

**STUDIES ON MANAGEMENT OF PINK
BORER, *Sesamia inferens* Walker
ON MAIZE**

PAVANI THATIKONDA

B.Sc. (Ag.)

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(ENTOMOLOGY)**



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BORER, *Sesamia inferens* Walker ON MAIZE**

BY

PAVANI THATIKONDA

B.Sc. (Ag.)

**THESIS SUBMITTED TO THE ACHARYA N.G. RANGA
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CHAIRPERSON: Dr. T. UMA MAHESWARI



**DEPARTMENT OF ENTOMOLOGY
COLLEGE OF AGRICULTURE
RAJENDRANAGAR, HYDERABAD-500 030
ACHARYA N.G. RANGA AGRICULTURAL UNIVERSITY
2011**

DECLARATION

I, **PAVANI THATIKONDA**, hereby declare that the thesis entitled, **“STUDIES ON MANAGEMENT OF PINK BORER, *Sesamia inferens* Walker ON MAIZE”** submitted to **Acharya N.G. Ranga Agricultural University** for the degree of **Master of Science in Agriculture** in the major field of Entomology, is the result of original research work done by me. It is further declared that the thesis or any part thereof has not been published earlier in any manner.

Place: Hyderabad

PAVANI THATIKONDA

I. D. No. RAM/2009-28

Date:

CERTIFICATE

Ms. PAVANI THATIKONDA has satisfactorily prosecuted the course of research and that the thesis entitled “**STUDIES ON MANAGEMENT OF PINK BORER, *Sesamia inferens* Walker ON MAIZE**” 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 neither the thesis nor part thereof has been previously submitted by her for a degree of any University.

Date:

Dr. T.UMA MAHESWARI
Chairperson

CERTIFICATE

This is to certify that the thesis entitled “**STUDIES ON MANAGEMENT OF PINK BORER, *Sesamia inferens* Walker ON MAIZE**” submitted in partial fulfillment of the requirements for the degree of ‘Master of Science in Agriculture’ of the Acharya N.G. Ranga Agricultural University, Hyderabad is a record of the bonafide original research work carried out by **Ms. PAVANI THATIKONDA** under our guidance and supervision.

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

Thesis approved by the student Advisory committee

Chairperson	Dr.T.UMA MAHESWARI Associate Professor Department of Entomology College of Agriculture, Rajendranagar Hyderabad-500 030	(Signature)
Member	Dr.J.C.Sekhar Principal Scientist Winter Nursery Centre Directorate of Maize Research Rajendranagar Hyderabad-500 030	(Signature)
Member	Dr.R.Ranga Reddy Principal Scientist and Head Maize Research Station, ARI Rajendranagar Hyderabad-500 030	(Signature)

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LIST OF ABBREVIATIONS AND SYMBOLS

%	:	Per cent
ANOVA	:	Analysis of variance
±	:	plus or minus
μ	:	Mean
μl	:	micro litre
AICMIP	:	All India Co-ordinated Maize Improvement Project
ARI	:	Agricultural Research Institute
@	:	at the rate of
cm	:	Centimeter
CIMMYT	:	Centro Internacional de Mejoramiento de Maiz y Trigo)
CMIE	:	Centre for Monitory Indian Economy
CD	:	Critical difference
CRD	:	Complete Randomised Design
DAE	:	Days After Emergence
DAG	:	Days After Germination
DAI	:	Days After Infestation
EIL	:	Economic Injury Level
<i>et al.</i>	:	and others
G	:	Granules
g	:	gram
EC	:	Emulsifiable concentrate
mm	:	millimeter
WP	:	Wettable Powder
No.	:	Number
RBD	:	Randomized Block Design
<i>viz.,</i>	:	namely
LIR	:	Leaf Injury Rating

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ABSTRACT

Experiments were conducted on “Studies on management of pink borer, *Sesamia inferens* walker on maize” during *rabi*, 2010-11 under field and green house conditions at College of Agriculture, Rajendranagar Hyderabad. Screening of maize genotypes against pink borer were carried out at Maize Research Center, All India Co-ordinated Maize Improvement Project (AICMIP), ARI, Rajendranagar, Hyderabad.

Twenty maize genotypes were evaluated for resistance to pink stem borer, *S. inferens* under artificial infestation in the field during *rabi* season, 2010-2011. Data were recorded on leaf injury on 1-9 scale. The maize genotypes viz., HQPM 1, DHM 117, Winsynthetic, HKI 193-1, HKI 163-1, V 351, BML 6, HKI C 322, CM 202, 30 V 92, BML 7, HKI MBR 139, CM 212 recorded a mean leaf injury rating (LIR) of 4.85, 5.08, 5.29, 6.21, 6.22, 6.49, 7.31, 7.31, 7.56, 7.87, 8.37, 8.50, 8.62, respectively. Among all only HQPM 1 with lowest LIR of 4.85 was found to be moderately resistant and the remaining genotypes were moderately susceptible to pink stem borer, *S. inferens*. The genotypes, CM 144, CM 139, CM 137, CM 132 and DMRQPM 58 have recorded mean LIR ranging from 8.87 to 9.00 above the susceptible check which were grouped as highly susceptible.

The effect of larval densities of *S. inferens* during different stages of crop growth of maize hybrid, DHM 117 under unprotected conditions indicated that with increase in the larval density there was an increase in LIR. Leaf injury rating was significantly more at two leaf stage (7 DAG) of the crop as compared to 14, 21, 28 day old plants. The

highest mean LIR was recorded when 20 larvae were released at 2 leaf stage (7 DAG) and the lowest was at 8 leaf stage (28 DAG) when 5 larvae were released. The LIR increased with increase in larval density irrespective of the crop age. Based on the findings, maize crop at 2 leaf stage was considered as the most critical stage for *S. inferens* irrespective of the larval densities.

Experiments conducted for evaluation of different management practices for *S. inferens* with maize hybrid, DHM 117 under green house conditions made clear that when different chemical insecticides viz., carbofuran, endosulfan, and bio pesticides viz., *Beauveria bassiana* and *Bacillus thuringiensis* were used against *S. inferens* and tested for efficacy expressed in terms of mean leaf injury rating, percent dead hearts, stem tunneling and number of exit holes per plant, percentage of live larvae recovered, indicated that the insecticidal treatments were effective over the untreated control. Among the treatments endosulfan was found to be more effective with 4.55 leaf injury rating, 26.25 per cent dead hearts, 0.33 cm per metre stem tunneling, 0.45 number of exit holes per plant, and 41.66 percentage of live larval recovery followed by carbofuran, *B. bassiana* and *B. thuringiensis*.

Chapter I

INTRODUCTION

Maize is versatile cereal crop grown in more than 160 countries in tropical, subtropical and temperate regions. In India, maize is the third important cereal crop after rice and wheat that provides food, feed and fodder. Maize also serves as a source of raw material for producing hundreds of industrial products like starch, protein, oil, alcoholic beverages, food sweeteners, pharmaceuticals, cosmetics, bio fuel, etc. In India, it is grown in an area of 8.26 m ha producing 16.68 m tonnes, with an average yield of 2415 kg ha⁻¹. In Andhra Pradesh, it is cultivated in an area of 0.85 m ha producing 4.15 m tonnes with an average yield of 4882 kg ha⁻¹.

Maize crop is subjected to attack by over 130 insect pests during different stages of its crop growth. However, not all of them are serious. The most serious pest is the spotted stem borer, *Chilo partellus* Swinhoe, which is the key pest throughout India during rainy season. This is followed by pink borer, *Sesamia inferens* Walker, (serious in peninsular India during post rainy season) and shoot fly, *Atherigona soccata* Rond and *Atherigona naqvii* Steyskal, (serious in spring season in Northern India), which cause economic yield losses, (Siddiqui and Marwaha, 1993).

The pink stem borer, *S. inferens* occurs in India, Pakistan, Bangladesh, Burma, China, Sri Lanka, Malaysia, Taiwan, Japan, Indonesia and the Philippines (Nayar *et al.*, 1976 and Teetes *et al.*, 1983). In India, it is reported as a pest in Andhra Pradesh, Karnataka, Tamilnadu, Madhya Pradesh, Maharastra, Orissa, West Bengal, Bihar, Assam, Uttar Pradesh, Delhi and Punjab, (Siddiqui and Marwaha, 1993).

In addition to maize, *S. inferens* also infests sorghum, bajra, finger millet, wheat, rice, oat, barley, sugarcane and some grasses (Jepson, 1954 and Butcheswera Rao, 1983a).

Larvae of the pink borer cause damage by feeding on all parts of maize plant except roots. On hatching, the larvae remain concealed behind the leaf sheath in groups and feed on the epidermal layer of the leaf sheath, preferably on first three leaf sheaths leading to gummy oozing with water soaked lesions. Some larvae migrate to the neighbouring leaf

sheaths, while others penetrate into the stem. Whorl feeding of the larvae result in the formation of rows of oblong, elongated holes in unfolded leaves. The larvae bore into the central shoot resulting in drying up of the growing point and formation of dead hearts in young plants. The larvae also form circular or “S” shaped tunnels filled with excreta inside the stem and, also show exit holes on the surface. Severe damage results in breaking of the stem. Larvae are found feeding on immature cobs, silks and tassel and severe infestation result in stunted plant growth and appearance of cob and tassel at one place (Reddy *et al.*, 2003)

The grain yield losses due to *S. inferens* in maize cultivars vary from 25.7 to 78.9 % (Chatterji *et al.*, 1969) (Siddiqui and Marwaha, 1993).

In recent years, pink borer, *S. inferens* has been reported as a serious pest limiting the production of maize grown under post rainy (*rabi*) season. To reduce infestation of *S. inferens* individual control measures may not be sufficient and it is necessary to integrate the available methods. Host plant resistance is one such method that has been successfully used for the management of lepidopteran stem borers. It is environmentally safe, economically feasible for the farmers and is compatible with other components of IPM.

Management practices against pink borer may significantly contribute towards reducing crop loss due to the pest infestation in *rabi* maize in peninsular India. However, management includes the basic tactics like recommendation of resistant cultivars, use of biopesticides followed by the synthetic insecticides. Hence present work was proposed to evaluate the available germplasm for resistance to *S. inferens* as well as to find out the efficacy of different groups of pesticides against *S. inferens* with the following objectives.

Objectives

1. Screening of maize genotypes against pink borer under artificial infestation in the field
2. Evaluation of different management practices for *S. inferens*

Chapter II

REVIEW OF LITERATURE

The pink borer, *Sesamia inferens* Walker was first reported as a pest of maize by Fletcher (1914) from Madras. Later on (Krishnamurthy and Usman, 1952) from Mysore found this pest feeding on finger millet. Kapur (1967) reported that pink borer causes considerable damage to maize and attacks all plant parts except roots. It is a pest on *rabi* maize particularly in peninsular India. The losses primarily due to this pest in *rabi* varied from 25.7 to 78.9 per cent (Chatterji *et al.*, 1969). (Siddiqui and Marwaha, 1993) emphasized that yield loss is mainly due to dead heart formation in maize crop. The information available on *S. inferens* is presented with the following headings.

2.1 Biology of *S. inferens*

Detailed biology of *S. inferens* was studied in finger millet by Krishnamurti and Usman (1952) and reported that the adult moths were straw coloured with coppery tinged shining scales and with brown streaks. Female moths laid creamy white eggs in longitudinal rows within the sheaths of bottom leaves of young plants. The incubation period was about a week and full grown larvae were stout, smooth bodied measuring about 25-30 cm in length and 3 mm width. The larva was purplish pink dorsally and white ventrally with reddish brown head. The larval period was 3-4 weeks and pupal period ranging from 7-10 days. Pupation took place inside the stem or in between stem and leaves. The pupae were stout and dark brown in colour. The life cycle from egg to adult was completed in 6-7 weeks. Four to five generations were recorded per year in South India, (Siddiqui and Marwaha, 1993).

2.2 Host Range

S. inferens is one of the serious insect pests of maize next in importance to *Chilo partellus*. In addition to maize it was reported to attack finger millet, Krishnamurthy and Usman 1952, sorghum (Ajayi *et al.*, 1996), rice (Tiwarly *et al.*, 1988 and Khan and Khaliq 1989), sugarcane (Sikchi *et al.*, 1989., Easwaramoorthy *et al.*, 1992 and Tanwar and Bajpai, 1993), wheat (Singh *et al.*, 1990 and Godhani and Koshiya, 1991), fodder maize, Jalali and Singh (2002), cotton Rishi Kumar (2004) and oil palm Jacob and Kochu Babu (1995).

2.3 Nature and Extent of Damage By *S. inferens*

(Siddiqui and Marwaha, 1993) reported that *S. inferens* damages every part of the maize plant except the roots. The young larvae feed on the epidermal layer of the leaf sheath followed by boring into the central shoot resulting in drying up of the growing point and formation of dead heart in young maize plants. They also cause damage to stem, tender tassel and immature cob.

2.3.1 Leaf Injury

On hatching, pink borer larvae remain concealed inside or behind the leaf sheath in groups and feed on epidermal layer of the leaf sheath, preferably on first three leaf sheaths. Due to feeding, gummy oozing with water soaked lesions appears on the affected leaf sheaths which was visible from outside in initial stages of feeding (Reddy *et al.*, 2003). In later stages, holes of 2-5 mm size appeared on first to sixth leaf sheath, followed by parallel rows of oblong, elongated or oval holes, slits, streaks on unfolded leaves. Some larvae migrate to the neighbouring leaf sheaths, while others penetrated into the stem.

The bottom most leaf sheath was the first feeding site of pink borer larvae. Subsequently, the larvae reaches the central growing point by boring through the sheaths and feed on unopened leaves in the whorl which results in formation of oblong (elongated or oval, little bigger than pin size) holes of 2-3 mm size in parallel rows in the unfolded leaves. As the plant grows, these holes were extended and become slits and streaks. By 15 days after infestation (DAI) slits become 2-4 cm long and finally turned into streaks of 10-16 cm by 30 DAI. In severe cases, tunneling of mid rib was evident on the leaf blades and plants shows ragged appearance. Infestation of the growing point of the shoot ultimately lead to drying up resulting in the formation of “dead heart” in young maize plants (Reddy *et al.*, 2003).

2.3.2 Stem Damage

Maximum damage to the stem was observed between first to fifth internodes. Entry and/or exit holes (2-5 holes per plant), 2-5 cm horizontal slits, 1-2 cm cross type slits, and dark circular ring like cuts on lower most internodes could be seen externally in the stem which may be of 1-6 cm in length filled with excreta. The stem tunnels may be horizontal

(some times extended to other internodes), “S” shaped or circular or vertical. In the case of severe tunneling, lodging of the plants occur (Reddy *et al.*, 2003).

