	0.10	-0.18	0.14	-0.01	0.05	-0.06	-0.04	0.13
RT_7_3	0.00	0.25*	0.02	-0.05	0.02	-0.18	-0.08	-0.21
RT_8_5	0.12	0.17	0.13	-0.06	0.16	0.01	0.15	-0.04
RT_9_4	0.16	0.10	-0.16	-0.03	0.05	0.17	0.13	0.27*
RT_9_7	0.00	0.14	-0.04	0.03	-0.07	-0.10	-0.11	0.04
RT_10_3	0.13	0.19	0.09	-0.04	-0.06	-0.12	0.06	0.14
Citric acid	-0.07	0.25	-0.15	-0.07	-0.16	-0.21	-0.11	-0.13
RT_15_5	0.21	0.12	-0.11	0.22*	0.04	0.20	0.30**	0.28**
Fumaric acid	0.16	-0.01	0.10	-0.13	0.00	-0.05	0.05	0.18
RT_17_1	0.08	0.31	0.05	-0.05	-0.10	-0.09	0.08	0.03
RT_19_9	-0.07	-0.14	-0.19	0.01	0.03	-0.13	-0.06	-0.12

Fig 10 : Amounts of organic acids on fresh weight (mg/g) basis of the leaf samples based on HPLC analysis.



4.2.2.5.3.3 Acetic acid

ICC 12479 showed highest amount of acetic acid 39.16 mg/g, followed by ICC 3137 (26.41), ICCV 2 (23.09), and ICC 12476 (20.47). ICCC 37 recorded the lowest amount of 9.71 mg/g of acetic acid.

4.2.2.5.3.4 Citric acid

The resistant genotype, ICC 506 recorded the highest amount of citric acid (12.24 mg/g) followed by ICC 4918 (8.29) and ICCV 2 (6.85 mg/g). Citric acid was absent in the susceptible genotype, ICCC 37.

4.2.2.5.3.5 Fumaric acid

Highest amount of fumaric acid was recorded in ICC 3137 (23.13), followed by ICC 12479 (18.77), ICCV 2 (17.6) and ICC 4918 (16.58). The resistant and susceptible genotypes (ICC 506 and ICCC 37) recorded 7.94 and 3.92 mg/g of fumaric acid, respectively (Table 54) (Fig 10).

4.2.2.5.4 **Amounts of organic acids on leaves of different genotypes – Dry weight (mg/g) basis**

4.2.2.5.4.1 **Oxalic acid**

Highest amount of oxalic acid was recorded in ICC 4918 (547.06), followed by ICC 12477 (316.94), ICC 506 (209.2) and ICC 12479 (175.01). The genotype ICC 3137 had the lowest amount of oxalic acid (102.57 mg/g) (Table 55) (Fig 11).

4.2.2.5.4.2 Malic acid

Among the nine parents, ICC 12476 recorded the highest amount of 362.79 mg/g of malic acid, followed by ICC 12479 (279.98 mg/g), and ICC 12477 (262.14). The resistant genotype ICC 506 recorded 245.05 mg/g. The susceptible genotype, ICCC 37 recorded the lowest amount of 112.67 mg/g.

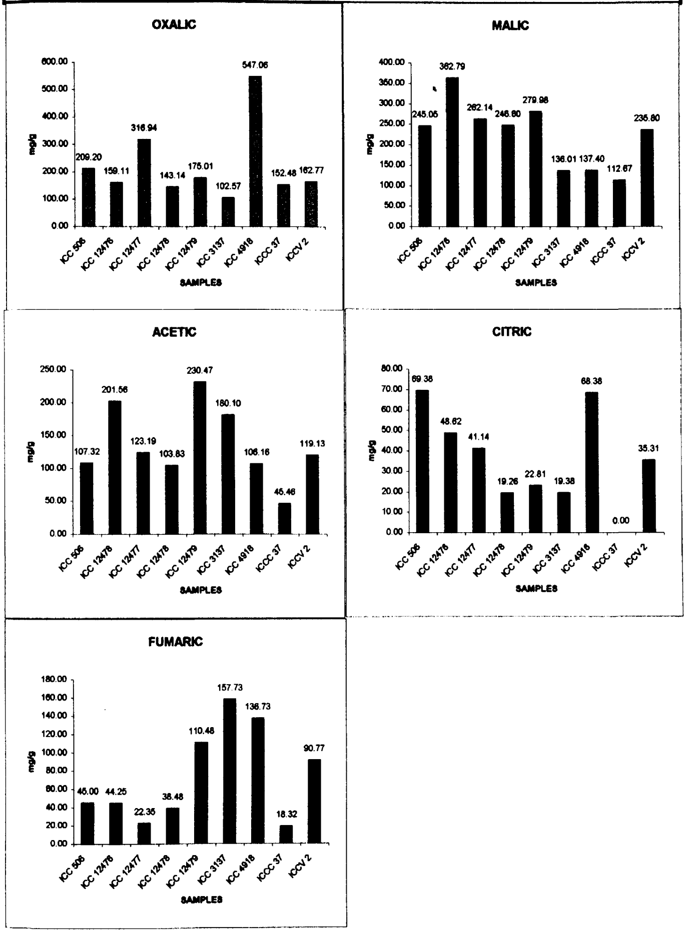
Table 54 : Amounts of organic acids on fresh weight basis of the leaf samples (mg/g) based on HPLC analysis.

Parents	Oxalic acid	Malic acid	Acetic acid	Citric acid	Fumaric acid
ICC 506	36.90	43.23	18.93	12.24	7.94
ICC 12476	16.15	36.84	20.47	4.94	4.49
ICC 12477	47.38	39.19	18.42	6.15	3.34
ICC 12478	23.87	41.12	17.31	3.21	6.42
ICC 12479	29.74	47.58	39.16	3.88	18.77
ICC 3137	15.04	19.95	26.41	2.84	23.13
ICC 4918	66.33	16.66	12.87	8.29	16.58
ICCC 37	32.58	24.08	9.71	-	3.92
ICCV 2	31.55	45.71	23.09	6.85	17.60

Table 55 : Amounts of organic acids on dry weight basis of the leaf samples (mg/g) based on HPLC analysis.

Parents	Oxalic acid	Malic acid	Acetic acid	Citric acid	Fumaric acid
ICC 506	209.20	245.05	107.32	69.38	45.00
ICC 12476	159.11	362.79	201.56	48.62	44.25
ICC 12477	316.94	262.14	123.19	41.14	22.35
ICC 12478	143.14	246.60	103.83	19.26	38.48
ICC 12479	175.01	279.98	230.47	22.81	110.48
ICC 3137	102.57	136.01	180.10	19.38	157.73
ICC 4918	547.06	137.40	106.16	68.38	136.73
ICCC 37	152.48	112.67	45.46	-	18.32
ICCV 2	162.77	235.80	119.13	35.31	90.77

Fig 11 : Amounts of organic acids on dry weight (mg/g)basis of the leaf samples based on HPLC analysis.



4.2.2.5.4.3 Acetic acid

ICC 12479 recorded the highest amount of 230.47 mg/g, followed by ICC 12476 (201.56), and ICC 3137 (180.1). Lowest amount of 45.46 mg/g was observed in the susceptible check, ICCC 37.

4.2.2.5.4.4 Citric acid

The resistant genotype ICC 506 recorded the highest amount of citric acid (69.38 mg/g), followed by ICC 4918 (68.38) and ICC 12476 (48.62). Citric acid was completely absent in the susceptible genotype, ICCC 37.

4.2.2.5.4.5 Fumaric acid

Highest amount of 157.73 mg/g was recorded in ICC 3137, followed by ICC 4918 (136.73), ICC 12479 (110.48) and ICCV 2 (90.77). The resistant genotype ICC 506 recorded 45.0 mg/g fumaric acid (Table 55) (Fig 11).

4.2.2.5.5 **Amounts of organic acids on the leaves of different chickpea genotypes – leaf area (mg/cm^2) basis**

4.2.2.5.5.1 **Oxalic acid**

Higher amounts of oxalic acid were observed in ICC 4918 (3.62), followed by ICC 12477 (1.99), ICC 12479 (1.2) and ICC 506 (1.04). ICC 3137 recorded the lowest amount of 0.53 mg/g (Table 56) (Fig 12).

4.2.2.5.5.2 Malic acid

The genotype ICC 12479 recorded the highest amount of malic acid (1.91), followed by ICC 12476 (1.74), ICC 12477 (1.64) and ICCV 2 (1.31). The susceptible genotype, ICCC 37 recorded the lowest amount of 0.54 mg/g.

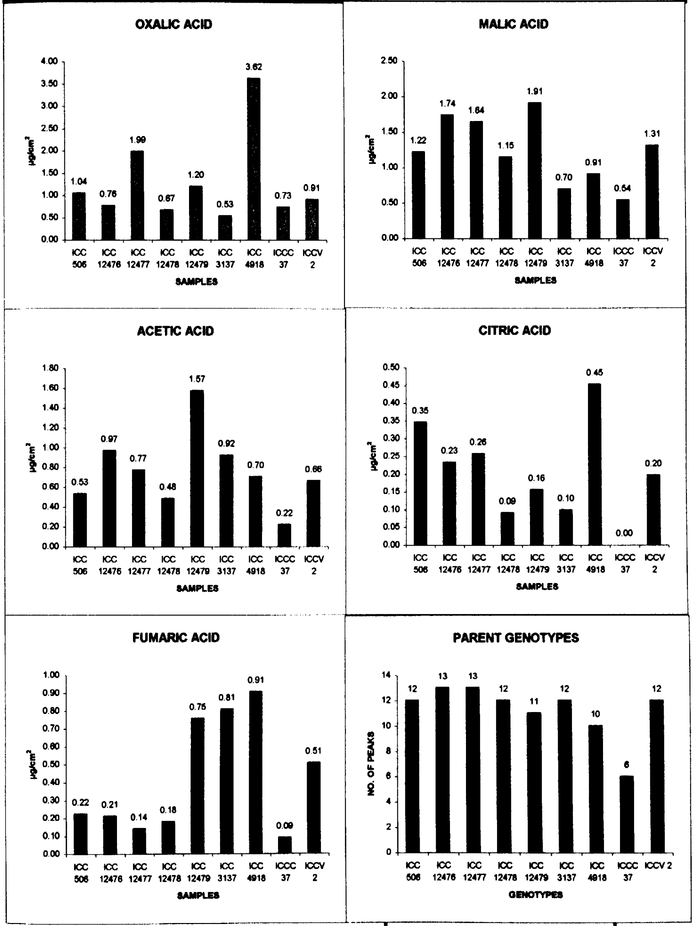
4.2.2.5.5.3 Acetic acid

The genotypes ICC 12479 (1.57), ICC 12476 (0.97), ICC 3137 (0.92) and ICC 12477 (0.77) recorded higher amount of acetic acid compared to ICC 506

Table 56 : Amounts of organic acids on fresh weight basis of the leaf samples (mg/cm^2) based on HPLC analysis.

Parents	Oxalic acid	Malic acid	Acetic acid	Citric acid	Fumaric acid
ICC 506	1.04	1.22	0.53	0.35	0.22
ICC 12476	0.76	1.74	0.97	0.23	0.21
ICC 12477	1.99	1.64	0.77	0.26	0.14
ICC 12478	0.67	1.15	0.48	0.09	0.18
ICC 12479	1.20	1.91	1.57	0.16	0.75
ICC 3137	0.53	0.70	0.92	0.10	0.81
ICC 4918	3.62	0.91	0.70	0.45	0.91
ICCC 37	0.73	0.54	0.22	-	0.09
ICCV 2	0.91	1.31	0.66	0.20	0.51

Fig 12: Amounts of organic acids on leaf area (mg/cm^2) based on HPLC analysis.



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(0.53), ICC 12478 (0.48), ICC 4918 (0.7) and ICCV 2 (0.66). The susceptible genotype, ICCC 37 recorded the lowest amount of 0.22 mg/g.

4.2.2.5.5.4 Citric acid

ICC 4918 recorded highest amount of citric acid (0.45), followed by ICC 506 (0.35). Citric acid was absent in the susceptible genotype, ICCC 37.

4.2.2.5.5.5 Fumaric acid

ICC 4918 recorded the highest amount of fumaric acid (0.91), followed by ICC 3137 (0.81), ICC 12479 (0.75) and ICCV 2 (0.51). The lowest amount of 0.09 mg/g was observed in susceptible check, ICCC 37 (Table 56) (Fig 12).

4.2.2.5.6 Association between organic acid content and chickpea damage by *H. armigera*

Significant and positive correlation was recorded between citric acid on fresh weight basis with larval survival (0.219*), and fumaric acid with pod damage (0.32**) and damage rating (0.232*) (Table 57).

On dry weight basis, citric acid showed a negative and significant correlation with damage rating at flowering (-0.226*) and a positive correlation with larval survival (0.264*). Fumaric acid showed a positive correlation with pod damage (0.318**) and damage rating (0.266*) (Table 58).

On leaf area basis (mg/cm^2) citric acid showed a positive and significant correlation with larval survival (0.238*). Fumaric acid showed a positive and significant correlation with pod damage (%) (0.326**) and damage rating (0.263*). Malic acid showed a positive correlation with damage rating (0.226*) (Table 59).

For leaf area (ug/cm^2), citric acid showed a positive correlation with larval survival (0.245*). Fumaric acid showed significant and positive correlation with pod borer (%) (0.327**) and damage rating (0.264*) (Table 60).

Table 57 : Correlations between *H. armigera* damage parameters and amounts of organic acids on fresh weight basis

Acid	Pod damage (%)	Total eggs	Total larvae	DR (flowering)	DR (maturity)	Damage rating	Larval survival	Larval weight
Acetic	0.07	0.06	0.12	-0.13	0.00	0.15	0.08	0.08
Citric	-0.16	-0.06	-0.16	-0.21	-0.09	-0.11	0.22*	-0.11
Fumaric	0.32**	-0.04	-0.06	0.01	0.20	0.23	0.09	0.05
Malic	0.05	-0.06	0.00	0.05	0.08	0.19	0.00	0.19
Oxalic	-0.11	-0.07	-0.20	-0.21	-0.16	-0.24	0.14	-0.17

Table 58 : Correlations between *H. armigera* damage parameters and amounts of organic acids on dry weight basis

Acid	Pod damage (%)	Total eggs	Total larvae	DR (flowering)	DR (maturity)	Damage rating	Larval survival	Larval weight
Acetic	0.08	0.04	0.08	-0.15	-0.04	0.17	0.09	0.03
Citric	-0.14	-0.06	-0.20	-0.23*	-0.12	-0.05	0.26*	-0.15
Fumaric	0.32**	-0.04	0.01	0.02	0.19	0.27*	0.10	0.06
Malic	0.12	-0.09	-0.11	0.00	0.04	0.25	0.03	0.08
Oxalic	-0.09	-0.07	-0.21	-0.19	-0.15	-0.17	0.18	-0.19

Table 59 : Correlations between *H. armigera* damage parameters and amounts of organic acids on leaf area (mg) basis

Acid	Pod damage (%)	Total eggs	Total larvae	DR (flowering)	DR (maturity)	Damage rating	Larval survival	Larval weight
Acetic	0.11	0.04	0.14	-0.12	-0.02	0.17	0.06	0.04
Citric	-0.11	-0.06	-0.13	-0.16	-0.05	-0.03	0.24*	-0.10
Fumaric	0.33**	-0.05	-0.01	0.02	0.19	0.26*	0.07	0.03
Malic	0.07	-0.07	0.06	0.06	0.05	0.23*	-0.02	0.14
Oxalic	-0.07	-0.04	-0.18	-0.10	-0.09	-0.10	0.15	-0.15

Table 60 : Correlations between *H. armigera* damage parameters and amounts of organic acids on leaf area (ug) basis

Acid	Pod damage (%)	Total eggs	Total larvae	DR (flowering)	DR (maturity)	Damage rating	Larval survival	Larval weight
Acetic	0.11	0.04	0.14	-0.12	-0.02	0.18	0.06	0.04
Citric	-0.11	-0.04	-0.14	-0.16	-0.05	-0.03	0.25*	-0.10
Fumaric	0.33**	-0.04	-0.01	0.03	0.19	0.26*	0.06	0.04
Malic	0.07	-0.07	0.05	0.06	0.05	0.23	-0.02	0.14
Oxalic	-0.07	-0.04	-0.18	-0.11	-0.09	-0.10	0.15	-0.15

4.2.2.5.7 Similarity co-efficient

The UPGMA dendrogram based on peak area at different RT, grouped the material into 17 distinct groups at 95 % similarity co-efficient. Amongest these, group 2 was the biggest, with 47 genotypes. This group included all the parents except ICC 506, ICC 12476 and ICCV 2. Groups 6, 11, 14, 15, 16 and 17 were the smaller groups and had only one genotype. At 90 % similarity co-efficient, the genotypes were placed into 5 groups. Among these, group 2 was the biggest with 19 genotypes (Fig 13).