2.3.3 Tassel and Cob Damage

During reproductive stage of the crop, larvae were found feeding on tender tassels and immature cobs, causing tunnels externally in unopened tassel. Boring of the tassel stalk often results in breaking and drying of the tassel. Larvae also prefer to feed on soft shank and milky seeds of immature cob forming tunnels in the cob (Chatterji *et al.*, 1969).

2.4 Screening of Maize Genotypes against Pink Borer, *S. inferens*

Reddy and Sekhar (2002) evaluated forty- six maize genotypes for resistance to stalk borer, *S. inferens* Walker under artificial conditions during *rabi* season 1998-99 and reported that the maize genotypes, viz., 221267-A, BIO 9691, 137868, JKMM-4095, 221267-D (full season maturity) PAC-9703, BIO-9637, PAC-9735, KH-5354 (medium maturity) were found to be tolerant. Satyanarayana *et al.* (2002) have screened 132 elite maize lines against *S. inferens* to identify the highly resistant donor parents under natural conditions during *rabi* 2000 - 01. According to them, the leaf injury rating of *S. inferens* infestation among the genotypes screened ranged from 1.20 (Entry No.681) to 8.95 (Entry No.762), where 42 inbred lines were classified as resistant while another 42 inbred lines as moderately susceptible and the remaining 48 genotypes as susceptible. The average borer incidence rating of these three groups was recorded as 2.25, 4.95 and 7.85 respectively where as resistant check (DHM 105) and susceptible check (Basilocal) recorded a rating of 1.85 and 8.85 respectively. The two entry numbers 681 and 691 recorded the lowest incidence of *S. inferens* rating of 1.20 and 1.25 and the highest grain yields of 7840 and 8000 kg ha⁻¹ respectively. Consequently, these genotypes were recommended as donor parents in hybrid breeding.

Sekhar *et al.* (2004) evaluated sixty two insect resistant genotypes obtained from the International Maize and Wheat Improvement Centre (CIMMYT), Mexico along with two Indian varieties, one resistant and one susceptible as checks against pink stem borer, *S. inferens* under artificial infestation during *rabi* season. The data recorded after one month of insect release, based on leaf injury rating scale 1-9 revealed that genotypes could be

categorized into three distinct groups namely least susceptible with 1-3 score, moderately susceptible 4-6 and highly susceptible with a scale of 7-9. The seven maize lines namely P391c₂F 147-2-2-1-1-B-B, P391c₂BcF 3-1-1-2-1-B-B, MIRTc₄AmF 86-B-3-1-B, MIRTc₄AmF 110-B-1-1-B, PT 963112-B-B-B-B-B-B, MIRTc₄AmF 36-B-2-2-B and PT 963128-B-B-B-B-B-B were found to be resistant to *S. inferens*.

Sekhar *et al.* (2008) conducted two trials involving twenty eight inbred lines and forty five single crosses, respectively received from CIMMYT India programme along with resistant and susceptible checks. Infestation was made by releasing 10–12 neonate larvae into the whorl of the individual plants using larval dispenser. Four weeks after infestation, plants were scored using 1- 9 scale. Of the twenty eight lines screened, four lines were found to be moderately resistant where CML 421 recorded the lowest leaf injury rating of 4.40 followed by CAO 3141 (4.60), CAO 3120 (4.60) and CAO 0106 (4.75). Among the forty five single crosses, two crosses, CML 429 x CML 474 and CML 421 x CML 470 were found to be highly resistant. The screening trials indicated that the inbred lines, CML 421, CAO 3141, CAO 0106 and CAO 3120 and single crosses CML 429 x CML 474 and CML 421 x CML 470 could be effectively utilized in the Pink stem borer breeding programme.

2.4.1 Quantification of Damage by Pink Borer, *S. inferens*

Satyanarayana *et al.* (2002) quantified the pest incidence based on per cent of leaf damage, dead hearts and number of plants damaged due to pink borer, *S. inferens* by following 1 to 9 rating scale (Directorate of maize Research .1999) for screening of maize genotypes where, the scale of 1 to 3 as resistant, > 3 to 6 as moderately susceptible and > 6 to 9 as susceptible. Based on reaction of maize genotypes to the pink borer, *S. inferens* in *rabi* season, the maize genotypes were categorized in to three distinct groups namely, (i) relatively more susceptible (ii) moderately susceptible (iii) relatively resistant/tolerant to pink borer, (Reddy and Sekhar, 2002)

Butcheswera Rao (1983a) adopted a rating scale of 1 to 9 based on plant injury due to stalk borer, *S. inferens* for screening of maize genotypes. Rating of 1 to 3 represents plants which are apparently healthy showing no visible symptoms of plant injury or with negligible extent of plant injury were kept under least susceptible group. A rating scale of

4 to 6 was assigned to plants with few holes on leaves, a few pellets of excreta, a few exit holes on stem and considered them to be intermediate in susceptibility and 7 to 8 scale was used for susceptible plants which exhibited crippled appearance, large quantities of excreta of larvae, large number of slit like elongate openings on leaves. Maximum rating of 9 was given to plants showing dead heart formation and considered as highly susceptible group.

Sekhar *et al.* (2004) reported that the maize lines bred for resistance to corn borers in Mexico showed differential reaction to pink borer, *S. inferens*. CIMMYT-IR and Population Thailand maize genotypes were classified in to three groups namely, (i) with leaf injury rating less than resistant check as highly resistant (ii) with leaf injury rating between resistant and susceptible checks as moderately resistant and (iii) with leaf injury rating more than susceptible check, highly susceptible.

The lines and crosses were categorized (Sekhar *et al.*, 2008) into four categories based on leaf injury rating : Highly resistant – Leaf injury rating less than resistant check; Moderately resistant - Leaf injury rating above the resistant check; Susceptible - Leaf injury rating less than susceptible check; Highly susceptible – Leaf injury rating above the susceptible check.

2.5 Identifying the Critical Stages for Pink Borer Incidence

Work on economic thresholds and economic injury levels of *S. inferens* is limited, hence the literature pertaining to *C. Partellus* is also reviewed. Sarup *et al.* (1977) determined economic threshold of maize stalk borer *C. partellus* by manually infesting maize plants at seven different ages viz., 10, 13, 15, 20, 25 and 30 day old plants with variable number of eggs (black-head stage) viz., 5, 10, 15, 20 and 25 eggs per plant constituting the borer population. Further it was reported that the severity of damage by *C. partellus* was significantly more in 10-day old crop as compared to later ages of crop and any control measures after 30 days of germination may not prove economical. Significantly low damage was recorded, when only 5 eggs were released at different ages of the crop.

Seshu Reddy and Sum (1991) determined economic injury level (EIL) of the maize stem borer *C. partellus* by artificially infesting maize plants with six larval densities viz., 2, 4, 6, 8, 10 and 12 per plant. Maximum yield reduction and stalk damage occurred on the 20-day old crop, while there was insignificant larval effect on yields for the 60-day old crop. The EIL was 3.2 and 3.9 larvae per plant for 20 and 40 day old plants, respectively.

Nwosu (1992) reported that one of the critical factors in assessing maize lines for resistance to *Sesamia calamistis* is the number of larvae/plant used for infestation. Artificial infestation of maize plants with 2 and 5 larvae/plant resulted in 29.10 and 39.50 per cent stand loss (dead hearts and stalk breakage) while 10 and 15 larvae/plant resulted in 52.00 and 72.90 per cent stand loss, respectively. For a satisfactory artificial infestation in maize screening trails against *S. calamistis* in Nigeria, a population level of 10-15 larvae/plant is recommended.

Reddy *et al.* (2003) reported that the economic injury level (EIL) of the pink borer, *S. inferens* Walker was determined by artificially infesting maize (DHM 103) plants at four different growth stages with varying densities of neonate larvae per plant. The grain yield data obtained from the infested and the protected plants showed that the maximum reduction in yield and damage was obtained between 7 and 14 day old crops, regardless of the number of larvae released. The regression of yield on larval density in the case of the 28 day old crop was less steep indicating that the tolerance of plants to borer population increases at 28 days crop age. The EIL was calculated at each stage. The sigmoid relationship between EIL and the crop age was established. The economic threshold lies between 7 and 14 day old crops with an EIL of 9-10 larvae per plant.

2.5 Management of Pink Stem Borer, *S. inferens*

2.5.1 Use of Biopesticides

There is no published report on the bio pesticide control of *S. inferens*. However some studies are available on the bio pesticide control of *C. partellus*, *C. suppressalis* and *Sesamia cretica* using bio pesticides. Control of maize stem borer presents a unique set of biological, chemical and technical challenges. The residual effect of chemical insecticides led to the change in crop protection pattern that gave way for the use of biocontrol agents.

Ravindra Pal *et al.* (2009) reported that among the bio pesticides, *B. bassiana* applied @ 2.5 kg ha⁻¹ was found better than *Bacillus thuringiensis* @ 1.0 kg ha⁻¹. According to them, biopesticides were found to be better than untreated control. Shilsar *et al.* (2007) reported a larval mortality of 75.55 and 71.11 per cent by applying *B. bassiana* and *M. anisopliae* respectively applied @1x10⁶ spores per ml against *C. suppressalis* in rice. Jalali and Singh (2003) tested the efficacy of commercial formulations of Bt k i.e. Dipel 8L resulted in more than 80.00 % and 95.00 % mortality of third instar of *C. partellus* after 2 and 6 days of treatment respectively in maize.

Kandalkar and Men (2006) conducted an experiment to test the efficacy of *B. thuringiensis* products in comparison with recommended conventional insecticide against sorghum stem borer, *Chilo partellus* and revealed the significant superiority of *B. thuringiensis* at one to three sprays than untreated control in case of leaf injury and in case of peduncle damage, application of two sprays of *B. thuringiensis* (at 1kg ha⁻¹) on 25th and 35th day was on par with three sprays of both endosulfan and *B. thuringiensis*. Three sprays of *B. thuringiensis* recorded maximum grain yield and it was greater than untreated control.

Syed and Gardezi (2006) tested a total of 40 species of fungi and two bacterial strains for their insecticidal activity against maize stem borer (*C. partellus*). They reported that six species of *Aspergillus*, two *Metarrhizium*, one *B. bassiana*, and two species of bacteria (*B. thuringiensis* and *B. sphaericus*) were identified as lethal to the insects.

Shojaj *et al.* (1995) studied the field efficiency of the parasitoids along with BT *B. thuringiensis subsp. Kurustaki* in the control of *S. cretica* concluded that the application of parasitoids along with application of microbial insecticide (BT) and cultural methods gave very good result in Integrated pest management (IPM) of the borer.

Lewis *et al.* (1995) determined the compatibility of *B. bassiana* with *B. thuringiensis* and carbofuran for the season-long management of *Ostrinia nubilalis*. Granular formulation of *B. bassiana* was applied to maize at whorl stage and the pollen-shed stage. *B. thuringiensis* or carbofuran was then applied to the same plants and reported that *B. bassiana* has reduced larval populations of *O. nubilalis* both at the whorl stage and the pollen-shed stage. They also reported that when either *B. thuringiensis* or carbofuran

was added to plants treated with *B. bassiana*, there was increased mortality of *O. nubilalis*. Although *B. bassiana* alone reduced borer tunnelling, in terms of the damage. Damage reduced further when *B. thuringiensis* or carbofuran was applied at the whorl-stage of the crop. *B. bassiana* application at pollen shedding stage reduced tunneling but had no significant increase in yield, unless *B. thuringiensis* was added.

2.4.2 Chemical Control

Chatterji *et al.* (1969) evaluated the avoidable losses caused by insect pests of maize with particular reference to stem borers by chemical protection of the crop. It was clear from their studies that the number of applications of insecticide did not play much role in reducing the pest incidence as well as yield. Hence, the average avoidable yield loss as calculated by the difference of plots treated with four applications of endrin over untreated plots was found to vary from 24.3 to 36.3 per cent.

Godbole (1983) reported that endosulfan 35EC @ 0.1% applied ten days after germination on maize crop followed by an application of endosulfan granules (4%) in the whorl of the plant at a reduced dosage of 5 kg ha⁻¹ was found to be effective in reducing stalk borer infestation.

The estimated yield losses due to stalk borer *S. inferens* during *rabi* 1986-87 in endosulfan treated plots (0.1% spray operation) was comparatively less compared to untreated ones. Endosulfan resulted in significantly maximum yield of 7.89 q ha⁻¹ (Directorate of Maize Research, 1987).

There were reports on the chemical control of other species of *Sesamia* including *S. critica*, Al-Dabbas and Al Salih (1978). Dreyer *et al.* (1987) reported that whorl treatment of maize plants with pure neem kernel powder or 50:50 mixture of it with saw dust reduced the population of *S. calamitis* to almost zero.

Ganguli *et al.* (1997) investigated the efficacy of certain insecticides and neem-based formulations for the management of maize stem borer, *Chilo partellus* and reported that, single application of endosulfan @ 0.035% was highly effective in protecting the crop when applied 2 days after infestation and moderately effective when applied up to 6 days

after infestation and also reported that insecticidal spraying at later stages of the crop growth was proved to be ineffective.

Naibo (1997) reported that seed treatment of maize with imidacloprid could reduce the number of spray applications and the quantity of chemicals applied to the vegetation for the control of *Sesamia nongriodes*

Reddy (2001) reported that endosulfan treatment has yielded significantly more than those where 5, 10, 15 and 20 larvae of *S. inferens* were released at 7, 14, 21 and 28 day old crop. Plants infested with *S. inferens* larvae at 28th day after emergence yielded significantly more than the plants infested at 7, 14 and 21 day old crop, even when infested with variable number of larvae. The mean grain yield of plants infested at 7, 14, 21 and 28 day old age (when variable number of larvae infested were released) was 49.34, 53.74, 58.60 and 64.93 q ha⁻¹ respectively during *rabi* 1998-99 while it was 43.04, 49.33, 57.44 and 68.89 q ha⁻¹ respectively during *rabi* 1999-2000 season. In comparison, the protected plot (control) yielded 69.21 q ha⁻¹ (1998-99 season) and 76.94 q ha⁻¹ (1999-2000 season). Dead hearts were recorded only when the plants were infested at the age of 7 days with *S. inferens*. The per cent dead hearts formed due to release of 5, 10, 15 and 20 larvae per plant on 7 day old crop found to be ranging from 0 to 3.33, 10.00 to 16.67, 6.67 to 13.33 and 10.00 to 16.67 per cent respectively.

Reddy *et al.* (2004) evaluated the bio efficacy of five insecticides viz., imidacloprid E 70WS, thiamithoxam 70WS, endosulfan 35EC, carbofuran 3G and neem seed kernel extract (NSKE) 5% alone and in combination against pink borer *S. inferens*, on maize hybrid, DHM- 103, where all the insecticides were significantly superior over control in reducing the stem borer damage. The mean leaf injury rating ranged from 2.94 to 4.61 based on 1-9 scale when treatments were imposed as compared to 6.45 in the control. Among the insecticides endosulfan in combination with carbofuran applied to soil and endosulfan alone were found significantly effective when compared to other insecticides in suppressing the pink borer damage. Stem tunneling in insecticide treated plants ranged from 0.143 to 0.55 cm per metre stem as compared to 1.94 cm per metre stem in susceptible check. The per cent increase in grain yield over untreated plants due to the application of insecticides ranged from 12.86 to 42.68. Among all insecticides endosulfan + carbofuran soil application and endosulfan alone were most effective against stalk

borer, consequently resulting in significantly higher grain yield (61.04 and 59.66 q ha⁻¹). Cost benefit ratio was highest (10.14) with endosulfan followed by NSKE 5% spray at 15 days after germination and endosulfan at 30 DAG with a ratio of 3.38. Two sprays of NSKE at 15 and 25 DAG resulted in cost benefit ratio of 3.37. Endosulfan alone was found to be the most effective against pink borer resulting in higher yield.

Sekhar *et al.* (2008) reported that three sprayings of endosulfan at 7, 14 and 21 days after plant emergence recorded the lowest *Spodoptera exigua* infestation of 15.60 % as against 31.70% in untreated control. With endosulfan application the per cent avoidable loss in grain yield due to *S. exigua* infestation ranged between 13.20 per cent to 22.60 per cent. The maximum avoidable loss in grain yield in maize hybrid DHM 105 was recorded with three sprays of endosulfan at 7, 14 and 21 days after plant emergence. They also emphasized that maximum loss in yield up to 42.00 per cent could be avoided by endosulfan application.

Ullah *et al.* (1989) observed better results with granular formulations compared to emulsion concentrates during the first ten days of application in trials with insecticides against *C. partellus* on maize averaged over 25 days, granular formulations were best. Endosulfan 10 G and parathion-methyl 50 EC gave good results, while dicrotophos, diazinon, disulfoton and carbofuran were less effective.

Sekhon *et al.* (1989) tested the efficacy of nine insecticide against *C. partellus* on maize and reported that seed treatment with carbofuran @ 3.5 g/100 seeds or 2 sprays of deltamethrin at 2.80 g ha⁻¹ or endosulfan at 157.50 g ha⁻¹ applied to 10 and 25-day-old crops very effective.

Talpur *et al.* (1995) conducted experiments in Pakistan to study the comparative effectiveness of eight different insecticide formulations against *C. partellus* in maize. The application of recommended doses of quinalphos, carbofuran, diazinon, disulfoton, Dimecron, phosphamidon, formothion, lambda-cyhalothrin and deltamethrin twice at 21-day intervals indicated that the granular formulations were significantly more effective than sprayable insecticides in reducing the population of *C. partellus*. Of the granular formulations, quinalphos and carbofuran were comparatively more effective than diazinon and Solvirex. Amongst the emulsifiable concentrates, phosphamidon was significantly more effective than formothion, lambda-cyhalothrin and deltamethrin. The effectiveness of

all the insecticides decreased with time interval of their application. The yield and yield components were positively correlated with the effectiveness of the insecticides. Quinalphos treated plots resulted in significantly higher seed yields than all other chemicals.

Ganguli *et al.* (1997) tested the efficacy of certain insecticides and neem-based formulations for the management of maize stem borer *C. partellus* and reported that a single application of carbofuran3G @ 7.5 kg ha⁻¹ in the leaf whorl to 15 days crop was proved to be most effective in protecting against *C. partellus* up to six days. Insecticidal spraying at later stages was found to be ineffective.

The effectiveness of commonly available insecticides for control of stem borers on maize was investigated in Uganda in 1992 by Kalule *et al.* (1998). The insecticide application influenced the occurrence and extent of stem borer damage. In the early stages of crop development, the lowest stem borer incidence was recorded when carbofuran was treated.

Radha *et al.* (2006), conducted an experiment to evaluate the efficacy of different insecticide groups against the major insect pests of maize (cv. DHM-105) and reported that of the 9 insecticides tested (phorate, carbofuran, chlorpyrifos, fipronil, endosulfan, phosphamidon, cypermethrin, azadirachtin & imidacloprid) effective formulations of cypermethrin, phosphamidon and endosulfan could be used in the management of major insect pests of maize.

Chapter III

MATERIAL AND METHODS

Experiments were conducted both under field and laboratory conditions. Field investigations on screening of maize genotypes to pink borer, *Sesamia inferens* Walker were carried out at Maize Research Center, All India Co-ordinated Maize Improvement Project (AICMIP), ARI, Rajendranagar, Hyderabad. Management studies on *Sesamia inferens* were carried out at green house, Dept. of Entomology, College of Agriculture, Rajendranagar. The procedures followed, materials used and the methods employed in the present investigation are presented hereunder.

3.1 Culturing of *S. inferens*

Pink stem borer, *S. inferens* was mass multiplied under laboratory conditions for artificial infestation in the field (Siddiqui *et al.*, 1983). For conducting varietal screening and management studies in green house neonate larvae cultured under laboratory conditions were used.

3.1.1 Nucleus Culture

Artificial infestation of maize genotypes with *S. inferens* in the field was done by using laboratory reared insect population. The larvae and pupae of *S. inferens* collected from maize fields of college farm and ARI, Rajendranagar, Hyderabad were kept separately in glass jars (10 x 15 cm) under laboratory conditions. In the initial stage, pieces of immature cobs and green husk were used as food for the developing larvae but the later instars were fed on stem portions of older maize plants. The top of each jar (10 x 15 cm) containing larvae and pupae was covered with muslin cloth and secured with rubber bands (Plate 3.1). The larvae were transferred to another clean jar containing fresh food for every 2-3 days, till all the larvae pupated. The pupae thus collected from each jar were kept separately for the emergence of moths. The moths (male and female in equal numbers) after emergence were kept in wooden ovipositional cages and were allowed to lay eggs on potted maize plants of 10 day old (Plate 3.2). Four days after the release of moths, the plants were removed and the leaf sheaths containing egg portion were cut and kept at 27 ± 2

°C for incubation (Plate 3.3). These eggs were used as nucleus culture for mass rearing of *S. inferens*.

3.2 Screening of Maize Genotypes against Pink Borer Under Artificial Infestation in the Field

Screening was done with twenty maize genotypes (Plate 3.4). The seeds were procured from Winter Nursery Centre, Directorate of Maize Research, Rajendranagar, Hyderabad. The field experiment was conducted in Randomised Block Design with twenty genotypes as twenty treatments and three replications during *rabi* season of 2010-11 (Figure 3.1). Each genotype was planted in three rows of 2.5 m length with row to row and plant to plant spacing of 75 x 20 cm respectively. Three border rows were maintained in between the treatments. A gap of 2 m distance was maintained between the replications. All the normal recommended agronomical practices were followed in raising the crop.

The Twenty maize genotypes used in the study are :

1. HQPM-13
2. DHM-117
3. 30V92
4. Winsynthetic
5. HKI 163-1
6. HKI 193-1
7. BML 6
8. BML 7
9. HKI MBR-139
10. HKI C 322
11. V351
12. DMR QPM 58
13. CM 132
14. CM137
15. CM139

16. CM144
17. CM202
18. CM212
19. CM 500 (Resistant check)
20. Basilocal (Susceptible check)

In each plot, ten neonate larvae of *S. inferens* per plant were artificially infested into the whorls of ten day old plants with the help of Bazooka (CIMMYT, 1997). For artificial infestation with Bazooka, the first instar larvae were mixed with the carrier poppy seeds (*Papavar spp.*) and transferred to plastic bottle of the Bazooka, with the help of a funnel. The bottle was fixed to the applicator and used in the field. To avoid drowning of larvae in accumulated water in the plant whorls, the whorls were gently tapped to remove the water before infestation. The plants were infested individually by placing the nozzle of the Bazooka close to the leaf whorl. A single stroke ensures the release of 10-12 larvae into each plant whorl. After every ten strokes, the Bazooka was rotated gently for ensuring uniformity in larval distribution. The crop was infested between 8 to 10 AM or 4 to 6 PM to avoid larval mortality due to higher temperatures.

3.2.1 Classification of Maize Genotypes

The leaf injury rating (LIR) of 1-9 scale (Reddy *et al.*, 2003) (Table 3.1) was used for screening the maize genotypes at 30 days after infestation (Plate 3.5). Based on leaf injury rating, the maize genotypes were categorized into five groups, viz., (I) highly resistant, with mean leaf injury rating less than resistant check (CM 500); (ii) resistant, with mean leaf injury rating equal to resistant check; (iii) moderately susceptible, with mean leaf injury rating between resistant check and susceptible check (Basilocal); (iv) susceptible, with mean leaf injury rating equal to susceptible check; (v) highly susceptible, with mean leaf injury rating above susceptible check (Sekhar *et al.*, 2004).

Table 3.1. Mean leaf injury rating (LIR) scale (1-9) used for screening of maize genotypes against *S. inferens*. (Reddy *et al.*, 2003)

Rating	Description
1	Apparently healthy plants.
2	Plant with parallel, oval or oblong holes, slightly bigger than pin sized (2-3 mm) on 1-2 leaves.
3	Plant with more elongated holes (4-5 mm or matchstick-head sized) or shot holes on 1-2 leaves.
4	Plant with injury (oval holes, shot holes and slits of 1-4 cm) in about one third of total number of leaves and mid rib damage on 1-2 leaves.
5	Plant with about 50% leaf damage, oblong holes, shot holes, slits and streaks of 5-10 cm and mid rib damage on leaves.
6	Plants with a variety of leaf injuries to about two thirds of the total number of leaves (ragged appearance) or one or two holes or slits at the base of the stem (>10 cm streaks are observed).
7	Plants with every type of leaf injury and almost all the leaves damaged (ragged or crimped appearance), with tassel stalk boring or circular dark ring at the base of the stem
8	Plants with stunted growth in which all the leaves are damaged.
9	Plants with dead hearts.

3.3 Identifying the Critical Stages for Borer Incidence

Green house experiment was conducted during *rabi*, 2010 - 11 at College of Agriculture, Rajendranagar, Hyderabad to estimate the critical stages due to *S. inferens* infestation in a susceptible single cross hybrid DHM 117. The experiment was conducted in pots consisting of 20 treatments and three replications. Five densities of newly hatched larvae viz., 0, 5, 10, 15 and 20 (here after called L₁, L₂, L₃, L₄ and L₅, respectively) were released at four different leaf stages of crop growth viz., 2 leaf (7 days after germination) (DAG), 4 leaf (14 DAG), 6 leaf (21 DAG) and 8 leaf (28 DAG) stages (hereafter called A₁, A₂, A₃ and A₄, respectively) into the leaf whorl. A total of 20 treatments were formed with the combination of 4 different leaf stages of the crop with five larval densities.

The 20 treatments were

- T₁ Release of 0 larvae at 2 leaf stage
- T₂ Release of 0 larvae at 4 leaf stage
- T₃ Release of 0 larvae at 6 leaf stage
- T₄ Release of 0 larvae at 8 leaf stage
- T₅ Release of 5 larvae at 2 leaf stage
- T₆ Release of 5 larvae at 4 leaf stage
- T₇ Release of 5 larvae at 6 leaf stage
- T₈ Release of 5 larvae at 8 leaf stage
- T₉ Release of 10 larvae at 2 leaf stage
- T₁₀ Release of 10 larvae at 4 leaf stage
- T₁₁ Release of 10 larvae at 6 leaf stage
- T₁₂ Release of 10 larvae at 8 leaf stage
- T₁₃ Release of 15 larvae at 2 leaf stage
- T₁₄ Release of 15 larvae at 4 leaf stage
- T₁₅ Release of 15 larvae at 6 leaf stage
- T₁₆ Release of 15 larvae at 8 leaf stage

- T₁₇ Release of 20 larvae at 2 leaf stage
- T₁₈ Release of 20 larvae at 4 leaf stage
- T₁₉ Release of 20 larvae at 6 leaf stage
- T₂₀ Release of 20 larvae at 8 leaf stage

In each treatment ten healthy plants were selected for larval release. The required numbers of neonate larvae of *S. inferens* were manually released into the whorl of each plant with the help of fine camel hair brush (Plate 3.6) at different leaf stages of crop. The number of dead hearts and the leaf injury rating in the unprotected plot, artificially infested with different larval densities of *S. inferens* at different stages of the crop growth period, were recorded at 30 days after infestation and the critical stage of the crop is estimated.

3.4 Evaluation of Different Management Practices for *S. inferens*

Green house experiment was conducted during *rabi*, 2010-11 at College of Agriculture, Rajendranagar, Hyderabad to evaluate the efficacy of different insecticides against *S. inferens* by using susceptible single cross hybrid DHM 117 where each plant was infested with 10 larvae. There were five treatments including endosulfan, carbofuran, *Beauveria bassiana* Balsamo and *Bacillus thuringiensis* Berliner and untreated control. Each treatment was replicated four times and data was recorded on leaf injury rating at 40 DAG. The data on percent dead hearts, stem tunneling, number of live larvae recovered, number of exit holes was recorded on 14 and 28 DAG.

The five treatments are

T1-*Beauveria bassiana* @ 1x10⁷ spores

T2-*Bacillus thuringiensis* @ 200g/acre

T3-Carbofuran@ 3kg/acre

T4- Endosulfan @ 400ml/acre

T5- untreated control

Replications 4

The details of the test insecticides used in the experiment are furnished in the Table 3.2.

Table.3.2. Details of test insecticides

S.No	Common name	Technical name	formulation	Trade name
1	Endosulfan	6,7,8,9,10,10-hexachloro-1,5,5a,6,9, 9a-hexahydro-6-9-Methano 2,4,3-benzodioxathiepine 3-oxide	35 EC	Endotaf
2	Carbofuran	2,3-dihydro-2,2-dimethylbenzofuran-Yl-carbamate	3G	Tatafuran
3	<i>Bacillus thuringiensis</i> Sero var kurstaki H 3a, 3b, 3c,		0.5 % WP	Halt
4	<i>Beauveria bassiana</i>		1 % WP	Daman

Sowing of maize seeds was done on 14th December 2010 and the plants were grown in pots in the green house and at 2-3 leaf stage of plants 10 neonate larvae of *S.inferens* per plant were artificially released in the whorls of the plant with the help of camel hair brush.

3.4.1 Bio Pesticides

The spore load of the fungal and bacterial formulations *B. bassiana* and *B. thuringiensis*, respectively was done with the help of a hemacytometer followed by spraying. Glass house experiment was conducted by raising maize plants. Maize plants were grown in pots where 20 plants were inoculated with *B. bassiana* into the space between the stem and 3rd leaf sheath by spraying with an inoculum level of 1×10^7 spores in 100 μ l. An additional 40 plants were maintained as untreated receiving water spray. Plants were irrigated regularly. At 2-3 leaf stage, 10 neonate larvae were manually released within the whorls of the plant with the help of a camel hair brush. At 14 and 28 days after

germination data were recorded on different damage symptoms. Destructive sampling was done at the end to record the number of live larva and dead larva. Live insects were removed from the plant and incubated in moist chambers to confirm sporulation.