The UPGMA dendrogram based peak height placed the test material into 23 distinct groups at 95 % similarity co-efficient. Among these, group 2 was the largest with 42 genotypes, with 3 parents (ICC 12477, ICC 12478 and ICCC 37). Group 1 included four parents (ICC 506, ICC 12479, ICC 3137 and ICC 4918). Groups 3, 12, 13, 14, 16, 18, 19, 20, 21, 22 and 23 had only one genotype. At 90 % similarity co-efficient, the genotypes were placed into 8 groups. Group 2 was the biggest with 10 genotypes (Fig 14).

4.2.3 Tolerance

Tolerance to *Helicoverpa armigera* damage in chickpea genotypes was studied for two seasons during 2003/04 to 2004/05 under protected and un-protected field conditions and results are presented.

4.2.3.1 Days to 50 % flowering

Days to 50 % flowering was significantly higher under un-protected conditions (57 days) compared to protected conditions (54 days). Significantly shortest days to 50 % flowering was recorded in ICCV 2 (33 days), an early maturing variety. The genotypes ICC 12475, ICC 12426, ICC 4918, ICC 12478 and

Fig 13 : Similarity matrix of chickpea genotypes and their 72 F_1 hybrids based on RT and peak area for leaf surface chemical (HPLC finger prints).

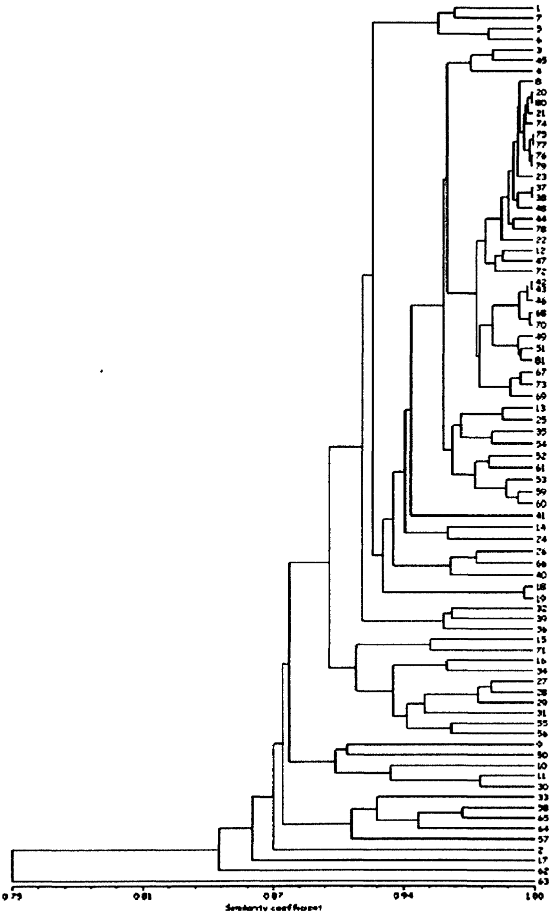

Fig 14 : Similarity matrix of chickpea genotypes and their 72 F_1 hybrids based on RT and peak height for leaf surface chemical (HPLC finger prints).

ICC 12477 were the medium duration varieties. ICC 3137, ICC 12476 and ICC 12479 were the mid-long duration varieties (Table 61).

4.2.3.2 Days to maturity

Significantly shortest and longest days to maturity was recorded on the genotypes ICCV 2 and ICC 3137 respectively. Rest of the genotypes, did not differ significantly for days to maturity. Mean days to maturity was significantly high (110 days) under un-protected conditions compared to protected conditions (106 days).

4.2.3.3 Seeds plant^{-1}

Significantly higher number of seeds per plant was recorded under protected conditions (108 seeds plant^{-1}) compared to un-protected conditions (82 seeds plant^{-1}). However there was no significant difference in the genotypes ICC 12477 (133 and 128 seeds plant^{-1}) and ICC 12475 (101 and 93 seeds plant^{-1}) under protected and un-protected conditions, respectively.

4.2.3.4 Pods plant^{-1}

Mean number of pods per plant was significantly high (107 pods plant^{-1}) under protected conditions compared to un-protected conditions (81 pods plant^{-1}). Significantly highest number of pods per plant was recorded by ICC 12477 (126 and 125 pods plant^{-1} under protected and un-protected conditions). ICC 12475 (92 pods plant^{-1}) and ICC 3137 (57 pods plant^{-1}) recorded lowest number of pods per plant under protected and un-protected conditions respectively (Table 61).

4.2.3.5 100-seed weight

Mean 100-seed weight was significantly high under un-protected conditions (18.44 g) compared to protected conditions (17.2 g). ICC 3137, ICCV 2, ICC 4918 and ICC 12426 recorded significantly higher 100-seed weight as compared to ICC

Table 61 : Mean performance (morphological and yield traits) of selected *H. armigera* resistant chickpea germplasm lines, ICRISAT, Patancheru, post-rainy season 2003/04 to 2004/05.

Genotype	Days to 50% flowering						Days to maturity						Seeds plant^{-1}						Pods plant^{-1}					
	2003/04		2004/05		Mean		2003/04		2004/05		Mean		2003/04		2004/05		Mean		2003/04		2004/05		Mean	
	Prot	Unprot	Prot	Unprot	Prot	Unprot	Prot	Unprot	Prot	Unprot	Prot	Unprot	Prot	Unprot	Prot	Unprot	Prot	Unprot	Prot	Unprot	Prot	Unprot	Prot	Unprot
ICC 3137	60	66	76	76	68	71	122	135	115	116	118	125	102	53	94	46	98	49	105	51	105	64	105	57
ICC 12476	55	60	73	73	64	67	105	116	112	112	109	114	120	72	97	78	108	75	112	71	112	81	112	76
ICC 12477	55	56	60	60	58	58	103	111	107	107	105	109	132	111	134	145	133	128	126	110	126	141	126	125
ICC 12478	48	54	57	57	53	56	103	110	106	107	105	109	105	80	112	108	109	94	104	80	104	109	104	95
ICC 12479	55	59	71	71	63	65	105	114	109	110	107	112	112	66	118	88	115	77	106	64	106	91	106	78
ICCV 2	30	31	36	36	33	33	89	90	102	104	96	97	101	57	78	77	89	67	98	56	98	79	98	68
ICC 4918	43	50	54	54	48	52	105	112	107	108	106	110	100	59	98	81	99	70	102	59	102	82	102	70
Controls																								
ICC 12475®	46	55	54	56	50	55	105	109	108	108	107	109	97	93	105	93	101	93	92	90	92	83	92	86
ICC12426(S)	47	55	59	59	53	57	104	111	107	107	106	109	124	67	121	105	122	86	121	64	121	86	121	75
Mean	49	54	60	60	54	57	105	112	108	109	106	110	110	73	106	91	108	82	107	72	107	91	107	81
Fp	<0.001	<0.001	0.00	< 0.001			<0.001	<0.001	< 0.001	< 0.001			<0.001	<0.001	< 0.001	< 0.001			0.002	<0.001	<0.001	<0.001		
SE	1.13	1.764	54.2	46.3			1.57	2.11	65.3	65.3			8.11	8.35	12.79	20.52			8.24	8.07	10.48	10.31		
LSD (5%)	3.26	5.071	4.78	4.78			4.53	6.06	4.32	3.350			24.31	25.02	36.75	22.48			24.72	24.2	30.11	20.11		
CV (%)	3.6	5.1	5.0	5.0			2.4	3.0	1.9	1.9			13.70	22.40	19.87	58.98			14.7	19.8	18.75	29.62		

R = Resistant check, S = Susceptible check

Prot = Protected crop; Unprot = Unprotected crop.

12476, ICC 12477, ICC 12478, ICC 12479 and ICC 12475 both under protected and un-protected conditions (Table 62).

4.2.3.6 Seeds pod^{-1}

Slightly high number of seeds per pod were recorded under protected conditions, except ICC 4918, ICC 12475 and ICC 12426. Every pod recorded on an average of 1.08 and 1.07 seeds per pod under protected and un-protected conditions respectively.

4.2.3.7 Grain yield plant^{-1}

Significantly higher grain yield was recorded under protected conditions (20.6 gm plant^{-1}) compared to un-protected conditions (16.61 gm plant^{-1}) in all the genotypes, except ICC 12475. The resistant check, ICC 12475 recorded higher grain yield under un-protected conditions (19.79 gm plant^{-1}) compared to protected conditions (17.88 gm plant^{-1}) (Table 62).

4.2.3.8 Pod borer damage (%)

As expected, significantly higher borer damage (17.01 %) was recorded under un-protected conditions compared to protected conditions (2.09 %). All the genotypes differed significantly under protected and un-protected conditions for pod borer damage (%). ICC 3137 suffered higher damage of 7.72 % and 40.33 % under protected and un-protected conditions. The resistant check, ICC 12475 suffered lowest borer damage of 0.39 % and 5.52 % under protected and un-protected conditions respectively (Table 63).

4.2.3.9 Yield (kg ha^{-1})

Significantly higher yield (kg ha^{-1}) was recorded under protected conditions (2023 kg ha^{-1}) compared to un-protected conditions (1554 kg ha^{-1}). Higher yield was recorded in ICC 12426 (2358 kg ha^{-1}) followed by ICC 12477 (2168 kg ha^{-1}), ICC

Table 62 : Comparision of grain yield components of nine chickpea genotypes under protected and unprotected conditions ICRISAT, Patancheru, post-rainy season 2003/04 to 2004/05.

Genotype	100- seed weight						Seeds per pod						Yield plant^{-1} (g)					
	2003/04		2004/05		Mean		2003/04		2004/05		Mean		2003/04		2004/05		Mean	
	Prot	Unprot	Prot	Unprot	Prot	Unprot	Prot	Unprot	Prot	Unprot	Prot	Unprot	Prot	Unprot	Prot	Unprot	Prot	Unprot
ICC 3137	23.84	27.68	22.55	26.69	23.19	27.19	1.03	1.11	1.00	0.71	1.01	0.91	13.27	6.92	22.00	13.52	17.64	10.22
ICC 12476	15.76	15.36	14.29	14.57	15.03	14.97	1.09	1.08	1.03	0.97	1.06	1.03	16.3	10.22	28.47	24.63	22.38	17.42
ICC 12477	12.85	12.72	11.27	11.56	12.06	12.14	1.07	1.14	1.10	1.03	1.09	1.09	14.95	12.91	27.95	22.87	21.45	17.89
ICC 12478	13.0	15.56	13.66	14.25	13.33	14.91	1.03	1.02	1.01	0.99	1.02	1.01	13.69	11.36	25.40	25.58	19.55	18.47
ICC 12479	15.41	15.96	14.66	15.69	15.04	15.83	1.10	1.15	1.05	0.96	1.08	1.06	15.87	9.95	24.85	26.79	20.36	18.37
ICCV 2	23.75	25.38	23.96	24.17	23.86	24.78	1.04	1.10	1.03	0.97	1.04	1.04	15.9	12.12	15.18	9.99	15.54	11.05
ICC 4918	20.53	22.22	17.03	19.16	18.78	20.69	1.10	1.27	1.09	0.98	1.09	1.13	19.46	9.74	27.83	25.95	23.65	17.84
Controls																		
ICC 12475 ®	15.78	17.15	14.98	15.49	15.38	16.32	1.06	1.13	1.08	1.12	1.07	1.13	14.97	15.91	20.78	23.68	17.88	19.79
ICC 12426(S)	18.76	19.49	17.58	18.84	18.17	19.16	1.24	1.39	1.26	1.22	1.25	1.31	21.28	12.84	32.64	24.00	26.96	18.42
Mean	17.74	19.06	16.66	17.83	17.2	18.44	1.08	1.15	1.07	0.99	1.08	1.07	16.19	11.33	25.01	21.89	20.60	16.61
F-prob	<0.001	<0.001	<0.001	<0.001			0.02	0.013	0.12	0.013			0.009	0.02	0.01	0.015		
SEM	2.722	0.816	4.56	0.816			0.04	0.058	0.14	0.579			1.311	1.35	44.5	41.02		
LSD(5%)	7.564	2.269	8.57	2.269			0.11	0.173	0.19	0.173			3.932	4.04	128	117.90		
CV%	11.2	13.6	14.7	11.8			6.00	8.7	6.0	5.8			14	20.60	32.9	19.20		

R = Resistant check, S = Susceptible check

Prot = Protected crop; Unprot = Unprotected crop.

Table 63 : Comparision of loss in grain yield due to *H. armigera* damage in nine chickpea genotypes under protected and unprotected conditions (ICRISAT, Patancheru, post-rainy season, 2003/04 to 2004/05).

Genotype	Pod damage (%)						Yield (kg/ ha)						Loss in grain yield		
	2003/04		2004/05		Mean		2003/04		2004/05		Mean		2003/04	2004/05	Mean
	Prot	Unprot	Prot	Unprot	Prot	Unprot	Prot	Unprot	Prot	Unprot	Prot	Unprot			
ICC 3137	11.82	45.45	3.62	35.21	7.72	40.33	1499	552	2400	1426	1949	989	63.18	40.57	51.87
ICC 12476	1.75	12.88	1.21	11.47	1.48	12.18	1876	962	2348	1998	2112	1480	48.75	14.89	31.82
ICC 12477	1.68	17.21	1.18	10.59	1.43	13.90	1944	1069	2393	2200	2168	1635	45.00	8.04	26.52
ICC 12478	0.98	10.98	0.53	5.87	0.76	8.43	1282	1104	2263	2278	1772	1691	13.83	-0.64	6.59
ICC 12479	4.28	14.19	0.31	8.68	2.30	11.44	1771	1047	2338	2256	2055	1651	40.89	3.54	22.21
ICCV 2	2.9	22.71	0.35	8.05	1.63	15.38	1533	939	1880	1594	1706	1267	38.71	15.18	26.95
ICC 4918	1.76	38.5	0.94	14.80	1.35	26.65	1844	969	2469	2298	2157	1634	47.44	6.90	27.17
Controls															
ICC 12475 ®	0.77	8.03	0.00	3.00	0.39	5.52	1829	1609	2024	2115	1927	1862	12.01	-4.47	3.77
ICC 12426 (S)	2.19	23.71	1.26	14.77	1.73	19.24	1724	1128	2992	2431	2358	1780	34.59	18.73	26.66
Mean	3.13	21.52	1.04	12.49	2.09	17.01	1700	1042	2345	2066	2023	1554	38.27	11.42	24.84
Fp	<0.001	<0.001	<0.001	<0.001			0.174	<0.001	0.174	<0.001					
SE	1.264	3.971	1.13	2.09			135.5	78.5	218.7	227.9					
LSD (5%)	3.512	11.035	157.9	6.15			332	159.3	628.6	654.9					
CV (%)	27.8	12.1	3.25	27.9			12.5	13.2	16.47	19.2					

R = Resistant check, S = Susceptible check

Prot = Protected crop; Unprot = Unprotected crop.