Glass house experiment was conducted by using the commercial formulation as Bt k, Halt. For testing its efficacy, at 2-3 leaf stage, 10 neonate larvae were manually released into the whorls of maize plants. The plants were inoculated with *B. thuringiensis* into the space between the stem and 3rd leaf sheath by spraying @ 1.0 g per litre of water in a suspension of 100 µl. About 40 plants were maintained as untreated receiving water spray. After inoculation, at 14 and 28 days after germination data were recorded on different damage symptoms.

3.4.2 Chemical Pesticides

Carbofuran 3G granules were applied in the whorls @ 3kg per acre after manual inoculation of the larvae @ 10 per plant into the whorl with the help of a camel hair brush. Spraying of endosulfan @ 0.07% was done after manual inoculation of the larvae with the help of hand sprayer.

Observations on damage symptoms like per cent dead hearts, stem tunneling, number of exit holes per plant and percentage of live larvae recovered were recorded at 14 and 28 days after germination. Observations are made from five plants which were treated as one per replication. Observations on leaf injury rating was recorded at 40 days after germination.

Another experiment was conducted where few plants were sprayed with commercial formulation of *B. bassiana* at a concentration of 1×10^7 per ml. After two days, larvae from the untreated plant with out any spraying and larvae from the plants sprayed with *B. bassiana* were collected and incubated at a temperature of $26 \pm 2^\circ\text{C}$. After three days of incubation, larvae were observed for recording the fungal growth.

3.4.3 Counting of Spores by Heamocytometer

Fungal or bacterial suspension (0.1 ml) prepared was placed on the engraved grid of the heamocytometer and the preparation was allowed to stand for one to two minutes and

the conidia were allowed to settle at the bottom. A cover glass was put over the grid carefully so that no air bubble enters between the slide and the cover glass. The cover glass was slid backwards and forwards until coloured rings are visible as the two surfaces of cover glass and slide came into the contact. The conidia of the fungus were counted which are in the middle square which consists of 25 groups of 16 small squares, each group 0.2 mm square. For larger spores or fewer spores, spores are counted in large squares of the four corners and in the middle, to have a total count of 200 - 250. Aliquot was prepared according to the requirement of spore load. (Aneja, 2003).

3.5 Statistical Data:

Data obtained on pest incidence and symptoms of damage were transformed into angular values, analysed statistically by RBD and CRD. The CD was worked out for assessing significant differences among the treatments and were utilised for comparing the treatments.



Plate 3.1. Jars containing larvae and pupae of *S. inferens*.



Plate 3.2. Wooden cages for oviposition of *S. inferens*.



Plate 3.3. Leaf sheath containing *S. inferens* eggs.



Plate 3.4. View of maize field screening trial experiment.



Plate 3.6. Releasing of *S. inferens* larvae into the seedling.



a. Parallel oblong holes on leaf due to larval feeding .



b. Slits and streaks formed on leaf due to larval feeding.



c. Ragged appearance of the plant.



d. Dead heart formation.

Plate 3.5. Damage symptoms caused by *S. inferens* in maize field.

3 rows T ₁	3 rows B	3 rows T ₂	3 rows B	3 rows T ₃	3 rows B	3 rows T ₄	3 rows B	3 rows T ₅	3 rows B	3 rows T ₆	3 rows B	3 rows T ₇	3 rows B	3 rows T ₈	3 rows B	3 rows T ₉	3 rows B	3 rows T ₁₀
3 rows T ₁₁	3 rows B	3 rows T ₁₂	3 rows B	3 rows T ₁₃	3 rows B	3 rows T ₁₄	3 rows B	3 rows T ₁₅	3 rows B	3 rows T ₁₆	3 rows B	3 rows T ₁₇	3 rows B	3 rows T ₁₈	3 rows B	3 rows T ₁₉	3 rows B	3 rows T ₂₀

Irrigation channel

3 rows T ₁₇	3 rows B	3 rows T ₁₅	3 rows B	3 rows T ₁₈	3 rows B	3 rows T ₁₆	3 rows B	3 rows T ₂₀	3 rows B	3 rows T ₁₃	3 rows B	3 rows T ₁₉	3 rows B	3 rows T ₁₂	3 rows B	3 rows T ₁₄	3 rows B	3 rows T ₁₁
3 rows T ₇	3 rows B	3 rows T ₉	3 rows B	3 rows T ₅	3 rows B	3 rows T ₁₀	3 rows B	3 rows T ₈	3 rows B	3 rows T ₃	3 rows B	3 rows T ₁	3 rows B	3 rows T ₆	3 rows B	3 rows T ₂	3 rows B	3 rows T ₄

Irrigation channel

3 rows T ₁₁	3 rows B	3 rows T ₁₂	3 rows B	3 rows T ₁₃	3 rows B	3 rows T ₁₄	3 rows B	3 rows T ₁₅	3 rows B	3 rows T ₁₆	3 rows B	3 rows T ₁₇	3 rows B	3 rows T ₁₈	3 rows B	3 rows T ₁₉	3 rows B	3 rows T ₂₀
3 rows T ₁₀	3 rows B	3 rows T ₉	3 rows B	3 rows T ₈	3 rows B	3 rows T ₇	3 rows B	3 rows T ₆	3 rows B	3 rows T ₅	3 rows B	3 rows T ₄	3 rows B	3 rows T ₃	3 rows B	3 rows T ₂	3 rows B	3 rows T ₁

B- border plants

T₁- HQPM 1

T₂- DHM 117

T₃- 30 V 92

T₄- CM 500

T₅- Winsynthetic

T₆- Basilocal

T₇- HKI 163-1

T₈- HKI 193-1

T₉- BML 6

T₁₀- BML 7

T₁₁- HKI MBR-139

T₁₂- HKI C 322

T₁₃- V 351

T₁₄- DMRQPM 58

T₁₅- CM 132

T₁₆- CM 137

T₁₇- CM 139

T₁₈- CM 144

T₁₉- CM 202

T₂₀- CM 212

Design-RBD

Crop -Maize

Spacing- 0.75X0.20m

Plot size- 2.25X2.5m

Plot size



2.5m

2.25m

Figure.3.1. Layout plan of the screening of maize genotypes to pink borer, *S. inferens*.

30V92
CM 500
Winsynthetic
Basilocal
HKI 163-1
HKI 193-1
BML 6
BML 7
HKI MBR-139
HKI C 322
V351
DMR QPM 58
CM 132
CM137
CM139
CM144
CM202
CM212

T₁₀- CM 500 (resistant check)

Fig.1: Layout plan of the screening of maize genotypes to pink borer, *S. inferens* Walker.

Design- RBD

T₃-

Crop - Maize

2.25m

T₄-

Spacing- 0.75X0.20m

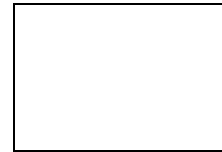
T₅-

Plot size- 2.25X2.5m

T₆-

2.5m

T₇-



Chapter IV

RESULTS AND DISCUSSION

The results obtained from the studies on screening of maize genotypes against pink borer, *Sesamia inferens* Walker under artificial infestation in the field conducted during rabi 2010- 11 and the results pertaining to the critical stages for infestation of the crop and efficacy of pesticides including biopesticides and chemicals are presented here under.

4.1 Screening of Maize Genotypes Against *S. inferens*

4.1.1 Leaf Injury Rating (LIR)

Results pertaining to screening of maize germplasm against their susceptibility to pink borer, *S. inferens* are presented in the Table 4.1 and Figure 4.1. It showed that there was a significant difference among the genotypes with regard to leaf injury rating (LIR) according to 1-9 scale. The leaf injury rating was maximum for the genotypes HKI 193-1(6.21), HKI 163-1(6.22), V 351(6.49) ,BML 6 (7.31), HKI C 322 (7.31), CM 202(7.56), 30 V 92 (7.87), BML 7 (8.37), HKI MBR 139 (8.50), CM 212 (8.62), CM 144 (8.87), CM 139(8.87), CM 137(8.93), CM 132 (9.00), DMRQPM 58 (9.00) as against CM 500 (Resistant check) with 2.80, having the total leaf injury rating ranging between 6.00 to 9.00 indicating their susceptibility to *S. inferens*. However, all the other genotypes HQPM 1 (4.85), DHM 117 (5.08), Winsynthetic (5.29) have got leaf injury rating from 3 to 6 which were considered as moderately susceptible. Among all the genotypes only CM 500 was found to be resistant recording only 2.80 leaf injury rating. Though CM 500 was recorded as resistant based on LIR, the three genotypes, HQPM 1 (4.85), DHM 117 (5.08), Winsynthetic (5.29) were on par with each other. Similarly, HKI 193-1 (6.21), HKI 163-1 (6.22), V 351 (6.49) were on par with each other. However , the genotypes BML 6 (7.31), HKI C 322 (7.31), CM 202 (7.56), 30 V 92 (7.87) recorded LIR ranging from 7.31 to 7.89, BML 7, HKI MBR 139 and Basilocal were on par with a LIR of 8.37 and 8.5 respectively. But the Six genotypes viz., Basilocal, CM 139, CM 144, CM 137, CM 312 and DMRQPM 58 have recorded maximum LIR ranging from 8.81 to 9.0 indicating their high susceptibility to *S. inferens* (Plate 4.1)

4.1.2. Per cent Dead Hearts

Data recorded on per cent dead hearts (Plate 4.2) produced due to *S. inferens* infestation on 20 maize genotypes were presented in the Table 4.2 and Figure 4.2. Results revealed that there was significant difference among the genotypes in production of dead hearts expressed as percentage. Maximum of 94.44 and 93.75 per cent dead hearts were recorded in the genotypes DMRQPM 58 and CM 137 and Basilocal which were said to be susceptible to *S. inferens*. No dead hearts were formed in the resistant check, CM 500. The two genotypes DHM 117 (5.56) and V 351 (8.57) recorded lowest per cent dead hearts next to CM 500 (0.00). The genotypes, Winsynthetic, HQPM 1 (20.20), HKI 163-1 (21.54), HKI 193-1 (22.5), HKI C 322 (25.0) were on par which recorded the dead hearts below 25.0 per cent. However, more than 50.0 per cent dead hearts were observed in genotypes BML 6 (56.25) and BML 7 (56.25) and were followed by 30 V 92 (62.5) and CM 202 (62.5). Three genotypes viz., CM 139, CM 144 and HKI C 322 recorded same per cent of dead hearts (87.50) followed by CM 212 (81.25) indicating their susceptibility to *S. inferens*.

The results of varietal screening of twenty maize genotypes under field conditions with artificial infestation of *S. inferens* clearly indicated that among the twenty genotypes, the LIR ranged from 2.80 to 9.00 and per cent dead hearts from 0.0 to 94.44. The genotypes, showing maximum LIR ranging from 7 to 9 indicated their susceptibility with more than 50.00 per cent dead hearts. However, the genotype HKI C 322 though had a maximum LIR of 7.31 recorded only 25.00 per cent dead hearts. Similarly V 351 recording 8.57 per cent dead hearts had 6.49 LIR indicating its moderate susceptibility to *S. inferens*. In general, two genotypes HQPM 1 with 4.85 and DHM 117 with 5.08 LIR indicating their moderate susceptibility had only dead hearts up to 20.2 and 5.56 per cent respectively. CM 500 said to be resistant had low LIR of 2.80 and 0.00 per cent dead hearts. This clearly indicated that though some genotypes were found to be possessing LIR of more than 7 indicating moderate susceptibility by recording low percent dead hearts. Present results are in confirmation with those obtained by Satyanarayana *et al.* (2002) who also recorded LIR ranging from 1.20 to 8.95 among the 132 genotypes, among which low LIR of 1.85 was observed in the resistant DHM 105 and maximum of 8.85 in the susceptible Basilocal.

Similarly Reddy *et al.* (2002), while screening 46 maize genotypes for their resistance to *S. inferens* under artificial condition also recorded LIR ranging from 3.21 to 7.00 among the genotypes and the LIR ranging from 3.1 to 8.3 was recorded by Sekhar *et al.* (2004) when 62 genotypes were screened against pink stem borer, *S. inferens*.

4.2 Classification of Maize Genotypes

Screened maize genotypes were categorized into five groups based on mean leaf injury rating (LIR) as (i) highly resistant, with mean leaf injury rating less than resistant check (CM 500); (ii) resistant, with mean leaf injury rating equal to resistant check; (iii) moderately susceptible, with mean leaf injury rating between resistant check and susceptible check, (Basilocal); (iv) susceptible, with mean leaf injury rating equal to susceptible check; (v) highly susceptible, with mean leaf injury rating above susceptible check as suggested by Sekhar (2004).

In the present studies among the twenty maize genotypes screened none of them recorded mean LIR less than or equal to the resistant check (2.80). The genotype HQPM 1 (4.85) which has LIR nearer to resistant check is grouped as moderately resistant. Twelve genotypes, HQPM 1 (4.85), DHM 117 (5.08), Winsynthetic (5.29), HKI 193-1 (6.21), HKI 163-1 (6.22), V 351 (6.49), BML 6 (7.31), CM 202 (7.56), 30 V 92 (7.87), BML 7 (8.37), HKI MBR 139 (8.50) CM 212 (6.25) were classified as moderately susceptible with mean LIR ranging between the resistant check CM500 (2.80) and susceptible check Basilocal (8.81). The remaining five genotypes, CM 144 (8.87), CM 139 (8.87), CM 137 (8.93), CM 132 (9.00), DMRQPM 58 (9.00) with mean LIR more than the susceptible check (Basilocal) were grouped as highly susceptible.