4918 (2157 kg ha^{-1}), ICC 12476 (2112 kg ha^{-1}) under protected conditions. The resistant check, ICC 12475 recorded highest grain yield of 1862 kg ha^{-1} under un-protected conditions. Lowest grain yield of 1706 kg ha^{-1} and 1267 kg ha^{-1} was recorded by ICCV 2 under protected and un-protected conditions respectively.

4.2.3.10 Yield loss (%)

Mean loss in grain yield was 24.84 %. Tolerance index was calculated based on yield loss (%). ICC 12475 (3.77 %) and ICC 12478 (6.59 %) were the most tolerant genotypes. Highest yield reduction was recorded in ICC 3137 (51.87 %) followed by ICC 12476 (31.82 %), ICC 4918 (27.17 %), ICCV 2 (26.95 %) and ICC 12426 (26.66 %) (Table 63).

4.2.3.11 Egg and larval counts

Oviposition rate (No. of eggs $plant^{-1}$) of *H. armigera* females on nine chickpea genotypes was higher under un-protected conditions compared to protected conditions. Greater oviposition was recorded on ICC 3137, ICC 12476, ICC 12479, ICCV 2, ICC 12475 and ICC 12426 under un-protected conditions compared to protected conditions during vegetative stage, while ICC 12477, ICC 12478 and ICC 4918 did not differ significantly both under protected and un-protected conditions. Mean oviposition rate of 3.47 and 4.75 during vegetative stage, 1.7 and 2.79 during flowering stage and 1.67 and 2.8 during podding stage of the crop was observed under protected and un-protected conditions respectively (Table 18).

Density of *H. armigera* larvae was higher under un-protected conditions as compared to protected conditions. During vegetative stage ICC 3137, ICC 12478, ICC 12479, ICCV 2 and ICC 4918 recorded higher larval density under un-protected conditions, while ICC 12476, ICC 12477 and ICC 12475 recorded under protected conditions. During flowering stage the density of larvae was higher under unprotected conditions compared to protected genotypes in all the genotypes except ICC 4918, however greater number of larvae were recorded on all the genotypes except ICC 12426 under un-protected conditions compared to protected conditions during podding stage of the crop. Mean density of *H. armigera* larvae was 3.87 and 4.1 during vegetative stage, 2.84 and 3.81 during flowering stage and 3.56 and 4.26 during podding stage of the crop under protected and un-protected conditions respectively (Table 64).

In the F_1 trial an average oviposition of 2.3, 1.25 and 1.21 (No. of eggs plant^{-1}) was recorded during vegetative, flowering and pod formation stage of the crop on parents, while the mean oviposition of 1.87, 1.34 and 1.1; 1.85, 1.31 and 0.97; 2.32, 1.41 and 1.24; 2.23, 1.29 and 1.07; 1.62, 1.32 and 1.03; 1.82, 1.38 and 1.04; 2.31, 1.3 and 1.03; 1.42, 1.37 and 0.88 and 1.88, 1.56 and 1.11 was recorded on hybrids of ICC 12476, ICC 12477, ICC 12478, ICC 12479, ICC 506, ICC 3137, ICCC 37, ICC 4918 and ICCV2 during vegetative, flowering and podding stage respectively (Table 19).

Mean density of *H. armigera* larvae was 3.79, 2.83 and 3.55 on parents during vegetative, flowering and pod formation stage of the crop, while an average of 4.03, 2.86 and 3.63; 3.88, 3.0 and 3.47; 3.81, 3.03 and 3.95; 3.53, 2.95 and 3.45; 4.08, 2.98 and 3.57; 3.42, 3.04 and 3.59; 3.67, 2.72 and 3.63; 3.97, 3.1 and 3.42 and 4.33, 3.06 and 3.74 was recorded on hybrids of ICC 12476, ICC 12477, ICC 12478, ICC 12479, ICC 506, ICC 3137, ICCC 37, ICC 4918 and ICCV 2 during vegetative, flowering and podding stage respectively (Table 65).

4.3 INTERACTION OF DIFFERENT COMPONENTS OF RESISTANCE AND GRAIN YIELD

4.3.1 Protected conditions

Table 64 : Density of *H.armigera* larvae on nine chickpea genotypes under protected and unprotected conditions ICRISAT,Patancheru,post-rainy season 2003/04 to 2004/05.

Genotype	Vegatative stage						Flowering stage						Poding stage					
	2003/04		2004/05		Mean		2003/04		2004/05		Mean		2003/04		2004/05		Mean	
	Prot	Unprot	Prot	Unprot	Prot	Unprot	Prot	Unprot	Prot	Unprot	Prot	Unprot	Prot	Unprot	Prot	Unprot	Prot	Unprot
ICC 3137	3.20	4.53	4.40	4.93	3.80	4.73	3.41	4.23	4.97	5.77	4.19	5.00	1.30	4.51	4.30	5.50	2.80	5.01
ICC 12476	4.00	3.31	4.00	4.00	4.00	3.66	2.40	3.37	2.40	3.37	2.40	3.37	3.67	3.83	3.67	3.83	3.67	3.83
ICC 12477	4.20	3.40	3.40	3.40	3.80	3.40	2.80	3.33	2.80	3.33	2.80	3.33	3.01	4.00	3.07	4.00	3.04	4.00
ICC 12478	3.23	3.73	3.23	3.73	3.23	3.73	2.90	3.87	2.90	3.87	2.90	3.87	4.00	4.10	4.00	4.10	4.00	4.10
ICC 12479	3.85	4.40	4.40	4.40	4.13	4.40	3.40	3.43	1.40	3.43	2.40	3.43	3.50	3.73	3.50	3.73	3.50	3.73
ICCV 2	4.23	4.60	4.60	4.60	4.42	4.60	3.67	4.32	3.67	4.37	3.67	4.35	3.30	4.93	3.30	4.93	3.30	4.93
ICC 4918	3.12	5.41	4.77	4.77	3.95	5.09	4.97	4.00	3.40	4.00	4.19	4.00	3.77	5.10	3.77	5.10	3.77	5.10
Controls																		
ICC 12475 ®	2.93	2.23	1.93	2.23	2.43	2.23	2.23	2.33	1.23	2.33	1.73	2.33	2.20	3.07	2.20	3.07	2.20	3.07
ICC 12426(S)	4.82	4.81	5.30	5.30	5.06	5.06	1.30	4.57	1.30	4.57	1.30	4.57	5.80	3.40	5.80	5.80	5.80	4.60
Mean	3.73	4.05	4.00	4.15	3.87	4.10	3.01	3.72	2.67	3.89	2.84	3.81	3.39	4.07	3.73	4.45	3.56	4.26
Fp	<0.001	<0.001	<0.001	<0.001			<0.001	<0.001	<0.001	<0.001			<0.001	<0.001	<0.001	<0.001		
SE	0.054	0.082	0.069	0.082			0.096	0.163	0.096	0.163			0.083	0.145	0.083	0.137		
LSD (5%)	0.206	0.214	0.206	0.244			0.289	0.49	0.289	0.49			0.249	0.411	0.249	0.411		
CV (%)	4.2	3.4	3	3.4			5.8	4.7	6.2	7.3			3.6	6.1	3.9	5.3		

R = Resistant check, S = Susceptible check

Prot = Protected crop; Unprot = Unprotected crop.

Table 65 : Density of *H.armigera* larvae on 9x9 full diallel crosses of chickpea under un-protected conditions, ICRISAT, Patancheru, post-rainy season 2004-05.

	LARVAL NUMBER			
	Vegetative stage	Flowering stage	Poding stage	Total
Parents				
ICC 3137	4.53	3.00	4.40	11.93
ICC 12476	3.93	2.47	3.40	9.80
ICC 12477	3.53	2.47	4.47	10.47
ICC 12478	4.53	2.33	3.27	10.13
ICC 12479	5.53	2.93	4.33	12.80
ICCV 2	2.20	3.00	3.13	8.33
ICC 4918	3.07	3.27	3.20	9.53
ICC 506 ®	2.60	3.34	2.87	8.81
ICCC 37 (S)	4.20	2.67	2.87	9.73
Mean	3.79	2.83	3.55	10.17
F_1s				
ICC 12476 X ICC 506	3.67	3.73	4.00	11.40
ICC 12476 X ICC 12477	2.87	2.47	3.00	8.33
ICC 12476 X ICC 12478	5.07	3.60	3.33	12.00
ICC 12476 X ICC 12479	3.60	2.53	3.00	9.13
ICC 12476 X ICC 4918	2.47	2.20	3.27	7.93
ICC 12476 X ICC 3137	3.13	2.60	4.07	9.80
ICC 12476 X ICCV 2	5.53	2.67	4.07	12.27
ICC 12476 X ICCC 37	5.87	3.07	4.27	13.20
Mean	4.03	2.86	3.63	10.51
ICC 12477 X ICC 506	3.07	3.20	4.20	10.47
ICC 12477 X ICC 12476	3.80	2.73	2.40	8.93
ICC 12477 X ICC 12478	5.60	3.33	3.67	12.60
ICC 12477 X ICC 12479	2.07	2.67	3.13	7.87
ICC 12477 X ICC 4918	5.00	3.20	3.87	12.07
ICC 12477 X ICC 3137	3.07	1.67	3.93	8.67
ICC 12477 X ICCV 2	4.40	4.33	3.20	11.93
ICC 12477 X ICCC 37	4.07	2.87	3.33	10.27
Mean	3.88	3.00	3.47	10.35
ICC 12478 X ICC 506	3.20	2.53	3.67	9.40
ICC 12478 X ICC 12476	4.33	3.07	4.20	11.60
ICC 12478 X ICC 12477	3.20	3.40	4.00	10.60
ICC 12478 X ICC 12479	3.87	2.60	4.53	11.00
ICC 12478 X ICC 4918	3.87	3.00	4.33	11.20
ICC 12478 X ICC 3137	4.13	2.73	3.20	10.07
ICC 12478 X ICCV 2	5.33	3.47	4.20	13.00
ICC 12478 X ICCC 37	2.53	3.40	3.47	9.40
Mean	3.81	3.03	3.95	10.78
ICC 12479 X ICC 506	2.60	2.60	3.73	8.93
ICC 12479 X ICC 12476	3.27	2.80	2.20	8.27
ICC 12479 X ICC 12477	3.60	2.53	3.87	10.00
ICC 12479 X ICC 12478	3.53	2.87	3.40	9.80
ICC 12479 X ICC 4918	3.80	3.00	3.40	10.20
ICC 12479 X ICC 3137	3.27	3.60	3.20	10.07
ICC 12479 X ICCV 2	3.80	3.13	4.27	11.20
ICC 12479 X ICCC 37	4.40	3.07	3.53	11.00
Mean	3.53	2.95	3.45	9.93

Contd ----- table 65

F₁s	LARVAL NUMBER			
	Vegetative stage	Flowering stage	Poding stage	Total
ICC 506 X ICC 12476	4.13	3.07	4.40	11.60
ICC 506 X ICC 12477	2.80	2.93	3.00	8.73
ICC 506 X ICC 12478	5.40	2.07	3.40	10.87
ICC 506 X ICC 12479	4.47	2.73	3.60	10.80
ICC 506 X ICC 4918	4.67	3.33	3.40	11.40
ICC 506 X ICC 3137	2.67	3.07	3.80	9.53
ICC 506 X ICCV 2	4.13	3.87	3.00	11.00
ICC 506 X ICCC 37	4.40	2.73	3.93	11.07
Mean	4.08	2.98	3.57	10.63
ICC 3137 X 506	3.47	2.73	4.00	10.20
ICC 3137 X ICC 12476	3.13	3.53	3.93	10.60
ICC 3137 X ICC 12477	3.60	3.47	3.60	10.67
ICC 3137 X ICC 12478	4.00	2.47	3.60	10.07
ICC 3137 X ICC 12479	4.67	3.00	3.47	11.13
ICC 3137 X ICC 4918	3.00	3.27	2.73	9.00
ICC 3137 X ICCV 2	2.60	2.87	3.80	9.27
ICC 3137 X ICCC 37	2.87	3.00	3.60	9.47
Mean	3.42	3.04	3.59	10.05
ICCC 37 X ICC 506	3.00	2.40	2.13	7.53
ICCC 37 X ICC 12476	3.53	2.13	4.13	9.80
ICCC 37 X ICC 12477	2.93	2.67	3.53	9.13
ICCC 37 X ICC 12478	3.67	2.53	3.73	9.93
ICCC 37 X ICC 12479	2.53	3.20	3.67	9.40
ICCC 37 X ICC 4918	4.80	3.00	4.13	11.93
ICCC 37 X ICC 3137	6.27	2.53	3.87	12.67
ICCC 37 X ICCV 2	2.60	3.33	3.87	9.80
Mean	3.67	2.72	3.63	10.02
ICC 4918 X ICC 506	2.60	3.27	3.80	9.67
ICC 4918 X ICC 12476	3.93	2.73	2.53	9.20
ICC 4918 X ICC 12477	3.27	3.87	2.80	9.93
ICC 4918 X ICC 12478	6.00	2.93	4.40	13.33
ICC 4918 X ICC 12479	3.47	3.33	2.40	9.20
ICC 4918 X ICC 3137	5.13	3.27	3.87	12.27
ICC 4918 X ICCV 2	2.60	2.47	2.93	8.00
ICC 4918 X ICCC 37	4.73	2.93	4.60	12.27
Mean	3.97	3.10	3.42	10.48
ICCV 2 X ICC 506	5.27	2.87	4.47	12.60
ICCV 2 X ICC 12476	4.33	2.80	3.47	10.60
ICCV 2 X ICC 12477	3.47	3.93	4.47	11.87
ICCV 2 X ICC 12478	5.13	2.93	4.00	12.07
ICCV 2 X ICC 12479	3.80	3.67	3.60	11.07
ICCV 2 X ICC 4918	4.47	2.87	3.47	10.80
ICCV 2 X ICC 3137	3.60	2.53	3.47	9.60
ICCV 2 X ICCC 37	4.53	2.87	3.00	10.40
Mean	4.33	3.06	3.74	11.13
Fp	0.245	0.79	0.508	
SE	0.934	0.505	0.574	
LSD (5%)	2.61	1.41	1.603	
CV (%)	41.7	29.8	27.6	

R= Resistant check; S= Susceptible check.

During 2003-04 post-rainy season, under protected conditions, positive and non significant correlation co-efficients were recorded between larva number and pod borer damage (%), leaf damage and borer damage (%), grain yield (kg ha^{-1}) and egg number, pod damage and egg number, leaf damage and larva number, pod damage and larva number, pod damage and leaf damage, grain yield per plant and leaf damage, pod damage and grain yield (kg ha^{-1}), grain yield per plant and grain yield (kg ha^{-1}) and grain yield per plant and pod damage, where as negative non significant correlation co-efficients were recorded between egg number and borer damage (%), grain yield (kg ha^{-1}) and borer damage (%), pod damage and borer damage (%), grain yield per plant and borer damage (%), grain yield (kg ha^{-1}) and larvae and grain yield (kg ha^{-1}) and leaf damage.

The correlation between larvae and egg number (r = 0.89**), leaf damage and egg number (r = 0.82*), grain yield per plant and egg number (r = 0.78*) and grain yield per plant and larva number (r = 0.76*) were significant and positive (Table 66).

During the 2004-05 post-rainy season, the correlation co-efficients between grain yield per plant and egg number (0.82*) and pod damage and larva number (0.91**) was highly significant and positive, where as positive and non-significant correlation co-efficient values were recorded for egg number and borer damage (%), larva number and borer damage (%), grain yield (kg ha^{-1}) and borer damage (%), pod damage and borer damage (%), grain yield per plant and borer damage (%), larva number and egg number, leaf damage and egg number, grain yield (kg ha^{-1}) and egg number, pod damage and egg number, leaf damage and larva number, yield (kg ha^{-1}) and larva number, grain yield per plant and larva number, yield (kg ha^{-1}) and leaf damage, pod damage and leaf damage, grain yield per plant and leaf

***Table 66 :* Correlations between pod borer damage and yield components in chickpea under protected conditions (ICRISAT, Patancheru, post- rainy season, 2003-04).**

Yield and damage parameters	Correlation co-efficient
Eggs and borer damage (%)	-0.20
Larvae and borer damage (%)	0.03
Leaf damage and borer damage (%)	0.26
Yield (kg/ha) and borer damage (%)	-0.31
Pod damage and borer damage (%)	-0.17
Yield/plant and borer damage (%)	-0.35
Larvae and eggs	0.89**
Leaf damage and eggs	0.82*
Yield (kg/ha) and eggs	0.02
Pod damage and eggs	0.62
Yield/plant and eggs	0.78*
Leaf damage and larvae	0.75
Yield (kg/ha) and larvae	-0.15
Pod damage and larvae	0.45
Yield/plant and larvae	0.76*
Yield (kg/ha) and leaf damage	-0.28
Pod damage and leaf damage	0.39
Yield/plant and leaf damage	0.42
Pod damage and yield (kg/ha)	0.10
Yield/plant and yield (kg/ha)	0.40
Yield/plant and pod damage	0.45

*, ** significantly different at P= 0.05 and 0.01 respectively.

damage, pod damage and yield (kg ha^{-1}), grain yield per plant and grain yield (kg ha^{-1}) and yield per plant and pod damage. Negative and non significant correlation was recorded for leaf damage and borer damage (%) (Table 67).

4.3.2 Un-protected conditions

Under un-protected conditions, during 2003-04 post-rainy season, negative and non-significant correlation co-efficients were recorded between grain yield (kg ha^{-1}) and borer damage (%), grain yield per plant and borer damage (%), yield (kg ha^{-1}) and egg number, grain yield per plant and egg number, yield (kg ha^{-1}) and larva number, grain yield per plant and larva number, yield (kg ha^{-1}) and leaf damage and grain yield per plant and leaf damage. Positive and highly significant correlation co-efficient values were recorded for leaf damage and larva number (0.85*) and grain yield per plant and pod damage (0.91**) (Table 68).

The correlation co-efficients between egg number and borer damage (%), larva number and borer damage (%), leaf damage and borer damage (%), pod damage and borer damage (%), larva number and egg number, leaf damage and egg number, pod damage and egg number, pod damage and larva number, pod damage and leaf damage, pod damage and grain yield (kg ha^{-1}) and grain yield per plant and yield (kg ha^{-1}) were positive but non-significant.

During 2004-05 post-rainy season, highly significant and positive correlation was recorded between larva number and egg number (0.94**), pod damage and egg number (0.84*), pod damage and larva number (0.89**) and grain yield per plant and leaf damage (0.76*), while positive non-significant correlation was recorded between egg number and borer damage (%), larva number and borer damage (%), pod damage and borer damage (%), leaf damage and egg number, grain yield per plant and egg number, leaf damage and larva number, grain yield per plant and larva

***Table 67* : Correlations between pod borer damage and yield components in chickpea under protected conditions (ICRISAT, Patancheru, post- rainy season, 2004-05).**

Yield and damage parameters	Correlation co-efficient
Eggs and borer damage (%)	0.60
Larvae and borer damage (%)	0.67
Leaf damage and borer damage (%)	-0.02
Yield (kg/ha) and borer damage (%)	0.37
Pod damage and borer damage (%)	0.37
Yield/plant and borer damage (%)	0.53
Larvae and eggs	0.75
Leaf damage and eggs	0.35
Yield (kg/ha) and eggs	0.66
Pod damage and eggs	0.62
Yield/plant and eggs	0.82*
Leaf damage and larvae	0.37
Yield (kg/ha) and larvae	0.45
Pod damage and larvae	0.91**
Yield/plant and larvae	0.66
Yield (kg/ha) and leaf damage	0.15
Pod damage and leaf damage	0.43
Yield/plant and leaf damage	0.50
Pod damage and yield (kg/ha)	0.48
Yield/plant and yield (kg/ha)	0.49
Yield/plant and pod damage	0.40

*, ** significantly different at P= 0.05 and 0.01 respectively.

Table 68 **: Correlations between pod borer damage and yield components in chickpea under un-protected conditions (ICRISAT, Patancheru, post- rainy season, 2003-04).**

Yield and damage parameters	Correlation value
Eggs and borer damage (%)	0.24
Larvae and borer damage (%)	0.28
Leaf damage and borer damage (%)	0.68
Yield (kg/ha) and borer damage (%)	-0.74
Pod damage and borer damage (%)	0.25
Yield/plant and borer damage (%)	-0.68
Larvae and eggs	0.66
Leaf damage and eggs	0.71
Yield (kg/ha) and eggs	-0.38
Pod damage and eggs	0.05
Yield/plant and eggs	-0.42
Leaf damage and larvae	0.85*
Yield (kg/ha) and larvae	-0.30
Pod damage and larvae	0.06
Yield/plant and larvae	-0.23
Yield (kg/ha) and leaf damage	-0.64
Pod damage and leaf damage	0.26
Yield/plant and leaf damage	-0.54
Pod damage and yield (kg/ha)	0.01
Yield/plant and yield (kg/ha)	0.28
Yield/plant and pod damage	0.91**

*, ** significantly different at P= 0.05 and 0.01 respectively.

number, pod damage and leaf damage, pod damage and grain yield (kg ha^{-1}), grain yield per plant and pod damage and grain yield per plant and grain yield (kg ha^{-1}).

Negative and non-significant correlation co-efficient values were recorded for leaf damage and borer damage (%), yield (kg ha^{-1}) and borer damage (%), grain yield per plant and borer damage (%), grain yield (kg ha^{-1}) and egg number, grain yield (kg ha^{-1}) and larva number and grain yield (kg ha^{-1}) and leaf damage (Table 69).

In F_1 trial negative and non-significant correlation co-efficient values were recorded for egg number and borer damage (%), leaf damage and borer damage (%), pod damage and egg number, grain yield per plant and egg number, leaf damage and larva number, grain yield (kg ha^{-1}) and larva number, pod damage and larva number, grain yield per plant and larva number, yield (kg ha^{-1}) and leaf damage, pod damage and yield (kg ha^{-1}) and grain yield per plant and pod damage, while the correlation between grain yield per plant and borer damage (%) was negative but significant.

The correlation between larva number and borer damage (%), grain yield (kg ha^{-1}) and borer damage (%), pod damage and borer damage (%), larva number and egg number, leaf damage and egg number, yield (kg ha^{-1}) and egg number, pod damage and leaf damage, grain yield per plant and leaf damage and grain yield per plant and yield (kg ha^{-1}) was positive but non-significant.

Negative and non significant correlation was recorded between yield per plant and borer damage (%) (-0.79*) (Table 70).

***Table 69 : Correlations between pod borer damage and yield components in chickpea under* un-protected conditions (ICRISAT, Patancheru, post- rainy season, 2004-05).**

Yield and damage parameters	Correlation co-efficient
Eggs and borer damage (%)	0.69
Larvae and borer damage (%)	0.74
Leaf damage and borer damage (%)	-0.12
Yield (kg/ha) and borer damage (%)	-0.54
Pod damage and borer damage (%)	0.51
Yield/plant and borer damage (%)	-0.29
Larvae and eggs	0.94**
Leaf damage and eggs	0.19
Yield (kg/ha) and eggs	-0.22
Pod damage and eggs	0.84*
Yield/plant and eggs	0.28
Leaf damage and larvae	0.23
Yield (kg/ha) and larvae	-0.31
Pod damage and larvae	0.89**
Yield/plant and larvae	0.26
Yield (kg/ha) and leaf damage	-0.25
Pod damage and leaf damage	0.22
Yield/plant and leaf damage	0.76*
Pod damage and yield (kg/ha)	0.38
Yield/plant and yield (kg/ha)	0.06
Yield/plant and pod damage	0.29

*, ** significantly different at P= 0.05 and 0.01 respectively.

Table 70 **: Correlations between pod borer damage and yield components in 72 chickpea hybrids (ICRISAT, Patancheru, post- rainy season, 2004-05).**

Yield and damage parameters	Correlation co-efficient
Eggs and borer damage (%)	-0.22
Larvae and borer damage (%)	0.04
Leaf damage and borer damage (%)	-0.61
Yield (kg/ha) and borer damage (%)	0.07
Pod damage and borer damage (%)	0.07
Yield/plant and borer damage (%)	-0.79*
Larvae and eggs	0.01
Leaf damage and eggs	0.11
Yield (kg/ha) and eggs	0.02
Pod damage and eggs	-0.02
Yield/plant and eggs	-0.14
Leaf damage and larvae	-0.02
Yield (kg/ha) and larvae	-0.05
Pod damage and larvae	-0.16
Yield/plant and larvae	-0.01
Yield (kg/ha) and leaf damage	-0.10
Pod damage and leaf damage	0.69
Yield/plant and leaf damage	0.01
Pod damage and yield (kg/ha)	-0.03
Yield/plant and yield (kg/ha)	0.09
Yield/plant and pod damage	-0.02

* Significantly different at P= 0.05 probability.

Chapter V
Discussion

CHAPTER V

DISCUSSION

Chickpea is damaged by nearly 57 species of insects, of which pod borer, *Helicoverpa armigera* is the most important pest in the semi-arid tropics. It attacks more than 182 species of host plants belonging to 47 families (Sithanantham, 1987 and Pawar, 1998).

Sources of resistance to insects in grain legumes have been identified long ago, but these have not been used effectively in crop improvement because of the difficulties involved in screening and selection of the test material under uniform conditions (Sharma and Crouch, 2004). 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 pivotal role in controlling *H. armigera* damage either alone or in combination with other methods of control.

Development of crop cultivars with resistance to pod borer is the most cost-effective and eco-friendly option and holds great promise for controlling *H. armigera*, particularly under subsistence farming conditions in the developing countries (Sharma *et al.*, 1999). Availability of stable resistance sources is a prerequisite for HPR breeding. ICRISAT genebank at Patancheru, India holds a world collection of more than 17,000 accessions of chickpea. Screening of more than 14,000 germplasm accessions and breeding lines at ICRISAT, Patancheru and in the All India Co-ordinated Pulses Improvement Project (AICPIP) centers, have resulted in the identification of several genotypes with low to moderate levels of resistance to *H. armigera* (Lateef, 1985, Lateef and Sachan, 1990 and Sharma *et al.*, 2002). Some of the sources of resistance have found to be resistant in different agro-climatic zones under infestation conditions at test locations. High levels of resistance to *H. armigera* have been observed in germplasm accessions belonging to the wild relatives such as, *Cicer bijugum*, *C. judaicum* and *C. pinnatifidum* (Sharma *et al.*, 2003).

An understanding of the mechanisms and inheritance of resistance is essential for systematic and efficient genetic enhancement of chickpea for pod borer resistance to *H. armigera*. The limited information available in literature was indicated the importance of additive (Singh *et al.*, 1991), and additive and dominance (Salimath *et al.*, 2003) genetic variance in desi types, while dominance genetic variance was important in the inheritance of pod borer resistance in kabuli types (Singh *et al.*, 1991).

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). The identification of sources of resistance and the knowledge of different mechanisms involved are essential for increasing the levels and diversity of resistance and transferring such resistance into high yielding cultivars. Screening of chickpea genotypes for resistance to *Helicoverpa* population has been in progress at various national programmes and at ICRISAT. The work at ICRISAT resulted in the identification of large number of less susceptible cultivars (ICRISAT, 1982, 83 and 84).

The results of the present studies on "Genetics of resistance to pod borer, *Helicoverpa armigera* in chickpea (*Cicer arietinum*)" are discussed in this chapter and the implications are drawn thereof in relation to the genetic enhancement of pod borer resistance in chickpea.

5.1 THE NATURE OF GENE ACTION AND MATERNAL EFFECTS

5.1.1 Mean performance of parents

5.1.1.1 Maturity related traits

The genotype, ICCV 2 was the earliest to flower and mature, followed by Annigeri, ICCC 37, ICC 12478 and ICC 12477, while ICC 12479, ICC 12476 and ICC 3137 were late flowering.

5.1.1.2 Yield characteristics

Germplasm line, ICC 506 (ICC 12475) with low pod borer damage has been found to be useful in the *Helicoverpa armigera* resistance breeding programmes (Singh *et al.*, 1991). Parental performance is a good indication of resistance to *H. armigera* in F_1 progenies (ICRISAT, 1981, Gowda *et al.*, 1990, Deshmukh *et al.*, 1996a and 1996b, Chaturvedi *et al.*, 1997 and Sreelatha, 2003).

The highest number of seeds per plant and pods per plant were recorded in ICC 12477 followed by ICC 12478. The lowest number of seeds was recorded in ICC 3137, with an average of 97 seeds and pods. The large seeded genotype ICC 3137 recorded the highest 100-seed weight (26.09 g 100^{-1} seeds) followed by ICCV 2, ICCC 37 and Annigeri. Least 100-seed weight was recorded on ICC 12477, with an average of 17.19 g. The genotype, ICC 12478 suffered significantly lowest damage (3.64 %) followed by ICC 506, ICC 12479 and ICC 12477, while ICC 3137 was highly susceptible to *H. armigera* damage. The seed yield per plant ranged from 20.14 g on Annigeri to 18.42 g on ICCV 2, while ICC 3137 recorded lowest seed yield of 8.87 g, with an average yield of 15.52 g. ICCC 37 recorded high total plot yield and yield (kg ha^{-1}) followed by ICC 12479 and ICC 12476. Lowest yield was observed in ICC 12477.

5.1.2 Mean performance of crosses

5.1.2.1 Maturity related traits

Most crosses with early maturing parents, ICCV 2, ICCC 37 and ICC 4918 (ICCV 2 × ICC 3137, ICCV 2 × ICCC 37, ICCV 2 × ICC 4918, ICCC 37 × ICCV 2, ICCV 2 × ICC 12477, ICCV 2 × ICC 12479, ICCV 2 × ICC 12476, ICC 4918 × ICCC 37, ICCV 2 × ICC 12478, ICCV 2 × ICC 506, ICC 12479 × ICCV 2, ICCC 37 × ICC 12477 and ICC 4918 × ICC 12477) were early to flower and mature.

5.1.2.2 Yield contributing traits

ICC 12477 × ICC 506 and ICC 12476 × ICC 12478 recorded the highest number of seeds and pods per plant followed by ICC 12477 × ICC 4918, ICC 12477 × ICC 12478, ICC 12477 × ICC 3137, ICC 12477 × ICC 4918, ICC 12476 × ICCC 37 and ICC 12477 × ICC 12478. The lowest number of seeds and pods plant^{-1} was recorded on ICC 3137 × ICCC 37 followed by ICC 4918 × ICCC 37, ICC 506 × ICC 3137, ICC 506 × ICCC 37 and ICCC 37 × ICCV 2.