Satyanarayana *et al.* (2002) classified maize genotypes with 1 to 3 rating scale as resistant, more than 3 to 6 as moderately susceptible and more than 6 to 9 as susceptible to *S. inferens* and found the entry numbers viz., 655, 660, 662, 673, 675, 681, 684, 686, 691 and 718 with LIR of 1.20-2.00 coupled with higher grain yield, and suggested these genotypes as potential parents for resistance breeding programme. Similar grouping was done by Reddy and Sekhar (2002) to the pink borer, *S. inferens* who has classified the maize genotypes in to three distinct groups namely, (i) Genotypes relatively more susceptible (ii) Genotypes moderately susceptible (iii) Genotypes relatively

resistant/tolerant to pink borer, and included GK-3014, GK-3026 (full season maturity), KH-510, JKMH-316-2, JKMH-245 (medium maturity), Kiran, R-EVT COMP and KH-5361 (early maturity) genotypes in the first category. Sekhar *et al.* (2004) screened the maize lines from Mexico for resistance showed differential reaction to pink borer, *S. inferens* and reported that P391c₂F 147-2-2-1-1-B-B, P391c₂BcF 3-1-1-2-1-B-B, MIRTc₄AmF 86-B-3-1-B, MIRTc₄AmF 110-B-1-1-B, PT 963112-B-B-B-B-B-B, MIRTc₄AmF 36-B-2-2-B and PT 963128-B-B-B-B-B-B maize genotypes recorded leaf injury rating higher than the resistant check and were regarded as highly resistant genotypes. Sekhar *et al.* (2008) categorized CML 421, CAO 3141, CAO 3120 and CAO 0106 inbred lines and Single crosses - CML 429 x CML 474 and CML 421 x CML 470 as highly resistant and CML 427 x Pop 147-F2-#-105-2-1-B-1-B*4 and CML 426 x CML 470 crosses as highly susceptible to *S. inferens* based on 1-9 scale of LIR. Several workers also reported differential levels of resistance/susceptibility of maize lines derived from CIMMYT-IR and MIRT, MBR and PT populations (Bergvinson *et al.*, 2002., Panwar *et al.*, 2001 and Sekhar *et al.*, 2004). Based on the varietal screening studies of maize genotypes against *S. inferens*, three maize genotypes viz., Madhuri, BML 7 and HKI 163 with varied level of resistance to *S. inferens* were reported to be the promising genotypes that could be utilized in the breeding programme for developing varieties or hybrids resistant to *S. inferens*, (Shailaja, 2009).

4.3 Identifying the Critical Stages for Borer Incidence

The prerequisite for formulating any screening programme for pest resistance is to determine the impact of insect population, its damage at different stages of crop growth. With reference to pink stem borer, the phenological stages of maize crop were tested for crop resistance to different levels of pest population that inflict damage. Results obtained in the greenhouse experiment conducted to understand the relationship between pink borer and per cent damage in terms of LIR and per cent dead hearts are presented in the Table 4.4.

4.3.1 Effect of Larval Density of *S. inferens* and plant age based on leaf injury rating (LIR)

Data presented in the Table 4.4 and Figure 4.3 clearly indicated that there was significant effect of larval density where increase in LIR (recorded at 30 DAI)was

observed when the larval population was increased from 5 to 10 larvae at different stages of the crop growth. With increase in larval density, the LIR was increased only up to 28 days after germination.

However, when the larval density was increased to 15 and 20 larvae per plant, no much increase in LIR was observed at 7 days crop age (only from 0.44 to 0.47). When LIR was recorded at 14 days of crop, with different larval populations, 10 and 15 larva caused damage on par with each other. However, at maximum larval density of 20 larvae per plant, there was an increase of 1.08 in LIR. At all larval densities of *S. inferens*, the plants recorded maximum LIR only up to 7 days compared to 14 days after germination. After 14 days, there was much decrease in LIR when 5 larvae were released. LIR was reduced by 0.80 from 7 to 14 days, and maximum decrease of 1.60 LIR was observed, from 14 days to 21 days, LIR was further reduced by 0.07 from 21 to 28 days. Similarly when 10 larvae were released, maximum decrease of LIR was 1.26 from 7 to 14 days, followed by 1.10 from 21 to 28 days. When the larval density was 15 larvae, a reduction of 1.53 in LIR was recorded and was followed by 1.0 and 0.78 at 14, 21 and 28 days after emergence. Similarly at maximum larval density of 20 larvae, much reduction in LIR of 1.24 to 1.30 was recorded from 14 days onwards.

Results clearly indicated that irrespective of the larval density, plant age between 7 and 14 days was more susceptible to pink borer as evidenced by decrease in LIR at 21 and 28 days age. Based on the present results, it is important to protect the crop at early stages that is from 7 to 14 days to prevent economic damage by the borer. Present findings are in confirmation with those of Sarup *et al.* (1977) who reported maximum damage by *C. partellus* between 10 and 20 days in maize. Lavakumar Reddy (2001) reported that the intensity of damage by pink borer on maize was significantly more in 7 day old plants and declined in 14, 21 and 28 day old plants and the damage was more with 20 larvae per plant followed by 15, 10 and 5 larvae per plant.

4.4 Evaluation of Different Management Practices for *S. inferens*

Different groups of chemical insecticides viz., carbofuran, endosulfan and biopesticides viz., *B. bassiana* and *B. thuringiensis* were evaluated against *S. inferens* during *rabi*, 2010-11 under glass house conditions. The plants were artificially infested with the larvae of *S. inferens* along with an un inoculated control. Insecticides were

sprayed at 10 and 25 days age crop and data were recorded on leaf injury rating (1-9 scale) at 40 days age of the crop and the data on per cent dead hearts, stem tunneling, number of exit holes per plant and number of live larvae recovered per plant were recorded at 14 and 28 days age of the crop and results were presented.

4.4.1 Efficacy of Insecticides on Leaf Injury Rating (LIR) at Different Crop Ages

Data recorded on LIR at 40 DAG presented in the Table 4.5 and Figure 4.4 indicated significant superiority of insecticidal treatments over control in reducing pink borer incidence. The mean leaf injury rating ranged from 4.55 to 6.3 based on 1-9 scale in the insecticidal treatments compared to 8.50 in untreated plants. Among the insecticides endosulfan with an LIR of 4.55 was found to be highly effective in reducing LIR to an extent of 46.47 % followed by carbofuran with an LIR of 5.65. Present results are in confirmation with the results of (Reddy *et al.*,2009) who reported endosulfan as the most effective insecticide recording an LIR of 3.11 at 30 DAI. More efficacy of endosulfan spray might be due to its toxicity that acted as a stomach poison when the larvae has fed on treated plant tissue. However, whorl application of carbofuran has resulted in slightly more LIR (5.65) compared to endosulfan (4.55). This might be due to the reason that carbofuran being systemic granular insecticide take time to dissolve and release the toxicant to have deleterious effect on the larvae of *S. inferens* with a reduction of LIR up to 33.52 %.

Among the biopesticides, the fungal pathogen has resulted in an LIR of 5.75 which was on par with carbofuran (5.65) and the bacterial pathogen, *B.thuringiensis* has resulted in maximum LIR of 6.30. When LIR caused due to the application of both the bio pesticides were compared, *B. bassiana* infect the larvae through contact action that occur immediately after infection over the integument and further led to disease resulting in moribund condition of the larvae. With regard to *B. thuringiensis*, as neonate larvae have to ingest the bacterial spores and multiply with in the gut to release endotoxin which take time to make the larvae get starved. This might be reason that has allowed the larvae to cause leaf injury with *B. thuringiensis* application resulting in more LIR compared to *B. bassiana*. Similar observations were made by Ravindar Pal *et al.* (2009) with respect to *C. partellus* where application of *B. bassiana* has resulted in low LIR of 5.0 and 5.4 at 20 DAS and 40 DAS, respectively followed by *B. thuringiensis* with high LIR of 6.2 and 6.5 at 20 DAS and 40 DAS, respectively.

4.4.2 Efficacy of Different Insecticides on Per cent Dead Hearts at Different Crop

Ages:

Results presented in the Table 4.6 and Figure 4.5 revealed that insecticide application resulted in significant reduction of dead heart formation due to *S. inferens* (Plate 4.3). Among all the treatments, endosulfan was found to be more effective in reducing dead heart formation recording only 26.25 per cent dead hearts as compared to 85.00 per cent in control at 14 days after germination. Carbofuran with 33.75 per cent dead hearts was found to be on par with the bio pesticides used i.e., *B. bassiana* (36.25 %) and *B. thuringiensis* (41.25 %). Even at 28 days after germination, similar trend showing more efficacy with endosulfan (28.75 per cent dead heart formation) was observed. All the remaining treatments including carbofuran (36.25 %), *B. bassiana* (38.75 %) and *B. thuringiensis* (43.75 %) dead hearts were on par with each other.

No attempts were made for testing the efficacy of bio pesticides including *B. bassiana* and *B. thuringiensis* against *S. inferens*. In terms of per cent reduction in dead heart formation due to insecticide application, it was clear that endosulfan at both the stages of the crop i.e., at 14 and 28 days after germination reduced the damage ranging from 69.12 to 67.10 per cent. Similarly, carbofuran application reduced damage ranging from 60.27 to 58.57 per cent. However, both the bio pesticides, *B. bassiana* and *B. thuringiensis* application resulted in reduction of 57.33 to 50.00 per cent and 50.78 to 55.71 per cent dead hearts, respectively at 14 and 28 days after germination. Ravindra pal *et al.* (2009) have observed reduction in dead hearts by spraying *B. bassiana* and *B. thuringiensis* against *C. partellus* in maize. They also recorded low per cent dead hearts with *B. bassiana* (19.20) compared to *B. thuringiensis* (21.35%). Difference in the LIR due to *B. bassiana* and *B. thuringiensis* might be due to the immediate infection of the larvae by the fungus resulting in its inactivation to cause less per cent of dead hearts where *B. thuringiensis* took some time to get infected. Mean while the larvae might have damaged the shoot causing more damage expressed in terms of dead hearts.

4.4.3 Effect of Different Insecticides on Stem Tunneling At Different Crop Ages

Data presented in the Table 4.7 and Figure 4.6 indicated that all the insecticidal treatments have significantly reduced stem tunneling. However, the two chemical

insecticides, endosulfan and carbofuran were found superior over the bio pesticides, *B. bassiana* and *B. thuringiensis*. Endosulfan spray resulted in lowest stem tunneling of 0.33 cm per metre stem which was on par with whorl application of carbofuran recording 0.35 cm per metre stem tunneling at 14 DAG. Similar results were recorded by Reddy *et al.* (2004) where endosulfan has resulted in only 0.30 cm per metre stem tunneling and soil application of carbofuran resulting in 0.29 cm per metre stem tunneling at 15 DAG. The bio pesticides, *B. bassiana* has resulted in 0.43 cm per metre stem tunneling followed by *B. thuringiensis* with 0.42 at 14 DAG. More efficacy in reducing stem tunneling with chemical insecticides might be due to the toxicity of insecticides affecting the nervous system causing mortality of the larvae, where the fungal pathogen, *B. bassiana* and bacterium, *B. thuringiensis* application might have taken time to cause disease in larvae during which significantly high stem tunneling was observed.

It was evident from the studies that as the age of the crop increased, significant reduction in stem tunneling was observed. However, similar trend was observed with insecticide application where in endosulfan and carbofuran have recorded 0.11 and 0.12 cm per metre stem tunneling at 28 DAG which was 0.33 and 0.35 at 14 DAG. Similarly *B. bassiana* has resulted in only 0.43 at 14 DAG that was reduced to 0.21 cm per metre stem tunneling at 28 DAG. *B. thuringiensis* resulted in stem tunneling of 0.18 per metre stem at 28 DAG which was 0.42 at 14 DAG. Similar result was observed by Lavakumar Reddy *et al.* (2001) where as the age of the crop increased there was a reduction in stem tunneling. In the present study, from 14 to 28 DAG, endosulfan has reduced stem tunneling from 29.78 to 86.50 % and carbofuran from 25.50 to 85.30 %, respectively. Similarly, *B. thuringiensis* reduced stem tunneling from 10.63 to 78.00 % and *B. bassiana* reduced from 8.50 to 74.39 cm per metre stem from 14 to 28 DAG. The reason for drastic decrease in stem tunneling from 14 to 28 DAG might be due to the toughness or hardness of the stem at 28 DAG that made difficult for the larvae to penetrate which might be comparatively less at 14 DAG allowing easy stem tunneling by the larvae.

4.4.4 Efficacy of Different Insecticides on Number of Exit Holes Per Plant at Different Crop Ages Infested by Pink Stem Borer

Infestation of maize crop with *S. inferens* not only resulted in leaf injury, dead heart formation but also stem damage that would be evident with symptoms like exit holes on

the stem, horizontal slits and circular and/or vertical tunnels in the stem and bushy stunted appearance of the plant. Damage caused by *S. inferens* was inflicted by symptoms like appearance of exit holes on the stem (Plate 4.4). Data recorded on number of exit holes presented in the Table 4.8. Results have clearly indicated that insecticidal application has reduced the infestation by *S. inferens* expressed in terms of exit holes per plant. As the age of the crop increased number of exit holes on the stem reduced. This reduction in number of exit holes due to insecticides might be due to the weakening of the larvae by toxic effect where infection by pathogens might have delayed the exit of the larvae causing holes. Similarly, it was evident from the study that as the age of the crop increased, number of exit holes decreased significantly, irrespective of the insecticide application. Endosulfan could cause 0.45 at 14 DAG that was reduced to 0.20 by 28 DAG, followed by carbofuran recording 0.80 at 14 DAG and 0.55 at 28 DAG. Similarly *B. bassiana* has recorded 1.1 holes per plant at 14 DAG that were reduced to 0.61 at 28 DAG followed by *B. thuringiensis* showing 1.15 at 14 DAG and 0.70 at 28 DAG. This has clearly indicated the toxic effect of insecticide on the development of larva as well as the inability of the larva to penetrate through the stem for coming out side as the age of the crop increases.

4.4.5 Efficacy of Different Insecticides on Percentage of Live Larvae Recovered at

Different Crop Ages

Results presented in Table 4.9 have clearly indicated that there was significant decrease in the per cent of live larvae recovered per plant due to insecticide application compared to untreated plants. Maximum of 90.42 % of the total larvae released were recovered from control. When endosulfan was sprayed, minimum of 41.66 % larvae were recovered causing mortality of *S. inferens* to an extent of 58.34 % by 14 DAG and 32.50 % recovery and 67.50 % mortality by 28 DAG. Similarly carbofuran has resulted in about 49.16 % recovery with 50.84 % mortality of larvae at 14 DAG and 36.66 % recovery with 63.34 % mortality. Among the biopesticides, less larvae of 48.33 % at 14 DAG and 37.50 % at 28 DAG were recovered with application of *B. bassiana* and *B. thuringiensis* was found to be least effective in resulting more percentage of recovery of live larvae (58.33 %) at 14 DAG and 50.84 % at 28 DAG. When *B. bassiana* and *B. thuringiensis* were compared for causing mortality of the larvae of *S. inferens*, *B. bassiana* was observed as more infective resulting in 51.67 % mortality at 14 DAG and 62.50 % mortality at 28 DAG which was about 41.67 % at 14 DAG and 49.16 % at 28 DAG by *B. thuringiensis*. It could

be understood from the above results that *B. bassiana* was equally effective in infecting and causing mortality of *S. inferens* with chemical pesticides, endosulfan and carbofuran. However *B. thuringiensis* was ineffective against neonate larvae of *S. inferens* causing mortality.

The infection of larvae with *B. bassiana* treatment was confirmed by incubating the infected larvae or cadaver recovered from stem at temperature of $26 \pm 2^{\circ}\text{C}$ in an incubator. Results have shown milky white growth of *B. bassiana* on the cadaver with shining conidial growth which was later confirmed by structure of conidia. They were hyaline, globose to ellipsoid in shape.