Highest number of seeds per pod was recorded on ICC 12476 × ICCC 37 followed by ICC 12478 × ICC 12476, ICCC 37 × ICC 12476, ICCC 37 × ICC 12479, ICC 4918 × ICC 12476 and ICC 12476 × ICC 4918. ICC 3137 × ICC 4918, ICC 3137 × ICCC 37, ICC 3137 × ICC 12478 and ICC 12477 × ICC 3137 recorded lowest number of seeds pod^{-1}. Crosses with large seeded line, ICC 3137 × ICC 4918, ICCC 37 × ICC 3137, ICC 3137 × ICCC 37, ICC 3137 × ICCV 2, ICC 4918 × ICC 3137, ICCV 2 × ICC 4918, ICCV 2 × ICCC 37 and ICCC 37 × ICCV 2 recorded the highest weight of 100 seeds. ICC 12477 × ICC 12479 and ICC 12477 × ICC 12476 recorded the lowest weight of 100 seeds, with an average of 16.98 g. ICC 12478 ×

ICC 506, ICC 12478 × ICC 12477, ICC 12479 × ICC 12477, ICC 12479 × ICC 506, ICC 12479 × ICCV 2, ICCV 2 × ICC 12476, ICCV 2 × ICC 12478, ICCV 2 × ICC 12479 and most of crosses involving ICC 506 suffered lower pod borer damage, indicating that crosses involving resistant parents were also less susceptible. These results were in agreement with those of Sreelatha (2003). Crosses involving ICC 3137 suffered high pod damage.

Most crosses with ICC 506, ICC 4918, ICC 12476, ICC 12478 and ICC 12479, recorded high seed yield. ICC 12477 × ICC 12476, ICC 12477 × ICC 12479, ICC 12478 × ICC 12476, ICC 12479 × ICC 12476, ICC 3137 × ICCC 37, ICC 506 × ICC 12476, ICC 506 × ICC 12477, ICC 506 × ICCC 37 recorded lowest grain yield. ICC 12477 × ICC 506, ICC 12479 × ICCC 37, ICC 12479 × ICC 12476, ICC 506 × ICC 12479 and ICCV 2 × ICC 4918 recorded highest yield. Lowest grain yield was recorded in ICCV 2 × ICC 3137.

5.1.3 NATURE OF GENE ACTION

Diallel analysis is one of the most important biometrical tools available to the plant breeders for evaluating and characterizing genetic variability and is of considerable value in making decisions concerning the type of breeding system to be used and in selection of breeding materials that show the greatest promise for success.

Diallel analysis has many advantages compared to other methods. It has been extensively used in almost all the sexually propagating crops to elucidate the information on the combining ability of parents and crosses and the nature of gene action. By this method, an overall genetic investigation is possible, which is useful in identifying promising parents and crosses. More genetic information can be obtained with one generation involving F_1s and their parents than with several generations by using other methods (Joshi *et al.*, 1961).

Interpretation of the components of genetic variation and related ratios derived from diallel crosses and their parents is dependent upon the fulfillment of certain assumptions about the parental material. The assumption on the absence of epistasis, and multiple alleles and uncorrelated gene distributions are difficult to meet. There are conflicting reports on the effect of independent distribution of genes on the estimates of variances due to general and specific combining ability effects (Baker, 1978). Nevertheless, the information derived from diallel analysis provides broad indications about the most probable gene action underlying the inheritance of traits of interest.

The results obtained in the present study on combining ability and gene action and their implications on genetic enhancement are discussed below under the following heads.

5.1.3.1 Genetic interpretation of different characters

5.1.3.2 General combining ability effects

5.1.3.2.1 Days to initial and 50 % flowering

The GCA mean squares and variances for days to initial and 50 % flowering were highly significant indicating the importance of additive gene action for the expression and inheritance of flowering genes. Higher magnitude of σ^2A than σ^2D adequately supported this argument. According to Griffing analysis, ICCC 37, ICC 4918 and ICCV 2 were good general combiners for days to initial flowering, while the genotypes ICC 506, ICCC 37, ICC 4918 and ICCV 2 were good general combiners for days to 50 % flowering. Good general combining ability of ICC 4918 and ICCV 2 for early flowering has been reported earlier (ICRISAT, 1981 and

1982). 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, Yadavendra and Kumar, 1987, 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 1985a and b) and Sreelatha, 2003).

5.1.3.2.2 Days to maturity

Significant GCA variances indicate the importance of additive gene action for days to maturity. In F_1 full diallel, the parents ICC 506, ICC 12477, ICC 12478, ICC 12479, ICC 4918 and ICCC 37 were good general combiners for days to maturity and these can be utilized successfully in breeding programmes for early maturity. Good GCA effects of ICC 4918 for early flowering and maturity have been reported in earlier studies (ICRISAT, 1981 and 1983) and ICC 12475 for early maturity (ICRISAT 1984 and 1985a). These results were similar to those of 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), Singh and Paroda (1989) and Sreelatha (2003).

5.1.3.2.3 Pod borer damage (%)

Percentage pod damage in parents ranged from 3.65 % (ICC 12476) to 34.06 % (ICC 3137). Statistically significant GCA variances indicated the importance of additive gene action for pod borer damage (%). Magnitude of GCA variance was comparatively greater than SCA variance indicating the importance of additive gene action in governing chickpea resistance to pod borer. Gowda *et al.*, (2005) reported that additive and dominance genetic variances were predominant in early and medium maturity diallel trials respectively. Additive as well as dominance components of genetic variances were equally important in the inheritance of pod borer resistance in late maturity group. Such differential nature of gene action governing pod borer resistance in different maturity groups has earlier been reported by Gowda *et al.*, (1983), Singh *et al.*, (1991) and ICRISAT (1981, 82, 83, 84 and 1985a). Recently, Salimath *et al.*, (2003) reported the involvement of both additive and non-additive gene action in the inheritance of pod borer resistance, although their results were maturity non-specific. The lines in the current study are mostly in the early and medium maturity genotypes. Hence the results indicating predominance of additive gene action is in conformity with earlier studies.

The resistant parents ICC 506, ICC 12477, ICC 12478, ICC 12479 and ICCV 2 proved to be the best general combiners with significantly negative GCA effects and low pod borer damage. The results were in accordance with ICRISAT (1981, 82, 83 and 84).

5.1.3.2.4 Total number of pods plant^{-1} and seeds plant^{-1}

The parent, ICC 12477 was the best general combiner with significant and positive GCA effects. The GCA variance was statistically significant, suggesting the importance of additive gene action for total number of pods per plant. 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 85a), Malhotra *et al.*, (1983), Singh and Paroda (1989) and Singh *et al.*, (1992).

5.1.3.2.5 Seeds pod^{-1}

For number of seeds per pod relatively narrow range was observed for GCA and SCA variances but were significant. The predictability ratio of 1.63 pointed out that GCA variances were important for the performance of single cross progenies. Among the 28 diallel trials conducted at ICRISAT the highest estimates of components of GCA and SCA mean squares were recorded for plant height and seeds per pod (ICRISAT, 1984). Present studies, indicated the importance of both SCA and GCA effects for seeds per pod. Similar results have earlier been reported by Singh *et al.*, (1982), Malhotra *et al.*, (1983) and Singh and Paroda (1984).

The parents ICC 12476 and ICCC 37 were good general combiners for increased seeds per pod. These results were in agreement with those of Sreelatha (2003).

5.1.3.2.6 Seed yield plant^{-1}

The GCA variance was significant indicating the importance of additive gene action. The parent ICC 4918 was good general combiner for increased seed yield per plant. The importance of both additive and non- additive gene effects for seed yield have been reported by Malhotra *et al.*, (1983) and Singh *et al.*, (1992).

5.1.3.2.7 100- seed weight

Among the parents the 100- seed weight ranged between 11.22 g (ICC 12477) to 26.09 g (ICC 3137), and in crosses the range was from 9.79 g (ICC 12477 × ICC 12479) to 24.94 g (ICC 3137 × ICC 4918). The GCA variance was statistically significant, indicating the importance of additive gene action. The magnitude of GCA variance was higher compared to SCA variance. The estimate of σ^2A was greater than σ^2D indicating the importance of additive gene action for 100- seed weight. Earlier reports supporting these results were made by Gupta and Ramanujam (1974), Asawa and Tewari (1976), Gowda and Bahl (1978), Singh and Mehra (1980), Dhaliwal and Gill (1973), Malhotra *et al.*, (1983), ICRISAT (1981, 82, 83, 84 and 85a), Tewari and Pande (1987), Shiv kumar *et al.*, 2001 and Sreelatha (2003). Malhotra and Singh 1997 reported that both additive and non- additive gene effects were important, with the preponderance of additive type of gene action for seed size and partial dominance of small seed over large seed size suggests that this trait is governed by recessive genes.

High predictability ratio (69.3) of trial indicated the importance of GCA in predicting the performance of single cross progenies.

Since both additive and additive × additive gene action contribute to this component, seed mass can be used effectively as an indirect selection criterion for improving seed yield in chickpea (Singh and Paroda, 1986). The bold seeded parents ICC 4918, ICC 3137, ICCV 2 and ICCC 37 were good general combiners for increased seed mass.

5.1.3.2.8 Total plot yield

The GCA variances were statistically significant for total plot yield indicating the importance of additive gene action. The parents ICC 12478, ICC 4918 and ICCC 37 were good general combiners for increased yield. The results were in accordance with Gupta and Ramanujam (1974), Gowda and Bahl (1978), Yadavendra and Kumar (1987) and Shivkumar *et al.*, (2001).

5.1.3.2.9 Yield (kg ha^{-1})

Statistically significant GCA variance indicates the importance of additive gene action for yield (kg ha^{-1}). The parents Annigeri and ICCC 37 were good general combiners for increased yield, but they are susceptible to *Helicoverpa* pod borer. The results 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), Singh and Paroda (1989), Yadavendra and Kumar (1987) and Shivkumar *et al.*, (2001).

5.1.3.3 Specific combining ability (SCA) effects

5.1.3.3.1 Straight crosses

5.1.3.3.1.1 Days to initial and 50 % flowering

In this trial days to initial flowering ranged between 34.3 to 61.7 days, while days to 50 % flowering ranged between 46.3 to 67.7 days. The SCA variances and mean squares were highly significant indicating the importance of non- additive gene action for this trait. The hybrid ICC 12478 × ICC 3137 showed significant and negative SCA effect, and was a good specific combiner for days to initial flowering, where as the hybrids ICC 12476 × ICC 3137, ICC 12479 × ICC 3137 and ICC 4918 × ICCC 37 were good specific combiners for days to 50 % flowering and can be utilized successfully in breeding programmes for early flowering.

Significant GCA and SCA variances were significant emphasizing the importance of additive, additive × additive interactions and also non- additive effects. The results were in accordance with the results obtained in two diallel (desi and kabuli) trials conducted by Sreelatha (2003).

5.1.3.3.1.2 Days to maturity

Significant SCA variances for direct crosses in F_1 trial indicated the importance of non- additive gene action for maturity. The hybrids, ICC 12476 × ICCV 2, ICC 12479 × ICCC 37 and ICC 3137 × ICCV 2 were good specific combiners for days to maturity. 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), Singh and Paroda (1989) and Sreelatha (2003) reported the importance of both GCA and SCA effects for days to maturity and discussed the importance of non- additive genetic effects.

5.1.3.3.1.3 Pod borer damage (%)

Both GCA and SCA variances were significant for pod damage by *H. armigera*, indicating the importance of additive and non-additive gene effects for pod borer resistance. The hybrids ICC 506 × ICC 3137, ICC 12476 × ICC 3137, ICC 12477 × ICC 4918, ICC 12479 × ICC 3137 and ICC 3137 × ICCV 2 showing significant and negative SCA effects were good specific combiners for resistance to pod damage by *H. armigera*. 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. Gowda *et al.*, (2005) reported that in desi type chickpea additive component of genetic variance was important in early maturity, while dominance component was predominant in medium maturity group. In late maturity group, additive as well as dominance components were equally important.

5.1.3.3.1.4 Total number of pods plant^{-1} and seeds plant^{-1}

The hybrids, ICC 12477 × ICC 4918, ICC 12477 × ICCC 37, ICC 12478 × ICC 12479, ICC 12476 × ICCC 37 and ICC 3137 × ICCV 2 were best specific combiners with significant and positive SCA effects. Both GCA and SCA variances were significant indicating the importance of additive and non- additive effects for the inheritance of these characters.

5.1.3.3.1.5 Seeds pod^{-1}

The GCA and SCA variances were significant for seeds per pod indicating the importance of additive and non-additive effects. The hybrids, ICC 506 × ICCV 2, ICC 12476 × ICC 12478, ICC 12476 × ICC 4918, ICC 12476 × ICCC 37, ICC 12479 × ICCC 37 and ICC 3137 × ICCV 2 with significant and positive SCA effects were good specific combiners for increased seeds per pod. 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), Singh and Paroda (1989) and Sreelatha (2003) reported the importance of both GCA and SCA effects for seeds pod^{-1} and discussed the importance of non- additive genetic effects, as reported by Shivkumar *et al.*, (2001).

5.1.3.3.1.6 Seed yield plant^{-1}

The combining ability variances were significant for both GCA and SCA. The predictability ratio of 0.23 showed that GCA alone was not sufficient for inferences regarding the performance of single cross progenies. Of the two genetic parameters, σ^2D was more than σ^2A, which emphasized that non- additive gene action was involved in inheritance and expression of yield per plant. These findings are in conformity with those of Bhatt and Singh (1980), Ugale (1980), Katiyar and Solanki (1983), Singh and Sidhu (1983), Kunadia *et al.*, (1986), Shinde (1988), Miah and Bahl (1989) and Deshmukh and Patil (1995). However, the reports of Gowda (1975), Asawa and Tewari (1976), Sandhu *et al.*, (1977) and Gowda and Bahl (1978) are contradictory to present findings, which indicated the involvement of additive genetic variance. Singh *et al.*, (1992), Singh and Ocampo (1993), Annigeri *et al.*, (1996), Sarode (1997) and Girase (1999) reported the importance of additive as well as non-additive genetic variance.

The hybrids, ICC 12476 × ICCC 37, ICC 12477 × ICC 4918 and ICC 12478 × ICC 12479 with highly significant and positive SCA effects were good specific combiners. Similar results were reported by 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), Singh and Paroda (1989) and ICRISAT (1985a).

5.1.3.3.1.7 100- seed weight

The SCA variances for direct crosses was non significant. The hybrid, ICC 506 × ICC 12478 with significant and positive SCA was good specific combiner for 100- seed weight. These results are similar to the reports of Dhaliwal and Gill (1973), Gupta and Ramanujam (1974), Gowda and Bahl (1978), Singh and Mehra (1980), Malhotra *et al.,* (1983) and ICRISAT (1981, 82, 83, 84 and 85a).

5.1.3.3.1.8 Total plot yield

The SCA variances were significant, indicating the importance of non-additive gene effects, further the magnitude of σ^2D was relatively greater 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 Ramanujam (1974), Gowda and Bahl (1978), Yadavendra and Kumar (1987) and Shivkumar *et al.,* (2001), who reported that non- additive genetic effects is of major importance for seed yield. The hybrids, ICC 506 × ICCV 2 and ICC 12477 × ICCC 37 were good specific combiners for high yield. Similar results were recorded by Sreelatha (2003).

5.1.3.3.1.9 Yield (kg ha^{-1})

Statistically significant SCA variances, indicated the importance of non-additive gene action. Predominance of σ^2D over σ^2A emphasizes the importance of non- additive gene action. The hybrids, ICC 506 × ICCV 2 and ICC 12477 × ICCC 37 with significant and positive SCA effects were the best specific combiners for improved grain yield production and can be used in breeding programmes for higher yields. The results 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), Singh and Paroda (1989), Yadavendra and Kumar (1987) and Shivkumar *et al.*, (2001).

5.1.3.4 Specific combining ability (SCA) effects

5.1.3.4.1 Reciprocal crosses

5.1.3.4.1.1 Days to initial and 50 % flowering

The SCA variances and mean squares for reciprocal crosses were highly significant indicating the importance of non- additive gene action for this trait. The hybrids ICCC 37 × ICC 12476, ICC 4918 × ICC 12477 and ICCV 2 × ICC 3137 with highly significant and negative SCA effects, were good specific combiners for days to initial flowering where as the hybrids ICCV 2 × ICC 12476, ICCV 2 × ICC 12477, ICCV 2 × ICC 12478, ICCV 2 × ICC 4918 and ICCV 2 × ICC 3137 were good specific combiners for days to 50 % flowering and these can be utilized successfully in breeding programmes for early flowering. There was no maternal inheritance for this trait.

5.1.3.4.1.2 Days to maturity

Significant SCA variances indicated the importance of non- additive gene action for maturity. The hybrids, ICCC 37 × ICC 4918 and ICCV 2 × ICC 3137 were good specific combiners for days to maturity. 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), Singh and Paroda (1989) and Sreelatha, (2003) reported the importance of both GCA and SCA effects for days to maturity and discussed the importance of non- additive genetic effects. None of the hybrids showed cytoplasmic inheritance for maturity.

5.1.3.4.1.3 Pod borer damage (%)

Both GCA and SCA variances were significant indicating the importance of additive and non- additive gene effects for pod borer resistance. The hybrid ICCV 2 × ICC 3137 showing significant and negative SCA effects was good specific combiner with respect to reduced 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. There was no maternal inheritance for pod borer damage.

5.1.3.4.1.4 Total number of pods plant^{-1} and seeds plant^{-1}

The hybrids, ICC 12477 × ICC 506, ICC 3137 × ICC 506 and ICCC 37 × ICC 506 were best specific combiners with significant and positive SCA effects. Both GCA and SCA variances were significant indicating the importance of additive and non- additive effects for the inheritance of these characters.

5.1.3.4.1.5 Seeds pod^{-1}

The GCA and SCA variances were significant indicating the importance of additive and non- additive effects. In reciprocal crosses, the SCA effects for the hybrid ICCC 37 × ICC 12476 was significant but negative showing cytoplsmic inheritance (Table 71). 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), Singh and Paroda (1989) and Sreelatha (2003) reported the importance of both GCA and SCA effects for seeds/ pod and discussed the importance of non- additive genetic effects as reported by Shivkumar *et al.*, (2001).

Table 71 : Yield contributing characters showing maternal inheritance, (ICRISAT, Patancheru, post-rainy season, 2004-05).

Pedigree	Seeds per pod	
	Straight crosses	Reciprocal crosses
ICC 506 X ICC 12477	0.006	0.005
ICC 506 X ICC 12478	-0.011	0.012
ICC 506 X ICC 12479	-0.015	-0.015
ICC 506 X ICC 4918	0.031	-0.003
ICC 506 X ICC 3137	0.039	0.019
ICC 506 X ICCV 2	0.057*	-0.043
ICC 506 X ICCC 37	-0.028	0.005
ICC 12476 X ICC 12477	-0.033	0.002
ICC 12476 X ICC 12478	0.057*	0.129
ICC 12476 X ICC 12479	-0.037	-0.006
ICC 12476 X ICC 4918	0.055*	0.004
ICC 12476 X ICC 3137	0.048	-0.037
ICC 12476 X ICCV 2	-0.01	-0.032
ICC 12476 X ICCC 37	**0.117****	**-0.059***
ICC 12477 X ICC 12478	-0.01	0.024
ICC 12477 X ICC 12479	0.013	-0.03
ICC 12477 X ICC 4918	0.047	0.012
ICC 12477 X ICC 3137	-0.017	0.018
ICC 12477 X ICCV 2	0.008	0.04
ICC 12477 X ICCC 37	-0.009	-0.01
ICC 12478 X ICC 12479	-0.023	-0.005
ICC 12478 X ICC 4918	-0.003	-0.033
ICC 12478 X ICC 3137	-0.003	-0.027
ICC 12478 X ICCV 2	-0.015	0.008
ICC 12478 X ICCC 37	-0.006	-0.002
ICC 12479 X ICC 4918	-0.001	-0.041
ICC 12479 X ICC 3137	0.02	0.006
ICC 12479 X ICCV 2	-0.016	-0.001
ICC 12479 X ICCC 37	0.083**	-0.002
ICC 4918 X ICC 3137	-0.03	-0.067*
ICC 4918 X ICCV 2	-0.042	-0.057
ICC 4918 X ICCC 37	-0.044	0.042
ICC 3137 X ICCV 2	0.078**	0.026
ICC 3137 X ICCC 37	-0.06*	0.056
ICCV 2 X ICCC 37	-0.029	0.023

5.1.3.4.1.6 Seed yield plant^{-1}

The combining ability variances were significant for both GCA and SCA. Of the two genetic parameters, σ^2D was relatively more than σ^2A, which emphasized that non- additive gene action was involved in the inheritance and expression of yield per plant.

The hybrids, ICC 12477 × ICC 506, ICC 3137 × ICC 506, ICCC 37 × ICC 506, ICCV 2 × ICC 12476 and ICCC 37 × ICC 3137 with highly significant and positive SCA effects were good specific combiners for increased grain yield. Similar results were reported by 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), Singh and Paroda (1989) and ICRISAT (1985b). The results showed no maternal effects for seed yield plant^{-1}

5.1.3.4.1.7 100- seed weight

The SCA variances were significant indicating the importance of non- additive gene effects for this trait. The hybrids ICCC 37 × ICC 506, ICCV 2 × ICC 12476, ICC 12479 × ICC 12477, ICC 3137 × ICC 12477, ICC 3137 × ICC 4918 and ICCV 2 × ICC 4918 with significant and positive SCA were good specific combiners for 100- seed weight.

5.1.3.4.1.8 Total plot yield

The SCA variances for reciprocal crosses were non- significant. The hybrid ICC 12479 × ICC 12477 was good specific combiner for high yield. The magnitude of σ^2D was relatively greater 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 Ramanujam (1974), Gowda and Bahl (1978), Yadavendra and Kumar (1987) and Shivkumar *et al.*, (2001), who reported that non-additive genetic effects is of major importance for seed yield.

5.1.3.4.1.9 Yield (kg ha^{-1})

SCA variances were non-significant for reciprocal crosses. Predominance of σ^2D over σ^2A in desi chickpea emphasizes the importance of non- additive gene action. The hybrid ICC 12479 × ICC 12477 with significant and positive SCA effects was the best specific combiner for improved yield production and can be used in breeding programmes for higher yields. The results 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), Singh and Paroda (1989), Yadavendra and Kumar, (1987) and Shivkumar *et al.*, (2001). Maternal inheritance was observed in none of the hybrids for yield (kg ha^{-1}).

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 greater than non additive effects (2Σ sca^2) for days to initial flowering, days to 50 % flowering, days to maturity, borer damage (%), pods plant^{-1}, seeds plant^{-1}, seeds per pod and 100- seed weight. while non- additive effects were greater than additive effects for yield plant^{-1}, plot yield, total plot yield and yield (kg ha^{-1}). The results which indicate the importance of both GCA and SCA effects in the study were days to initial flowering, days to 50% flowering, days to maturity, borer damage (%), pods plant^{-1}, seeds plant^{-1}, seeds per pod, 100- seed weight, yield plant^{-1}, total plot yield 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 *et al.*, (2001).

The A : D ratio is greater than unity for the characters days to initial flowering, days to 50 % flowering, days to maturity, borer damage (%), pods plant^{-1}, seeds plant^{-1}, seeds per pod and 100- seed weight indicating over dominance, while yield plant^{-1}, total plot yield and yield (kg ha^{-1}) the ratio is less than unity, indicating partial dominance (Table 72). Earlier reports supporting these results were made by 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 85a and b), Gowda *et al.*, (1983) and Singh *et al.*, (1992). Thus days to flowering and 100-seed weight can be improved by a simple selection scheme such as the pedigree method, since 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 parents used in the present investigation constitute a selected set of eight desi and one kabuli chickpea varieties. Hence, the information regarding the gene action and estimates of combining ability effects and their variances applicable only to this set (ICC 506, ICC 12476, ICC 12477, ICC 12478, ICC 12479, ICC 3137, ICC 4918, ICCC 37 and ICCV 2) of parents.

5.2 THE MECHANISMS AND INHERITANCE OF DIFFERENT COMPONENTS OF RESISTANCE

Knowledge of the mechanisms, nature and inheritance of resistance is critical for developing germplasm with durable and stable resistance to insects. In view of

Table 72 : Gene action for morphological and yield traits associated with chickpea genotypes (ICRISAT, Patancheru, 2004-05).

Trait	Genotypic variance		Gene action	A : D	
	σ^2A	σ^2D			
Days to initial flowering	36.08	7.15	Additive	2.52	Over dominance
Days to 50% flowering	27.92	4.93	Additive	2.83	Over dominance
Days to maturity	3.56	0.63	Additive	2.83	Over dominance
Pod borer damage (%)	17.39	3.93	Additive	2.21	Over dominance
No. of pods plant^{-1}	207.13	59.21	Additive	1.75	Over dominance
No. of seeds plant^{-1}	287.9	104.5	Additive	1.37	Over dominance
No. of seeds pod^{-1}	0.005	0.001	Additive	1.63	Over dominance
Yield plant^{-1} (g)	1.61	3.45	Dominant	0.23	Partial dominance
100- seed weight (g)	11.19	0.08	Additive	69.3	Over dominance
Total plot yield (g)	2223.4	2977.4	Dominant	0.37	Partial dominance
Yield (kg ha^{-1})	154400.4	206762.3	Dominant	0.37	Partial dominance

limited success in the past in developing crop cultivars with resistance to *H. armigera* by using known sources of resistance, there is a need to identify genotypes with different mechanisms (genes) of resistance. Resistance genes from diverse sources need to be combined (gene pyramiding) to increase the levels, and diversify the bases of resistance to this pest. All the three mechanisms, antixenosis, antibiosis and tolerance have been reported against *H. armigera* in chickpea (Chabhra *et al.*, 1990).

Studies on inheritance of resistance have indicated that resistance to *Helicoverpa armigera* in chickpea may be additive (ICRISAT, 1984).

The different mechanisms of resistance to *H. armigera* in chickpea include preference and non- preference for oviposition, antibiosis and tolerance. The results of different experiments conducted under this objective are discussed below.

5.2.1 Preference and non- preference for oviposition (or) Antixenosis

The genotype ICC 12475 recorded the lowest number of eggs under no-choice conditions, followed by ICC 12476, ICC 12477 and ICC 12478. The susceptible genotypes, ICC 12426 and ICC 4918 were preferred by *H. armigera* females for oviposition. A female laid an average of 1052.5 eggs. The genotypes ICC 12475, ICC 12476, ICC 12477, ICC 12478 and ICC 12479 were least preferred by *H. armigera* females compared to ICC 4918, ICC 3137 and ICCV 2. Significantly lower number of eggs were recorded on ICC 12476, ICC 12477, ICC 12478, ICC 12479, ICCV 2 and ICC 506 as compared to susceptible check, ICCC 37 under dual choice conditions. There was no significant difference in the number of eggs laid on the test genotype and susceptible check for ICC 4918 and ICC 3137. ICC 3137, ICC 4918, ICC 12476, ICC 12477, ICC 12478, ICC 12479 and ICCV 2 recorded highest per cent oviposition compared to the resistant check, ICC 506.

Srivastava and Srivastava (1989), Cowgill and Lateef (1996) and Sison *et al.*, (1996) reported that oviposition non- preference is one of the components of resistance to *H. armigera* in chickpea.

During 2004/05 post-rainy season, on comparing the hybrids of each parent, significantly lower number of eggs were recorded on all the hybrids compared to the susceptible genotype, ICCC 37. Eggs laid by each female ranged between 154 egg day^{-1} (ICC 506) to 360 (ICC 4918) on parents, while in hybrids, it ranged from 131.5 on ICC 506 × ICC 12476 to 284 eggs day^{-1} on ICCC 37 × ICC 4918. There were significant difference between the test genotype and susceptible check among the nine parents and their 72 F_1 hybrids, except in case of ICC 12479 × ICC 12477. On hybrids of ICC 12476, ICC 12477, ICC 12478, ICC 12479, ICC 506, ICC 3137, ICCC 37, ICC 4918 and ICCV 2 parents a female laid average number of 189.1, 171.9, 174.4, 177.1, 175.4, 212.8, 223.8, 220.6 and 202.4 eggs day^{-1}, respectively.

Under multi-choice conditions, lowest number of eggs were recorded on the resistant check, ICC 506 (692 eggs female^{-1} week^{-1}), followed by ICC 12476 (758 eggs female^{-1} week^{-1}), while susceptible check, ICC 12426 (1127 eggs female^{-1} week^{-1}) recorded highest number of eggs. Cowgill and Lateef (1996) and Sison *et al.*, (1996) recorded fewer eggs on resistant line, ICC 506 than on ICCC 37 and ICC 4918 over two seasons in multi-choice field and laboratory tests. Non-preference was not evident in long duration genotypes of chickpea. Cowgill and Lateef (1996) also reported non-significant oviposition in long duration chickpea genotypes. The genotypes ICCV 2, ICC 4918 and ICC 12478 were highly preferred for oviposition by the *H. armigera* females compared to ICC 12475, ICC 12476, ICC 3137, ICC 12479 and ICC 12477.

Sreelatha (2003), studied oviposition of *H. armigera* under no-choice, dual choice and multi- choice conditions, revealed that the genotypes ICC 12475, ICC 12476, ICC 12477, ICC 12478 and ICC 12479 were less preferred for oviposition compared to ICCV 2.

Under field conditions, resistant genotypes recorded less number of eggs than the susceptible ones, and there was a direct positive correlation between number of eggs laid and larval abundance. Similar results were reported earlier by Srivastava and Srivastava (1989), who stated that oviposition non- preference is the major cause of observed differences in pod damage and found direct relationship between number of eggs laid and larval abundance.

The number of eggs recorded on all the genotypes were lower under field conditions compared to laboratory. 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 conditions. Therefore it is important to use detached leaf assay (Sharma *et al.,* 2005) and no-choice cage screening (Sharma *et al.*, 2005) techniques under field and greenhouse conditions to confirm the resistance observed under the natural infestation in the field.

5.2.2 Antibiosis

Antibiosis is the adverse effect of a plant on some aspects of the insect's biology (Painter 1951 and 1958). The effects of antibiosis may be reduction in size and weight, fecundity, abnormal length of life and increased mortality of the insects (Owens, 1975, Yoshida *et al.*, 1995 and Mann, 2002).

5.2.2.1 Detached leaf assay

Screening for resistance to *H. armigera* under natural conditions is a long-term process because of variations in insect population in space and time. As a result, it is difficult to identify stable sources of resistance under natural infestation (Sharma *et al.*, 1997). Therefore, development and standardization of techniques to screen for resistance to insect pests is the key for an effective insect resistance breeding program, marker-assisted selection, and development of transgenic plants with resistance to insects. Genotypic reactions to feeding by *H. armigera* are diverse, and therefore, careful consideration should be given to use the insect density that results in maximum differences between the resistant and susceptible genotypes. Percentage of damage to bolls/pods is the most common parameter used for determining genotypic resistance or susceptibility to *H. armigera* under field conditions (Sharma *et al.*, 2003). However, this criterion often leads to variable results due to variations in insect population and the stage at which the crop is infested. In addition, the damage to foliage, flowers, and small pods, which are devoured by the larvae, is not reflected in percentage of pod damage. At times, the pods or bolls sampled for recording insect damage may be from the second flush, which might have escaped insect damage. To overcome these problems, the test material can be evaluated for resistance to the target insect by using the detached leaf assay under uniform insect pressure at the seedling, flowering or pod developmental stages (Sharma *et al.*, 2005).