4.4 Evaluation of Different Management Practices for *S. inferens*

Different groups of chemical insecticides viz., carbofuran, endosulfan and biopesticides viz., *B. bassiana* and *B. thuringiensis* were evaluated against *S. inferens* during *rabi*, 2010-11 under glass house conditions. The plants were artificially infested with the larvae of *S. inferens* along with an un inoculated control. Insecticides were sprayed at 10 and 25 days age crop and data were recorded on leaf injury rating (1-9 scale) at 40 days age of the crop and the data on per cent dead hearts, stem tunneling, number of exit holes per plant and number of live larvae recovered per plant were recorded at 14 and 28 days age of the crop and results were presented.

4.4.1 Efficacy of Insecticides on Leaf Injury Rating (LIR) at Different Crop Ages

Data recorded on LIR at 40 DAG presented in the Table 4.5 and Figure 4.4 indicated that all the insecticidal treatments were significantly superior over control in reducing pink borer incidence. The leaf injury rating ranged between 4.55 to 6.3 when insecticides were applied compared to the leaf injury rating of 8.50 in untreated plants. Among different insecticides, endosulfan was found to be significantly effective with low LIR of 4.55 over rest of the treatments. The LIR recorded with carbofuran (5.65) was on par with *B. bassiana* (5.75). Among all the insecticides, the bacterial formulation, *B. thuringiensis* was less effective with highest LIR of 6.30. Similar observations were made by Reddy (2004), who recorded endosulfan as highly effective in suppressing the stalk borer damage. Ravindra Pal *et al* .(2009) also emphasized the use of endosulfan against *C. partellus* recording low LIR of 3.1 as compared to LIR of 5.0 with *B. bassiana* followed by *B. thuringiensis* with LIR of 6.2.

In terms of per cent reduction in LIR due to insecticidal application, it was clear that endosulfan would reduce the damage to an extent of 46.47 per cent. Similarly, carbofuran, *B. bassiana* and *B. thuringiensis* application resulted in a reduction of 35.52, 25.88 and 32.35 per cent, respectively.

4.4.2 Efficacy of Different Insecticides on Per cent Dead Hearts at Different Crop Ages:

Results presented in the Table 4.6 and Figure 4.5 revealed that insecticide application resulted in significant reduction of dead heart formation due to *S. inferens* (Plate 4.3). Among all the treatments, endosulfan was found to be more effective in reducing dead heart formation recording only 26.25 per cent dead hearts as compared to 85.00 per cent in

control at 14 days after germination. Carbofuran with 33.75 per cent dead hearts was found to be on par with the bio pesticides used i.e., *B. bassiana* (36.25 %) and *B. thuringiensis* (41.25 %). Even at 28 days after germination, similar trend showing more efficacy with endosulfan (28.75 per cent dead heart formation) was observed. All the remaining treatments including carbofuran 36.25 per cent, *B. bassiana* with 38.75 per cent and *B. thuringiensis* with 43.75 per cent dead hearts were on par with each other.

In terms of per cent reduction in dead heart formation due to insecticide application, it was clear that endosulfan at both the stages of the crop of 14 and 28 days after germination reduced the damage ranging from 69.12 to 67.10 per cent. Similarly, carbofuran application reduced damage ranging from 60.27 to 58.57 per cent. However, both the bio pesticides *B. bassiana* and *B. thuringiensis* application resulted in reduction of 57.33 to 50.00 per cent and 50.78 to 55.71 per cent dead hearts, respectively at 14 and 28 days after germination. Ravindra pal *et al.* (2009) recorded lowest per cent dead hearts of 14.3 with endosulfan against *C. partellus* in maize and among bio pesticides used, *B. bassiana* recorded about 19.2 per cent dead hearts which was better than *B. thuringiensis* showing 21.3 per cent dead hearts as observed in the present investigations.

4.4.3 Effect of Different Insecticides on Stem Tunneling At Different Crop Ages

Data presented in the Table 4.7 and Figure 4.6 indicated that all the insecticidal treatments were found to be significantly superior over control in reducing stem tunneling. The chemical insecticides were found to be effective than the bio pesticides. Endosulfan treatment recorded lowest stem tunneling of 0.33 cm per metre stem at 14 days and 0.11 cm per metre stem at 28 days after germination. Both the bio pesticides, *B. bassiana* and *B. thuringiensis* were on par with each other in reducing stem tunneling compared to control. However, *B. bassiana* was found to be better with only 0.43 and 0.21 cm per m stem tunneling at 14 and 28 days after germination, respectively, where as *B. thuringiensis* recorded slightly lower tunneling of 0.42 and 0.18 cm per m stem, respectively. It could be concluded based on the present investigation that as the age of the crop increases, stem tunneling decreases significantly irrespective of the pesticide usage. Present results were similar to the findings of Reddy *et al.* (2004) where in lowest stem tunneling of 0.3 cm per metre stem at 14 days after germination was recorded with endosulfan which was found to be 0.4 cm per metre stem at 14 days after germination in the present study. As the age of

the crop increased, stem tunneling was reduced as reported by Lavakumar Reddy *et al.* (2001).

It was evident from the present study that endosulfan reduced stem tunneling to a maximum extent of 29.78 per cent in 14 days crop. Application of carbofuran also resulted to an extent of 25.5 per cent reduction in stem tunneling. However both the biopesticides, *B. bassiana* and *B. thuringiensis* have resulted in 10.63 and 8.5 percent reduction in stem tunneling, respectively at 14 days after germination. A drastic decrease in stem tunneling was observed at 28 days after germination when insecticides were used. Both endosulfan and carbofuran reduced stem tunneling by 85.30 to 86.50 per cent compared to the control. Similarly *B. thuringiensis* was found better with 78.00 per cent reduction than *B. bassiana* with 74.39 per cent reduction.

4.4.4 Efficacy of Different Insecticides on Number of Exit Holes Per Plant at Different Crop Ages Infested by Pink Stem Borer

Infestation of maize crop with *S. inferens* not only resulted in leaf injury, dead heart formation but also stem damage that would be evident with symptoms like exit holes on the stem, horizontal slits and circular and/or vertical tunnels in the stem and bushy stunted appearance of the plant. Damage caused by *S. inferens* was inflicted by symptoms like appearance of exit holes on the stem (Plate 4.4). Data recorded on number of exit holes presented in the Table 4.8 revealed that the number of exit holes were more at early crop age of 14 days after germination. In untreated plants, maximum number of exit holes of 1.45 were observed which were only 1.20 at 28 days after germination. Similar results were obtained by Lavakumar Reddy *et al.* (2001) who have reported significantly maximum number of exit holes when the crop was infested at early stages.

Results presented in the Table 4.9 clearly indicated that when insecticides were applied for control of *S. inferens*, there was significant decrease in the number of exit holes per plant. However, minimum number of exit holes were recorded with endosulfan (0.45) and was followed by carbofuran (0.80). When both *B. bassiana* and *B. thuringiensis* were applied, similar number of exit holes being 1.1 and 1.15, respectively were recorded at 14 days after germination. At 28 days after germination, significant reduction in the number of exit holes was observed due to insecticide application. Among the insecticides, endosulfan recorded minimum number of exit holes of 0.20. Other insecticides, viz.,

carbofuran, *B. bassiana* and *B. thuringiensis* recorded 0.55, 0.61 and 0.70 number of exit holes per plant, respectively and were on par with each other. Results have clearly indicated that with the application of insecticides, infestation caused by *S. inferens* decreased and the number of exit holes per plant were reduced with increase in the crop age.

4.4.5 Efficacy of Different Insecticides on Percentage of Live Larvae Recovered at Different Crop Ages

Application of bio pesticides like *B. bassiana* and *B. thuringiensis* for the control of pest was mainly to reduce infestation through infection of the larva (Table 4.9 and Figure 4.8). It was clear from the data that insecticidal treatments had significant effect in killing the larvae after artificial inoculation where endosulfan had resulted in survival of 41.66 per cent larvae and carbofuran with 49.16 per cent larvae. *B. bassiana* has resulted in about 48.33 per cent larval recovery followed by *B. thuringiensis* with 58.33 per cent larvae at 14 days after germination. There was a significant difference in the number of live larvae recovered from 14 days to 28 days after germination. At 28 days after germination, endosulfan, carbofuran and *B. bassiana* have equally resulted in lowest survival of the larvae with 32.50, 36.65 and 37.50 per cent larval recovery per plant, respectively. But *B. thuringiensis* was found to be less effective in causing death of the larvae by infecting *S. inferens* resulting in maximum of 58.33 per cent live larvae. In terms of per cent reduction it was clear that endosulfan at both the crop age of 14 and 28 days after germination would reduce the percentage of live larvae recovered ranging from 63.00 to 53.92 per cent. Similarly, carbofuran application reduced recovery ranging from 58.30 to 45.62 per cent. However, both the bio pesticides *B. bassiana* and *B. thuringiensis* had resulted in reduction of 48.33 to 57.34 per cent and 42.17 to 35.48 per cent percentage of live larva respectively at 14 and 28 days after germination. (Plate 4.5)

As *B. bassiana* was found to be equally effective in causing mortality of the larvae of *S. inferens* at 28 days after germination, the live larvae were incubated at a temperature of $26 \pm 2^{\circ}\text{C}$ in an incubator confirming the infection. Milky white growth was observed (Plate

4.6). Larva had shown conidial growth over its body which was confirmed by structure of conidia. Mycelium was hyaline and septate. Conidia were hyaline, globose to broadly ellipsoidal in shape.



Plate 4.1. leaf injury damage in maize due to *S. inferens*.



Plate 4.2. Dead hearts and stunted growth due to *S. inferens*.



Plate 4.3. Dead hearts due to *S. inferens* .



Plate 4.4.Exit holes on plants infested with *S. inferens*.



Plate 4.5. Live larvae recovered.



Plate 4.6. Growth of *B. bassiana* on the infected larvae.

Table 4.1. Relative susceptibility of maize genotypes to pink borer, *Sesamia inferens* under field conditions based on leaf injury rating

S.No.	Maize genotype	Mean Leaf injury rating(LIR) (1-9 scale)
1	HQPM 1	4.85
2	DHM 117	5.08
3	30 V 92	7.87
4	Winsynthetic	5.29
5	HKI 163-1	6.22
6	HKI 193-1	6.21
7	BML 6	7.31
8	BML 7	8.37
9	HKI MBR -139	8.50
10	HKI C 322	7.31
11	V 351	6.49
12	DMRQPM 58	9.00
13	CM 132	9.00
14	CM 137	8.93
15	CM 139	8.87
16	CM 144	8.87
17	CM 202	7.56
18	CM 212	8.63
19	CM 500 (Resistant check)	2.80
20	Basilocal (Susceptible check)	8.81
	CD at 5%	0.45
	SE(m)	0.16
	CV	3.71

Table. 4.2. Relative susceptibility of maize genotypes to pink borer, *Sesamia inferens* under field conditions based on per cent dead hearts

S.No.	Maize genotypes	Per cent dead hearts
1	HQPM I	20.20 (26.68)
2	DHM 117	5.56 (11.03)
3	30 V 92	62.50 (52.22)
4	Winsynthetic	14.29 (21.20)
5	HKI 1631	21.53 (27.63)
6	HKI 1931	22.50 (28.28)
7	BML 6	56.25 (48.59)
8	BML 7	56.25 (48.59)
9	HKI MBR 139	87.5 (69.27)
10	HKI C 322	25.00 (29.47)
11	V 351	8.57 (16.98)
12	DMRQPM 58	94.44 (78.94)
13	CM 132	100 (90.00)
14	CM 137	93.75 (78.25)
15	CM 139	87.50 (73.01)
16	CM 144	87.50 (73.08)
17	CM 202	62.50 (52.21)
18	CM 212	81.25 (64.51)
19	CM 500 (Resistant check)	0.00 (0.00)
20	Basi local (Susceptible check)	93.75 (78.25)
	CD at 5%	11.66
	SE(d)	5.74
	SE(m)±	4.06
	CV	14.50

Values in parentheses are angular transformed values

Table.4.3.Classification of maize genotypes against pink borer based on leaf injury rating (1-9 scale)

Maize genotype	Mean LIR (1-9 scale)	Classification
HQPM-1	4.85	Moderately resistant
DHM117	5.08	Moderately Susceptible
Winsynthetic	5.29	
HKI-193-1	6.21	
HKI-163-1	6.22	
V351	6.49	
BML-6	7.31	
HKI-C 322	7.31	
CM 202	7.56	
30 V 92	7.87	
BML 7	8.37	
HKI MBR 739	8.50	
CM 212	8.62	
CM 144	8.87	Highly Susceptible
CM 139	8.87	
CM 137	8.93	
CM 132	9.00	
DMRQPM	9.00	
CM 500 (Resistant check)	2.80	
Basilocal (Susceptible check)	8.81	

Table. 4.4. Effect of larval densities of *Sesamia inferens* on leaf injury rating (at 30 DAI) and percent dead hearts at different stages of crop growth in maize under unprotected conditions

Larval density/plant	Crop age (days after germination)									
	7 (2 leaf stage)		14 (4 leaf stage)		21 (6 leaf stage)		28 (8 leaf stage)		Mean	
	LIR (1-9 scale)	Per cent dead hearts	LIR (1-9 scale)	Per cent dead hearts	LIR (1-9 scale)	Per cent dead hearts	LIR (1-9 scale)	Per cent dead hearts	LIR (1-9 scale)	Per cent dead hearts
0	0	0.00 (0.00)	0	0.00 (0.00)	0	0.00 (0.00)	0	0.00 (0.00)	0	0.00 (0.00)
5	5.17	8.00 (16.40)	4.37	0.00 (0.00)	2.77	0.00 (0.00)	2.70	0.00 (0.00)	3.75	2.00 (4.10)
10	6.36	12.33 (20.54)	5.10	0.00 (0.00)	4.33	0.00 (0.00)	3.23	0.00 (0.00)	4.75	3.08 (5.13)
15	6.83	12.00 (20.25)	5.30	0.00 (0.00)	4.30	0.00 (0.00)	3.52	0.00 (0.00)	4.98	3.00 (5.06)
20	7.27	8.66 (17.11)	6.38	0.00 (0.00)	5.14	0.00 (0.00)	3.84	0.00 (0.00)	5.66	2.16 (4.27)
Mean	5.13	8.2 (14.86)	4.23	0.00 (0.00)	3.31	0.00 (0.00)	2.65	0.00 (0.00)		
	CD at 5%					SE(m)±				
	LIR		Percent dead hearts			LIR		Percent dead hearts		
Larval density	0.20		0.31			0.07		0.11		
Crop age	0.18		0.28			0.06		0.10		
Larval density X Crop age	0.41		0.63			0.14		0.22		

Values in parentheses are angular transformed values.