Significantly lower leaf feeding was observed on the resistant check, ICC 12475 followed by ICC 12476. Survival rate and larval weights were lowest on the resistant check, ICC 12475 followed by ICC 12476, ICC 12477, ICC 12478 and ICC 12479, suggesting that antibiosis is one of the components of resistance to *H.*

armigera in chickpea. Leaf exudates play an important role in *H. armigera* resistance in chickpea (Rembold, 1981; Rembold and Winter, 1982; Srivastava and Srivastava, 1989; Rembold *et al.*, 1989b and 1990a; Rembold and Weigner, 1990 and Yoshida, 1997) and may be responsible for antibiosis to this pest.

During the flowering stage, the genotypes ICC 12478, ICC 12479 and ICC 12475 suffered significantly lower leaf damage than the susceptible check, ICC 12426. The genotypes ICC 12475, ICC 3137, ICC 12478 and ICC 12479 were less preferred by *H. armigera* larvae compared to susceptible checks, ICC 4918 and ICC 12426. In another experiment, greater number of larvae survived on ICC 4918, ICC 12426, ICC 12478, ICC 12476 and ICC 12479 as compared to that on resistant check, ICC 506. The larval weights were significantly lower on ICC 12475, ICC 12477 and ICC 12478 as compared to susceptible check, ICC 12426.

The detached leaf assay not only gives an idea of the relative feeding by the larvae on different genotypes but also provides useful information on antibiosis component of resistance in terms of larval weight (Sharma *et al.*, 2005).

For F_1s damage rating ranged between 3.6 (ICC 12475) to 7.8 (ICCC 37) for parents and 3.2 (ICC 12479 × ICC 506) to 7.8 (ICCC 37 × ICC 4918) for the hybrids, indicating considerable variation for susceptibility to neonate larvae of *H. armigera* among the parents and their F_1 hybrids. Damage rating, larval survival and/or weight gain by the larvae were lower on the hybrids based on ICC 12475, ICC 12476, ICC 12477, ICC 12478 and ICC 12479 as compared to the hybrids crossed based on ICC 3137, ICCC 37, ICC 4918 and ICCV 2.

Chickpea varieties differ in their susceptibility to *Helicoverpa armigera* due to differences in antibiosis mechanism (Singh and Sharma, 1970). Lateef (1985) suggesting that amounts of acid exudates on leaves could be used as criteria for distinguishing chickpea genotypes for resistance to *H. armigera.* Rembold (1981) recommended it as a marker to identify resistance in chickpea. Low amounts of acidity in the leaf extracts of genotypes were associated with susceptibility to *H. armigera* (Srivastava and Srivastava, 1990a, Bhagwat *et al.*, 1995 and Yoshida, 1997). Larvae gained maximum weights on susceptible genotypes compared to resistant genotypes (Srivastava and Srivastava, 1990b).

The relative susceptibility of the test genotypes in the field and in the detached leaf assay may be influenced by the relative importance of non-preference for oviposition and feeding, antibiosis and tolerance. Therefore, care should be exercised to see that the results of excised leaf assays are not totally different than those under field conditions. However, where the non-preference for feeding and antibiosis are important components of resistance, this technique can be used effectively for rapid and large scale screening of germplasm, breeding material, and mapping populations under uniform insect pressure and optimum environmental conditions. It also provides useful information on antifeedant and antibiosis components of resistance.

5.2.2.2 Relative susceptibility of different chickpea genotypes under no-choice cage conditions

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 IC 12476, ICC 12477, ICC 12478 and ICC 12479 were found to be resistant and their levels of resistance were comparable to the resistant check, ICC 12475. Reduced leaf damage rate, low larval survival and larval growth in these genotypes indicated that antibiosis is one of the components of resistance.

Under un-infested conditions, the per plant yield was greater in ICC 12426 followed by ICC 12478 and Annigeri. The resistant cultivars ICC 12478 and ICC 12475 recorded total higher yield. In some of the plants recovered from the leaf feeding and survived. In the susceptible genotypes (ICC 12426, ICC 3137 and ICC 4918) some plants failed to recover because of heavy damage. In the podding stage of the crop, when plants were infested with the third instar larvae, the recovery rate was very low, as most of the pods were consumed.

Olla and Saini (2000), studied the feeding preference of the third instar larvae of *H. armigera.* In no- choice feeding tests, the resistant genotypes showed less leaf and pod damage than susceptible genotypes. Similar results were recorded by Sreelatha (2003).

The ability to collect precise quantitative data on *H. armigera* damage is a critical element for successful development of resistant varieties and reliable marker-assisted selection systems. Percentage of damage to pods is the most common parameter used for determining genotypic susceptibility to *H. armigera* under field conditions (Sharma *et al.*, 2003). However, this criterion often leads to unreliable results due to variations in insect populations and the stage at which the crop is infested. In addition, the damage to foliage, flowers and small pods, which were devoured by the larvae, is not reflected in percentage pod damage. This criterion also does not take into account the genotypic ability to produce a second flush in case the first flush is lost due to *H. armigera* damage. To overcome these problems, the test material can be evaluated for foliar damage by the neonates at the seedling and flowering stages and pod damage by the third instars at the podding stage. Measurement of yield reduction indicates direct feeding injury to plants. This also takes into account the effects of leaf feeding on grain yield at the seedling stage, and tolerance or recovery from *H. armigera* damage during the vegetative phase. Reduction in grain yield also provides a good measure of agronomic performance and the genotypic ability to withstand *H. armigera* damage at different growth stages and under different insect densities.

Caging the test plants with insects is a dependable method of screening for resistance to *H. armigera*. In this method, considerable control can be exercised on maintaining uniform insect pressure on the test materials, and the plants can be infested at the same phenological stage. This also prevents insects from moving away from the test plants, and the larvae also are protected from the natural enemies. For valid comparison, resistant and susceptible checks of appropriate maturity should be infested at the same time as the test genotypes. The no-choice test can be used to screen chickpea plants for resistance to *H. armigera* at the seedling and reproductive stages and provides information on antibiosis mechanism of resistance to *H. armigera*. This technique can also be used to measure genotypic resistance at different growth stages of plant and at different densities.

During vegetative stage, the plants suffered high leaf damage and greater number of larva survived on ICCC 37 and ICC 4918 as compared to resistant check, ICC 12475. Recovery rate of the infested plant was maximum in the genotype ICC 12475. Lowest recovery rate was recorded on ICC 12426 and ICC 4918 and these were poor yielders under infested conditions.

The recovery of the infested plants was better in case of ICC 12475, ICC 12476, ICC 12477, ICC 12478, ICC 12479 and ICCV 2 as compared to ICC 3137, ICC 4918 and ICC 12426. The loss in grain yield was greater in case of ICC 3137, ICC 12476, ICC 4918 and ICC 12426 than on resistant check, ICC 12475 during the flowering stage.

Larval survival was greater on susceptible check, ICCC 37 as compared to resistant check, ICC 506. Grain yield of infested plants was greater in case of ICC 12475, ICC 12477 and ICC 12478 as compared to ICC 12426.

5.2.2.3 Survival and development of *H. armigera* on leaf material of different chickpea genotypes

Weights of the 10- day old larvae reared on leaves of different genotypes differed significantly. Highest larval and pupal weights were recorded on susceptible checks, ICC 12426 and on ICC 3137, indicating the presence of less amount of acid exudates, where as lowest weights were recorded with the resistant check, ICC 12475. Larval and pupal periods were longer on the resistant check, ICC 506 than on susceptible control, ICCC 37. There is no much difference in the larval period on ICC 3137, ICC 12476, ICC 12477, ICC 12478, ICC 12479 and ICCV 2. Larval survival was > 80 % on ICC 3137, ICCV 2, ICC 4918 and ICCC 37 as compared to 66 % in the resistant check, ICC 12475. Male to female sex ratio and mean adult longevity of insects reared on different genotypes did not differ significantly.

Highest growth index, adult index, oviposition index and pupal index were higher on ICC 12426 and ICC 4918, while lowest indices were observed on resistant check, ICC 12475. These results were in accordance with the reports of Srivastava and Srivastava, 1989; Chabhra *et al.,* 1993; Bhagwat *et al.,* 1995 and Patnaik and Senapati, 1995 who reported that low amount of acidity of leaf exudates and malic acid content were associated with the susceptibility of the genotype to *H. armigera.* Cowgill and Lateef (1996), reported that the larvae reared on the leaves and pods of resistant lines (ICC 12475 and ICC 14876) and pupae formed from these larvae weighed substantially lower than those reared on the susceptible genotypes (ICC 4918 and ICC 3137).

A better knowledge of inheritance of pod borer resistance in conjugation with malic acid content is very essential to develop appropriate breeding strategies for improving grain yield and host plant resistance to pod borer in chickpea (Salimath *et al.,* 2003).

5.2.2.4 Survival and development of *H. armigera* on artificial diet impregnated with lyophilized leaf and pod powder of different chickpea genotypes

The mean larval and pupal weights and larval survival were high when the larvae were reared on lyophilized leaf and pod powder compared to those reared on leaves. This may be because of more nutrients available in the artificial diet, as standard diet (diet without lyophilized leaf and pod powder) recorded higher larval and pupal growths.

Ten day old larvae weighed highest on the standard diet followed by those recorded on diets with ICC 4918 and ICCC 37 leaf powder. Lowest larval and pupal weights were recorded on the resistant check, ICC 506. Larval survival in diet impregnated with leaf powder of F_1 hybrids, ranged from 54 % (ICC 12476 × ICC 506) to 90 % (ICC 4918 × ICCC 37). Weight of the 10-day old larva ranged from 252 mg on ICC 12478 × ICC 12477 to 452.4 mg on ICC 12478 × ICCC 37. pupal weight ranged between 245.8 mg on ICC 12478 × ICC 12476 to 341.9 mg on ICC 12476 × ICC 12478.

Larvae reared on diet with lyophilized pod powder of ICC 12475, ICC 12476 and ICC 12479 weighed significantly lower than those reared on the standard diet.

There were no difference in the pupal weights on diet with leaf powder of different genotypes.

Larval period was longer on resistant genotypes compared to susceptible ones, and on the standard diet. These results suggested that a growth inhibitor or antifeedant substance or both existed in the resistant genotypes. The larval survival, larval weight, pupal weight, pupation and adult emergence were consistently lower in the resistant genotypes than on 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).

Malic acid and oxalic acid are the principal components of resistance to *H. armigera* in the cultivated chickpea, which result in oviposition non-preference and antifeedant effects on *H. armigera* (Yoshida *et al.*, 1995). However, antibiosis seems to be the major component of resistance in the wild relatives of chickpea, which may be due to secondary plant substances such as several isoflavones, pterocarpans and 2-arylbenzofuran, which have been isolated from the roots of wild chickpea, *C. bijugum*. These flavonoids have also shown antifeedant and antibiotic activity towards the larvae of *H. armigera* (Simmonds and Stevenson, 2001), and may be responsible for the adverse effects of wild relatives of chickpea on the survival and development of *H. armigera*. Developing seeds of wild chickpeas have also shown significant variation in trypsin inhibitors for the *H. armigera* gut proteinases were insensitive to proteinase inhibitors from *Cicer* sp (Patankar *et al.*, 1999). Thus, wild relatives of chickpea seem to have different mechanisms of resistance to *H. armigera* than in the cultivated chickpeas, which can be exploited to increase the levels and diversify the basis of resistance to this pest.

There has been little success in introgressing resistance genes from the tertiary gene pool of *Cicer* sp into the cultigen. The crossability barriers are believed to be the factors operating after fertilization, which possibly can be overcome through embryo rescue techniques. The possibility of gene transfer from *C. reticulatum* and *C. echinospermum* to the cultigen is quite high (Pundir and Maesen, 1983, Pundir and Mangesha, 1995, Singh *et al.*, 1984, Badami *et al.*, 1997, Sheila *et al.*, 1992 and Verma *et al.*, 1990 and 1995), and the accessions of these wild species showing resistance to *H. armigera* can be exploited to increase the levels of resistance to this pest (Sharma *et al.*, 2005).

5.2.2.5 HPLC profiles of leaf exudates

To be able to screen the extensive plant material and to know which characters to incorporate into the high-yielding varieties, it was considered necessary to study the chemical background of resistance and susceptibility.

ICC 12476 and ICC 12477 and ICCC 37 recorded highest (13) and lowest number of peaks (6) in the surface water soluble components. The peaks at retension times, 3.51, 3.71, 3.92, 5.82, 6.77 and 16.2 were observed in all the 81 entries. Peak at RT 12.8 was observed in all the parents except in ICCC 37. ICC 506 had 5 major peaks. ICC 12476 and ICC 12477 had 4 major peaks, including citric acid and fumaric acid. Oxalic acid, malic acid, acetic acid and fumaric acid were the 4 major peaks in the leaf samples of ICC 12479, ICC 3137, ICCC 37. The kabuli genotype, ICCV 2 had 4 major peaks including oxalic acid, malic acid and acetic acid.

Malic acid content was significantly and negatively correlated with damage rating at flowering (-0.28*), at maturity (-0.32**) and pod damage (-0.22*). Oxalic acid was negatively and significantly correlated with damage rating in detached leaf assay (-0.22*). Acetic acid showed a negative correlation with larval weight (-

0.45*), damage rating at flowering (-0.33**) and at maturity (-0.26*). Citric acid showed negative and significant correlation with damage rating at flowering (-0.23*).

Oxalic acid and malic acids has been reported to have an antibiotic effect on *H. armigera* larvae (Yoshida *et al.*, 1995), and it is possible that the antibiotic properties of oxalic acid may negate differences due to ovipositional antixenosis and determine the size of the larval population and therefore pod damage on a particular genotype (Yoshida 1997, Rembold, 1981, Rembold and Winter, 1982 and Rembold *et al.*, 1990a and b).

Oxalic and malic acid levels could be used to select material for further screening. Leaves in the flowering-early podding or tender pod stage would be the most appropriate sample unit, as the differences in the oxalic acid levels between resistant and susceptible genotypes are most marked at this time. In addition, the duration of the podding period could also be used as a selection criterion. This would be particularly useful for medium duration genotypes where plants with shorter podding periods should be selected to minimize the period of exposure to the pest.

Another reason to study the plant chemistry often forgotten in plant breeding for resistance, is to detect substances in the crops that are unsuitable for consumption by humans and animals. This is necessary even if the work is carried out at the genetic level, because resistance to insects does not act at such a level, it is the allelochemicals, the product of the genes, that are the active components.

HPLC method was found to be specific and suitable for acid exudates analysis because of its simplicity, specificity, accuracy and reproducibility.

5.2.3 Tolerance

Tolerance provides plants the ability to produce satisfactory yield in the presence of a pest population that would otherwise result in significant damage and reduction of economic yield 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, nutrient and growth regulation. Cultivars with tolerance mechanism of resistance have a great value in pest management, as such cultivars 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 tool in resistance breeding (Tingey, 1981).

Days to 50 % flowering and days to maturity were delayed under un-protected conditions compared to protected conditions (pesticide sprays were given, as per economic threshold levels), as the plants tend to produce more flowers and pods as a result of loss of pods due to *Helicoverpa* damage.