Larval density/plant	Difference in LIR		
	Between 7 and 14 days	Between 14 and 21 days	Between 21 and 28 days
0	0.00	0.00	0.00
5	0.80	1.60	0.07
10	1.26	0.77	1.10
15	1.53	1.00	0.78
20	0.89	1.24	1.30

**Table 4.5. Efficacy of different insecticides on leaf injury rating
infested by pink stem borer, *S. inferens***

	Crop age (40 Days after germination)	
Treatments	LIR(1-9 scale)	Percent reduction
T₁. <i>B.bassiana</i>	5.75	32.35
T₂-<i>B. thuringiensis</i>	6.30	25.88
T₃.Carbofuran	5.65	33.52
T₄.Endosulfan	4.55	46.47
T₅.Control	8.50	
CD at 5 %	8.065	
SE m±	0.26	

Table 4.6. Efficacy of different insecticides on per cent dead hearts at different crop ages infested by pink stem borer, *S. inferens*

Treatments	Crop age (Days after germination)			
	14 DAG		28 DAG	
	Per cent dead hearts	Per cent reduction	Per cent dead hearts	Per cent reduction
T₁- <i>B. bassiana</i>	36.25 (36.93)	57.33	38.75 (38.41)	55.71
T₂-<i>B. thuringiensis</i>	41.25 (39.76)	51.45	43.75 (41.31)	50.00
T₃-Carbofuran	33.75 (35.46)	60.27	36.25 (36.50)	58.57
T₄-Endosulfan	26.25 (30.55)	69.12	28.75 (32.30)	67.10
T₅-Control	85.0 (67.38)		87.50 (69.50)	
CD at 5% SE(m)±				
Treatments(F ₁)		5.13	1.77	
Crop age(F ₂)		N.S	1.12	
F ₁ x F ₂		N.S	2.51	

Values in parentheses are angular transformed values

Table 4.7. Efficacy of different insecticides on stem tunneling at different crop ages infested by pink stem borer *S. inferens*

Treatments	Crop age (Days after germination)			
	14 DAG		28 DAG	
	Stem tunneling (cm/m stem)	Per cent reduction	Stem tunneling (cm/m stem)	Per cent reduction
T₁- <i>B. bassiana</i>	0.43	8.50	0.21	74.39
T₂-<i>B. thuringiensis</i>	0.42	10.63	0.18	78.00
T₃-Carbofuran	0.35	25.50	0.12	85.30
T₄-Endosulfan	0.33	29.78	0.11	86.50
T₅-Control	0.47		0.82	
CD at 5% SE(m)±				
Treatments (F ₁)		0.03	0.01	
Crop age (F ₂)		0.02	0.01	
F ₁ x F ₂		0.06	0.02	

Table 4.9. Efficacy of different insecticides on percentage of live larvae recovered at different crop ages infested by pink stem borer, *S. inferens*

Treatments	Crop age (Days after germination)			
	14 DAG		28 DAG	
	Live larvae recovered (%)	Per cent mortality	Live larvae recovered (%)	Per cent mortality
T₁- <i>B. bassiana</i>	48.33	51.67	37.50	62.50
T₂-<i>B. thuringiensis</i>	58.33	41.67	50.84	49.16
T₃-Carbofuran	49.16	50.84	36.66	63.34
T₄-Endosulfan	41.66	58.34	32.50	67.50
T₅-Control	90.42		87.91	
CD at 5% SE(m)±				
Treatments(F ₁)		5.01	1.73	
Crop age (F ₂)		3.17	1.10	
F ₁ X F ₂		N.S	2.45	

Table 4.8. Efficacy of different insecticides on number of exit holes per plant at different crop ages infested by pink stem borer, *S. inferens*

Treatments	Crop age (Days after germination)			
	14 DAG		28 DAG	
	Number of exit holes per plant	Per cent reduction	Number of exit holes per plant	Per cent reduction
T₁- <i>B. bassiana</i>	1.1	24.13	0.61	49.16
T₂-<i>B. thuringiensis</i>	1.15	20.68	0.70	41.66
T₃-Carbofuran	0.80	44.82	0.55	54.16
T₄-Endosulfan	0.45	68.96	0.20	83.33
T₅-Control	1.45		1.20	
CD at 5% SE(m) ±				
Treatments(F₁)	0.21		0.07	
Crop age(F₂)	0.13		0.05	
F₁x F₂	N.S		0.10	

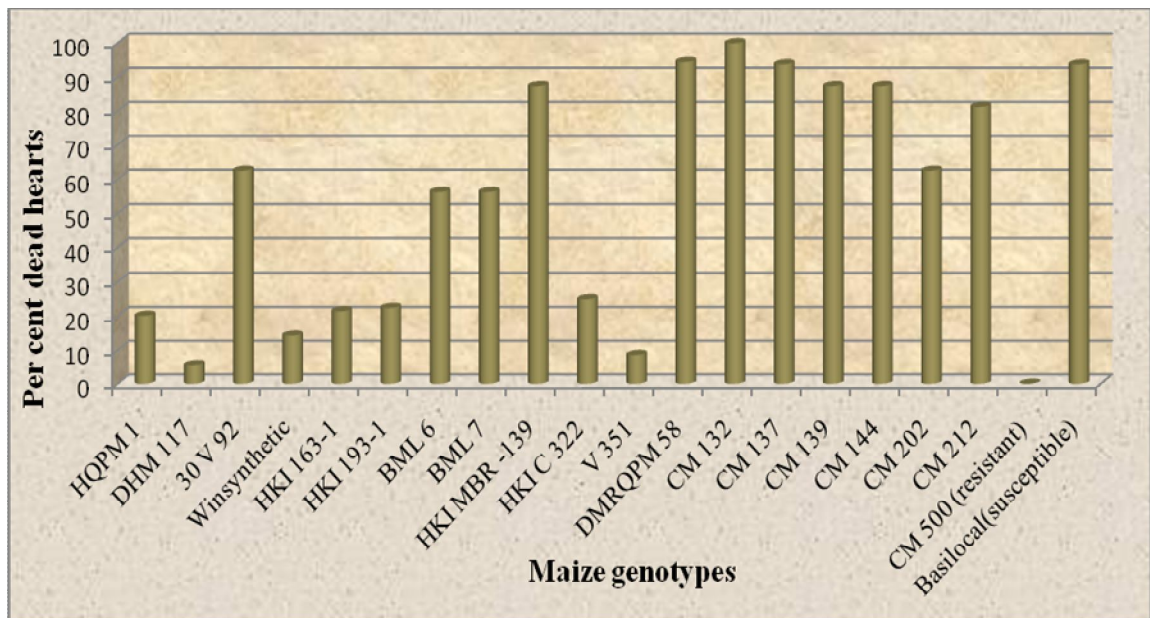


Figure 4.1. Relative susceptibility of maize genotypes to pink borer, *S. inferens* based on leaf injury rating.

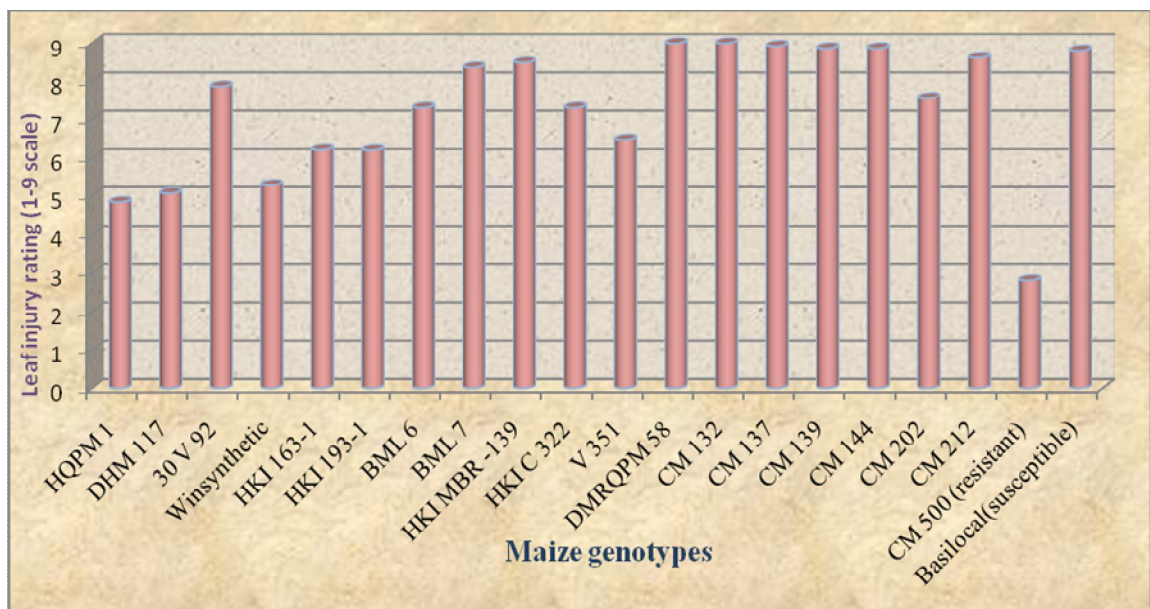


Figure 4.2. Relative susceptibility of maize genotypes to pink borer, *S. inferens* based on per cent dead hearts.

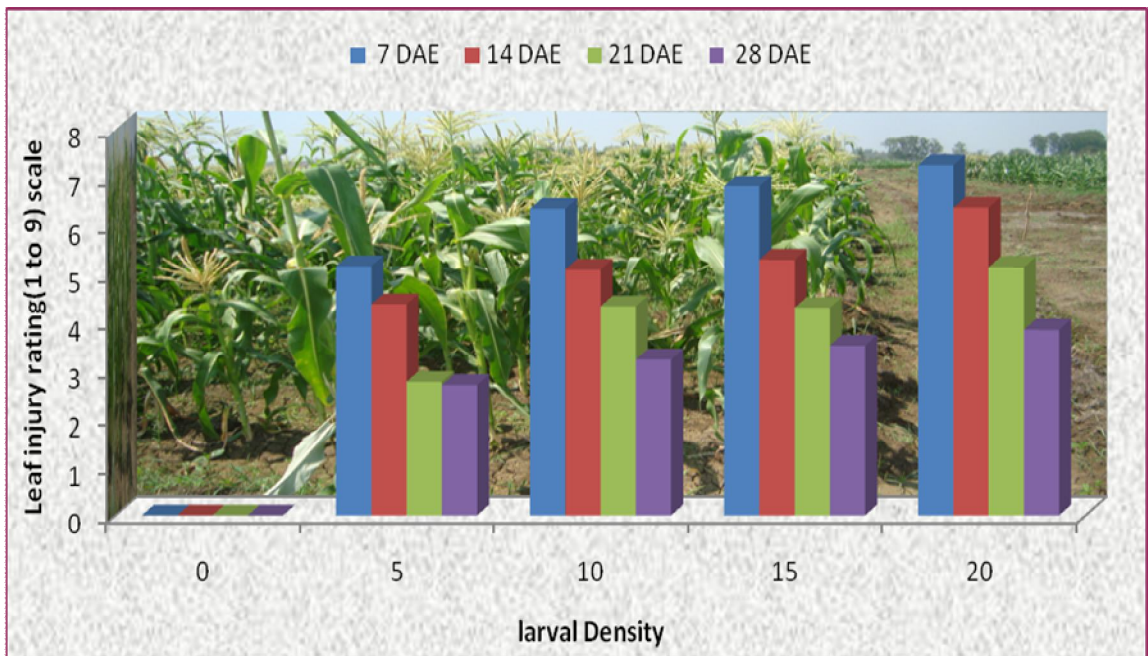


Figure 4.3. Effect of larval densities of *S. inferens* on leaf injury rating and at different stages of crop growth in maize.

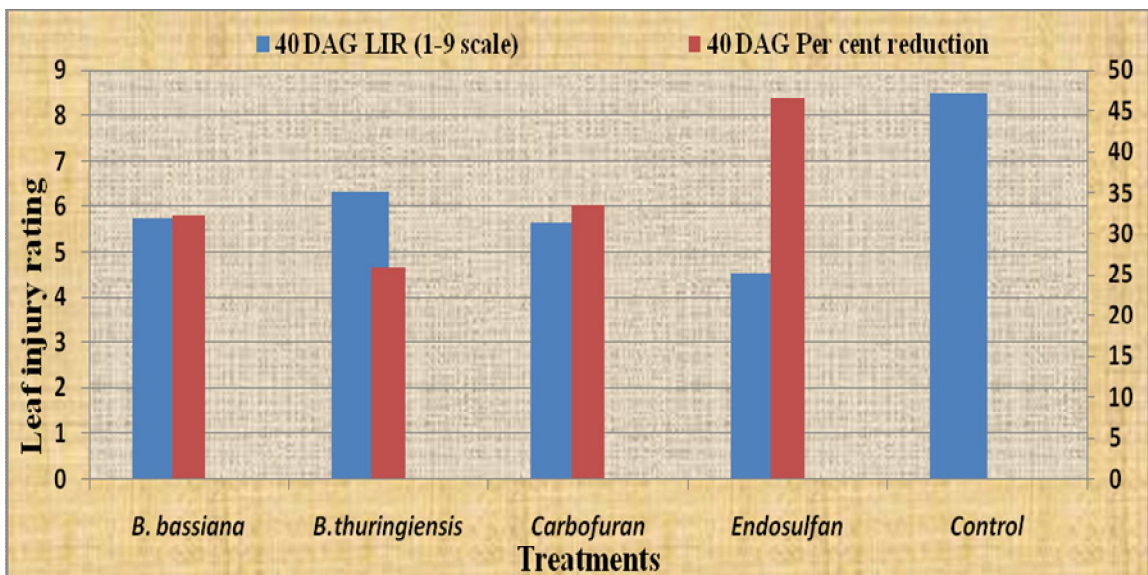


Figure 4.4. Efficacy of different insecticides on leaf injury rating infested by pink stem borer, *S. inferens*.