Significantly higher pod borer damage (%) was recorded under un-protected conditions, compared to protected conditions. However the resistant check, ICC 12475 recorded the lowest pod borer damage both under protected and un- protected conditions. The susceptible genotypes, ICC 12426, ICC 4918 and ICC 3137 recorded the highest damage rating under un-protected conditions compared to protected conditions. The susceptible cultivar, ICC 3137 recorded damage (%) of 7.72 % and 40.33 % pod damage under protected and un-protected conditions, respectively. It is a medium duration genotype, but starts podding earlier than the other medium duration genotypes and retained green leaves and pods as late as the other late duration genotype. Longer podding period resulted in prolonged exposure to *Helicoverpa armigera.* The length of podding period may therefore to be used as one of the factors associated with resistance to *H. armigera.* Genotypes with shorter podding period are preferred and have low pod damage especially in the medium duration genotypes (Yoshida, 1997).

The genotypes, ICC 12476, ICC 12477, ICC 12478, ICC 12479 and ICCV 2 were on par with the resistant check, ICC 12475 for pod borer damage under protected conditions. Lateef and Sachan (1990), stated that some of the chickpea lines suffered considerably less borer damage than others due to tolerance to pod borer. This has necessitated the need for selecting genotypes with greater ability to tolerate or recover from the pod borer damage (Lateef, 1985 and Srivastava and Srivastava, 1989).

Significantly high grain yield was recorded in ICC 12426, Annigeri and ICC 12476 under protected conditions. High yield was recorded under un-protected conditions in ICC 12475, ICC 12426, ICC 12478 and ICC 12479 but the differences among them were not significant.

The eggs and larvae of *H. armigera* were recorded on chickpea at 15 days after sowing when the crop was at the vegetative stage. When the crop reached pod formation stage, larvae damaged pods by feeding on developing grains. Under field conditions, the mean density of *H. armigera* larvae and oviposition rate for parents and hybrids were 3.79, 2.83 and 3.55 and 2.3, 1.25 and 1.21 respectively. The correlation between number of larvae and egg number ($r = 0.89^{**}$), leaf damage and egg number ($r = 0.82^{*}$), yield per plant and egg number ($r = 0.77^{*}$) and yield per plant and larvae ($r = 0.76^{*}$) were significant and positive, under protected conditions. Under un- protected conditions, significant and positive correlations were recorded between leaf damage and number of larvae (r= 0.85*) and yield per plant and total grain yield (kg ha^{-1}) (r = 0.91*). The damage with respect to yield parameters was significantly lower in un- protected crop as compared to the crop protected with chemical insecticides.

The genotypes ICC 12475 (3.77) and IC 12478 (6.59) recorded lowest reduction in grain yield under un-protected conditions as compared to ICC 3137 (51.87), ICC 12476 (31.82), ICC 12477 (26.52), ICC 12479 (22.21), ICCV 2 (26.95), ICC 4918 (27.17) and ICC 12426 (26.66), indicating the presence of tolerance mechanism in chickpea to *H. armigera.* The results were in agreement with the reports of Singh *et al.,* 1985, who reported that mean reduction in the grain yield was low in protected crop compared to un- protected one. The avoidable loss in grain yield by applying a single spray of endosulfan was 60 to 87.5 %. Shukla *et al.,* (1998), Yelshetty *et al.,* (1996), Kaur *et al.,* (1999), Bhatt and Patel (2001), Patnaik and Senapati (2001) and Suryawanshi *et al.,* (2003) have discussed the tolerance of chickpea cultivars against the pod borer, *H. armigera.*

Sreelatha (2003), reported that the 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. ICC 12477 and ICCV 2 were highly tolerant as there was slight increase in yield under un-protected conditions.

5.3 INTERACTION OF DIFFERENT COMPONENTS OF RESISTANCE AND GRAIN YIELD

Crop yield may fluctuate due to sensitivity of varieties to different growing seasons or climatic conditions. Knowledge about its inheritance is useful to bring about genetic improvement of a crop.

Significant and positive correlations were observed under protected conditions between larvae and eggs ($r = 0.89^{**}$), leaf damage and egg number ($r = 0.82^{*}$), yield per plant and egg number ($r = 0.77^{*}$), yield per plant and larva number ($r = 0.76^{*}$), yield per plant and egg number (0.82^{*}) and pod damage (%) and larva number ($r = 0.91^{**}$). Similar results were recorded by Gowda *et al.,* (1983), who studied the interaction between borer damage and grain yield.

The correlation between larval number and pod borer damage (%), yield (kg ha^{-1}) and egg number, pod damage and egg number, leaf damage and larva number, pod damage and leaf damage, yield per plant and leaf damage, pod damage and yield (kg ha^{-1}), yield per plant and yield (kg ha^{-1}) and yield per plant and pod damage was positively non-significant, under protected conditions. Srivastava *et al.,* (1975) studied 20 chickpea lines and found significant variation in the per cent of pods damaged. They found no correlation between seed yield and pod damage by *H. armigera.* Singh and Singh (1995), reported positive and significant correlation between pod damage and single plant yield in chickpea.

Under un- protected conditions, the correlation between yield (kg ha^{-1}) and borer damage (%), yield per plant and borer damage (%), yield (kg ha^{-1}) and egg number and yield (kg ha^{-1}) and leaf damage were negative and non-significant, but positive and non-significant correlation was recorded between egg number and borer damage (%), larva number and borer damage (%), pod damage and borer damage (%), leaf damage and egg number, pod damage and egg number, pod damage and leaf damage, pod damage and yield (kg ha^{-1}) and yield per plant and yield (kg ha^{-1}). Significant and positive correlation between the larval population and pod damage (%) ($r = 0.19^{*}$) was reported by Sreelatha, 2003. Interaction of different components of resistance and grain yield will help in gene pyramiding.

Significantly positive correlations between number of pods per plant and grain yield was reported by Bejiga *et al.*, (1991), Chhina *et al.*, (1991) and Abdali (1992) in chickpea.

A better understanding of the mechanisms and inheritance of resistance and magnitude of gene action governing yield and yield components will help in deciding on a proper selection strategies for improvement of grain yield. A better knowledge of inheritance of pod borer resistance in conjunction with the resistance mechanisms is important to develop strategies for improving grain yield and developing pod borer resistant cultivars in chickpea. Development of chickpea cultivars with polygenic resistance to *H. armigera* combining insect antixenosis, antibiosis and tolerance would slowdown the breakdown of chickpea resistance to *Helicoverpa armigera* and used to sustainable chickpea production in semi-arid tropics.

Chapter VI
Summary

CHAPTER VI

SUMMARY

The present studies were carried out at the International Crops Research Institute for the Semi-Arid Tropics, Patancheru, India, between 2003-2005 to elucidate the "Genetics of resistance to pod borer, *Helicoverpa armigera* in chickpea (*Cicer arietinum*)". These studies largely focussed on the nature of gene action and maternal effects, plant resistance mechanisms and the inheritance of different components of resistance to pod borer in chickpea. The results of the different experiments are summarized as follows.

Eight desi (ICC 12475, ICC 12476, ICC 12477, ICC 12478, ICC 12479, ICC 4918, ICC 12426 and ICC 3137) and one kabuli (ICCV 2) parents were selected based on earlier screening trials to evaluate the genetics of resistance to pod borer. The genotype, ICCV 2 was the earliest to flower and mature followed by ICC 4918, ICCC 37, ICC 12478 and ICC 12477, while ICC 12479, ICC 12476 and ICC 3137 were late to flower and mature. The genotype, ICC 12478 suffered significantly lowest damage followed by ICC 506, ICC 12479 and ICC 12477. ICC 3137 was highly susceptible to *H. armigera* damage and recorded lowest seed yield. Most all the crosses with ICC 506, ICC 12478 and ICC 12479 suffered lower damage due to pod borer, while those with ICC 3137, suffered higher damage. ICCC 37 recorded higher yield followed by ICC 12479 and ICC 12476.

Additive genetic effects (2Σ gca^2) were greater than non additive effects (2Σ sca^2) for days to initial flowering, days to 50 % flowering, days to maturity, pod borer damage (%), pods plant^{-1}, seeds plant^{-1}, seeds per pod and 100- seed weight, indicating that additive gene action was important. Non- additive effects were greater than additive effects for yield plant^{-1}, total plot yield and yield (kg ha^{-1}). The results which indicate the importance of both GCA and SCA effects in the study were days to initial flowering, days to 50 % flowering, days to maturity, borer damage (%), pods plant^{-1}, seeds plant^{-1}, seeds per pod, 100- seed weight, yield/plant, total plot yield and yield (kg ha^{-1}). The A : D ratio is greater than unity for the characters, days to initial flowering, days to 50 % flowering, days to maturity, borer damage (%), pods plant^{-1}, seeds plant^{-1}, seeds per pod and 100- seed weight indicating over dominance, while yield plant^{-1}, total plot yield and yield (kg ha^{-1}) the ratio is less than unity, indicating partial dominance.

There was no maternal inheritance for maturity traits, pod borer damage, grain yield and yield (kg ha^{-1}). The hybrid, ICC 12476 × ICCC 37 showed positive and significant SCA effects for seeds per pod, but ICCC 37 × ICC 12476 showed negatively significant SCA effects for number of seeds pod^{-1}. So the hybrid ICCC 37 × ICC 12476 may be showing cytoplasmic inheritance for the number of seeds/ pod.

The genotype ICC 12475 recorded the lowest number of eggs under no-choice conditions, followed by ICC 12476, ICC 12477 and ICC 12478. The genotypes ICC 12475, ICC 12476, ICC 12477, ICC 12478 and ICC 12479 were non-preferred for oviposition by *H. armigera* females for oviposition compared to ICCC 37, ICC 4918, ICC 3137 and ICCV 2. Significantly lower number of eggs were recorded on ICC 12476, ICC 12477, ICC 12478, ICC 12479, ICCV 2 and ICC 506 as compared to susceptible check, ICCC 37 under dual choice conditions. There were significant differences between the number of eggs laid on the test genotype and susceptible check among the nine parents and their 72 F_1 hybrids, except in ICC 12479 × ICC 12477. Under multi-choice conditions, the pod borer resistant genotypes recorded less number of eggs than the susceptible genotypes, and there was a positive correlation between number of eggs laid and larval abundance under field conditions.

Larval survival and larval weights were lowest on the resistant check, ICC 12475 followed by ICC 12476, ICC 12477, ICC 12478 and ICC 12479. Water soluble compounds in the leaf exudates (malic and oxalic acid) were primarily responsible for the resistance of the chickpea genotypes to *H. armigera*. The detached leaf assay not only gives an idea of the relative feeding by the larvae on different genotypes but also provides useful information on antibiosis component of resistance in terms of larval weight. The relative susceptibility of the test genotypes in the field and in the detached leaf assay is influenced by the relative importance of non-preference for oviposition and feeding, antibiosis and tolerance components of resistance.

Screening under no-choice cage conditions in the greenhouse 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. The genotypes IC 12476, ICC 12477, ICC 12478 and ICC 12479 were found to be resistant to *H. armigera* in no-choice cage tests, and their levels of resistance were comparable to the resistant check, ICC 12475. Reduced damage rate, low larval survival and larval growth on these genotypes indicated that antibiosis is one of the components of resistance to *H. armigera* in chickpea.

Under un-infested conditions, the per plant yield was greater in ICC 12426 followed by ICC 12478 and Annigeri. The resistant cultivars ICC 12478 and ICC 12475 recorded total higher yield. In the susceptible genotypes (ICC 12426, ICC 3137 and ICC 4918) some of the plants failed to recover because of heavy damage.

At the podding stage of the crop, when plants were infested with the third instar larvae, the recovery resistance was very poor, as most of the plants were damaged.

Highest larval and pupal weights were recorded on susceptible cultivars, ICC 12426 and ICC 3137, whereas lowest weight was recorded on the resistant check, ICC 12475. Larval and pupal periods were longer on the resistant check, ICC 506 than on susceptible control, ICCC 37. There were no difference in larval period on ICC 3137, ICC 12476, ICC 12477, ICC 12478, ICC 12479 and ICCV 2. Highest growth index, adult index, oviposition index and pupal index were recorded in ICC 12426 and ICC 4918, while lowest indices were recorded on the resistant check, ICC 12475.

Ten day old larvae weighed greater on standard diet followed by the larvae reared on diets with leaf powder of ICC 4918 and ICCC 37. Lowest larval and pupal weights were recorded on diets impregnated with lyophilized leaf powder of ICC 506. Larvae fed on diet with lyophilized pod powder of ICC 12475, ICC 12476 and ICC 12479 weighed significantly lower than those fed on standard artificial diet. Larval period was longer on resistant genotypes compared to that on the susceptible ones and standard diet. Larval survival, larval weight, pupal weight, pupation and adult emergence were consistently lower on the resistant genotypes than on the susceptible ones.

Malic acid content was negatively correlated with damage rating at flowering (-0.28*), at maturity (-0.32**) and pod damage (-0.22*). Oxalic acid showed negative and significant correlation with damage rating with detached leaf assay (-0.22*). Acetic acid showed a negative correlation with larval weight (-0.45*), damage rating at flowering (-0.33**) and at maturity (-0.26*). Citric acid showed a negative and significant correlation with damage rating at flowering (-0.23*). Oxalic acid and malic acids has been reported to have an antibiotic effect on larvae, and it is possible that the antibiotic properties of oxalic acid may negate differences due to ovipositional non-preference and determine the size of the larval population and therefore pod damage on a particular genotype.

Days to 50 % flowering and days to maturity were delayed under un-protected conditions compared to protected conditions. Significantly higher pod borer damage (%) was recorded under un-protected conditions, compared to protected conditions. However the resistant check, ICC 12475 recorded the lowest pod borer damage both under protected and un- protected conditions. The susceptible cultivars, ICC 12426, ICC 4918 and ICC 3137 showed higher damage rating under un-protected conditions compared to the protected conditions. The susceptible check, ICC 3137 recorded damage (%) of 7.72 % and 40.33 % pod damage under protected and un-protected conditions, respectively.

The genotypes, ICC 12476, ICC 12477, ICC 12478, ICC 12479 and ICCV 2 were on par with the resistant check, ICC 12475 for pod borer damage under protected conditions. Grain yield of the genotypes, ICC 12475, ICC 12426, ICC 12478 and ICC 12479 was quite high under un-protected conditions. The genotypes ICC 12475 (3.77) and IC 12478 (6.59) showed lowest reduction in grain yield under un-protected conditions, as compared to ICC 3137 (51.87), ICC 12476 (31.82), ICC 12477 (26.52), ICC 12479 (22.21), ICCV 2 (26.95), ICC 4918 (27.17) and ICC 12426 (26.66), indicating tolerance mechanism as an important component of resistance in chickpea to *H. armigera.*

Significant and positive correlations were observed under protected conditions between larvae and eggs (r = 0.89**), leaf damage and egg number (r = 0.82*), yield per plant and egg number (r = 0.77*), yield per plant and larva number (r = 0.76*), yield per plant and egg number (0.82*) and pod damage (%) and larva number (r = 0.91**). The correlations between larval numbers and pod borer damage (%), yield (kg ha^{-1}) and egg number, pod damage and egg number, leaf damage and larval numbers, pod damage and leaf damage, yield per plant and leaf damage, pod damage and yield (kg ha^{-1}), yield per plant and yield (kg ha^{-1}) and yield per plant and pod damage was negative and non-significant under un-protected conditions, but positive under protected conditions. Under un-protected conditions, the correlations between yield (kg ha^{-1}) and pod borer damage (%), yield per plant and borer damage (%), yield (kg ha^{-1}) and egg number and yield (kg ha^{-1}) and leaf damage were negative and non-significant. Positive and non-significant correlations were recorded between egg number and borer damage (%), larval numbers and pod borer damage (%), pod damage and borer damage (%), leaf damage and egg numbers, pod damage and egg numbers, pod damage and leaf damage, pod damage and yield (kg ha^{-1}) and yield per plant and yield (kg ha^{-1}). These correlations and interaction of different components of resistance and grain yield will help in gene pyramiding.

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*Originals not seen