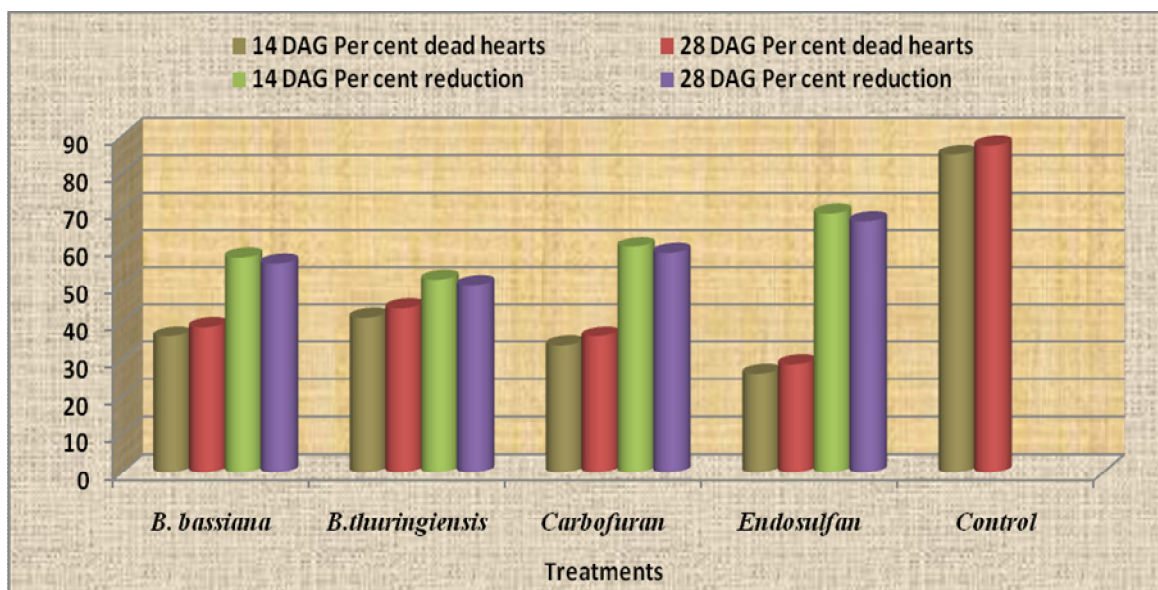


Figure 4.5. Efficacy of different insecticides on per cent dead hearts at different crop ages infested by pink stem borer, *S. inferens*.

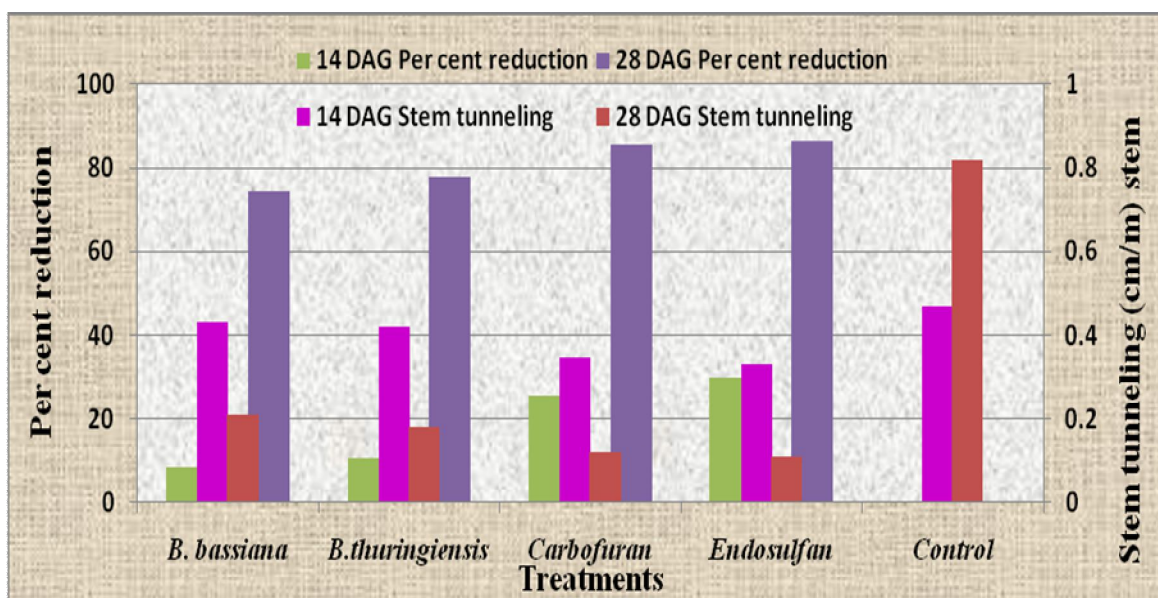


Figure 4.6. Efficacy of different insecticides on stem tunneling at different crop ages infested by pink stem borer, *S. inferens*.

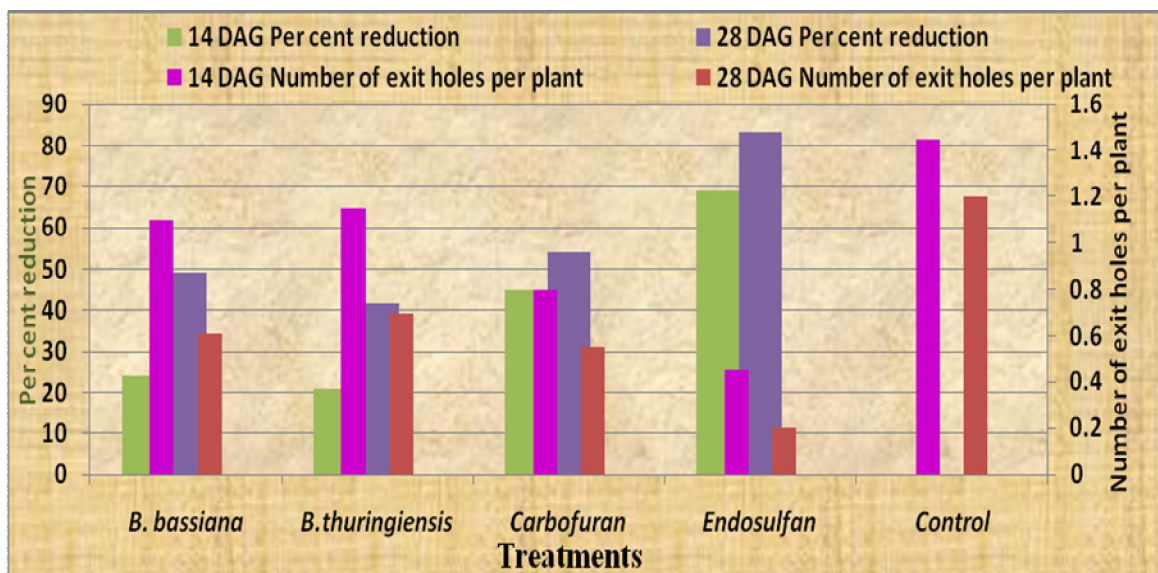


Figure 4.7. Efficacy of different insecticides on number of exit holes per plant at different crop ages infested by pink stem borer, *S. inferens*.

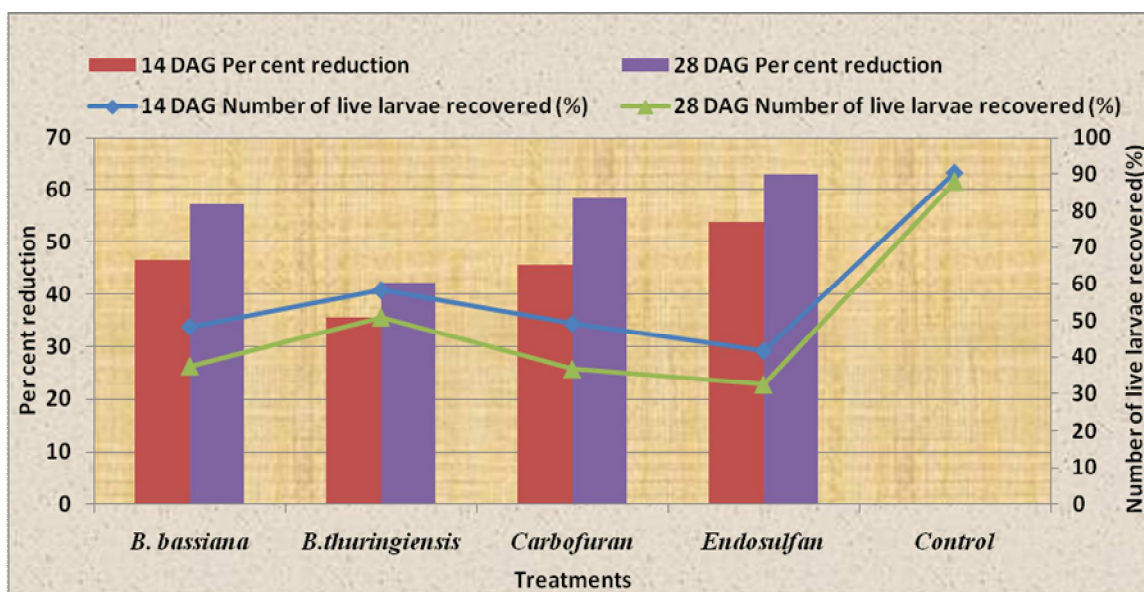


Figure 4.8. Efficacy of different insecticides on percentage of live larvae recovered at different crop ages infested by pink stem borer, *S. inferens*.

Chapter V

SUMMARY AND CONCLUSIONS

“Studies on management of pink borer, *S. inferens* walker on maize” were conducted during *rabi*, 2010 - 11 under field and green house conditions at College of Agriculture, Rajendranagar. Screening of maize genotypes against pink borer were carried out at Maize Research Center, All India Co-ordinated Maize Improvement Project (AICMIP), ARI, Rajendranagar, Hyderabad.

The Results obtained from the varietal screening studies of maize genotypes under field conditions with artificial infestation of *S. inferens* indicated that among the twenty maize genotypes tested the leaf injury rating (LIR) ranged from 2.80 to 9.00 based on 1-9 scale. The maize genotypes viz., HQPM 1, DHM 117, Winsynthetic, HKI 193-1, HKI 163-1, V 351, BML 6, HKI C 322, CM 202, 30 V 92, BML 7, HKI MBR 139, CM 212, CM 144, CM 139, CM 137, CM 132 and DMRQPM 58 recorded a mean leaf injury rating of 4.85, 5.08, 5.29, 6.21, 6.22, 6.49, 7.31, 7.31, 7.56, 7.87, 8.37, 8.50, 8.62, 8.87, 8.87, 8.93, 9.00 and 9.00, respectively as against that of the resistant check, CM 500 (2.80) and the susceptible check, Basilocal (8.81).

Per cent dead hearts among the twenty maize genotypes ranged from 0.00 to 100 per cent. Maximum percent dead hearts were recorded in the genotypes CM 132 (100), DMRQPM 58 (94.44) and CM 137 (93.75) and Basilocal (93.75). No dead hearts were recorded in the resistant check, CM 500 and was followed by DHM 117 (5.56) and V 351 (8.57). The genotypes, Winsynthetic (14.29), HQPM 1 (20.20), HKI 163-1(21.54), HKI 193-1(22.5), HKI C 322 (25.0) were on par in recording the dead hearts below 25.0 per cent. However, more than 50.0 per cent dead hearts were observed in genotypes BML 6 (56.25). BML 7 (56.25) and was followed by 30 V 92 (62.5) and CM 202 (62.5). Three genotypes viz., CM 139, CM 144 and HKI C 322 recorded same per cent of dead hearts (87.50) and was followed by CM 212 (81.25) indicating their susceptibility to *S. inferens*.

The classification of genotypes was done based on the leaf injury rating. Among the twenty maize genotypes none of them recorded mean LIR of less than or equal to the

resistant check (2.80). However, the genotype HQPM 1 with leaf injury rating of 4.85 was categorized as moderately resistant. Twelve genotypes, DHM 117 (5.08), Winsynthetic (5.29), HKI 193 1 (6.21), HKI 163 1 (6.22), V 351 (6.49), BML 6 (7.31), CM 202 (7.56), 30 V 92 (7.87), BML7 (8.37), HKI MBR 139 (8.50) CM 212 (6.25) were classified as moderately susceptible with mean LIR ranging between 2.80 (resistant check) and 8.81 (susceptible check). The remaining 5 genotypes, CM 144 (8.87), CM 139 (8.87), CM 137 (8.93), CM 132 (9.00), DMRQPM 58 (9.00) with mean LIR more than the susceptible check, Basilocal (8.81) were grouped as highly susceptible.

The effect of larval densities of *S. inferens* during different growth stages of maize hybrid, DHM 117 under unprotected conditions indicated that with increase in the larval density there was an increase in LIR. Leaf injury rating was significantly more at two leaf stage (7 DAG) of the crop as compared to 14, 21, 28 day old plants. The highest mean LIR was recorded when 20 larvae were released at 2 leaf stage (7 DAG) and the lowest was at 8 leaf stage (28 DAG) when 5 larvae were released. The LIR increased with increase in larval density irrespective of the crop age. Based on the findings, maize crop at 2 leaf stage was considered as the most critical stage for *S. inferens* infestation irrespective of the larval densities.

Experiments conducted on evaluation of different management practices for *S. inferens* with maize single cross hybrid, DHM 117 under green house conditions clearly indicated endosulfan as the most effective with 4.55 leaf injury rating, 26.25 percent dead hearts, 0.33 cm per metre stem tunneling, 0.45 number of exit holes per plant, and 41.66 percentage of live larval recovery followed by carbofuran with 5.65 leaf injury rating, 33.75 percent dead hearts, 0.35 cm per metre stem tunneling, 0.80 number of exit holes per plant, and 49.16 percentage of live larval recovery. Among the biopesticides *B. bassiana* was more effective with 5.75 leaf injury rating, 36.25 percent dead hearts, 0.43 cm per metre stem tunneling, 1.10 number of exit holes per plant and 48.33 percentage of live larval recovery compared to *B. thuringiensis* with 6.30 leaf injury rating, 41.25 percent dead hearts, 0.42 cm per metre stem tunneling, 1.15 number of exit holes per plant and 58.33 percentage of live larval recovery. Growth of *B. bassiana* was confirmed as white mycelial growth on infected larvae.

- Among the twenty maize genotypes leaf injury rating (LIR) ranged between 2.80 to 9.00 based on 1-9 rating scale and the per cent dead hearts varied from 0 to 100 per cent.
- The genotype HQPM 1 was found to be moderately resistant with low LIR of 4.85. Twelve genotypes DHM 117 (5.08), Winsynthetic (5.29), HKI 193 1(6.21), HKI 163 1 (6.22), V 351 (6.49), BML 6 (7.31), CM202(7.56), 30V92(7.87), BML7(8.37), HKI MBR 139 (8.50) CM 212 (6.25) were grouped as moderately susceptible with LIR ranging between 2.80 (resistant check, CM 500) and 8.81 (susceptible check). The remaining 5 genotypes CM 144 (8.87), CM 139(8.87), CM 137(8.93), CM 132(9.00), DMRQPM 58 (9.00) with mean LIR more than the susceptible check (Basilocal) were grouped as highly susceptible.
- Maize crop at 2 leaf stage (7 DAG) was considered as the most critical stage for *S. inferens* infestation irrespective of the larval densities.
- Endosulfan was found to be more effective with 4.55 leaf injury rating, 26.25 percent dead hearts, 0.33 cm per metre stem tunneling, 0.45 number of exit holes per plant, and 41.66 percentage of live larval recovery followed by carbofuran.
- Among the biopesticides, *B. bassiana* was more effective compared to *B. thuringiensis*.

Scope for Future Work

- Utilisation of bio control agents in the management of *S. inferens* especially in maize planted under zero tillage after rice in coastal districts of Andhra Pradesh.
- Management of *S. inferens* at grain filling stage.

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