

**STUDIES ON THE POPULATION DYNAMICS OF
MAJOR PESTS OF SORGHUM AND BIOECOLOGY
AND CROP LOSS ASSESSMENT DUE TO THE
SHOOT BUG, *Perigrinus maidis* ASHMEAD**

BY
PACHIPALA RAJA SEKHAR
M. Sc. (Ag)

THESIS SUBMITTED TO THE
ANDHRA PRADESH AGRICULTURAL UNIVERSITY
IN PARTIAL FULFILMENT OF THE REQUIREMENTS
FOR THE AWARD OF THE DEGREE OF
DOCTOR OF PHILOSOPHY
IN THE FACULTY OF AGRICULTURE SCIENCE



ANGRAU
Central Library
Hyderabad



DEPARTMENT OF ENTOMOLOGY
COLLEGE OF AGRICULTURE
ANDHRA PRADESH AGRICULTURAL UNIVERSITY
RAJENDRANAGAR, HYDERABAD - 500 030

CERTIFICATE

Mr.P. RAJA SEKHAR has satisfactorily prosecuted the course of research and that the thesis entitled STUDIES ON THE POPULATION DYNAMICS OF MAJOR PESTS OF SORGHUM AND BIOECOLOGY AND CROP LOSS ASSESSMENT DUE TO THE SHOOT BUG,Peregrinus maidis ASHMEAD* submitted is the result of original research work and is of sufficiently high standard to warrant its presentation to the examination. I also certify that the thesis or part thereof has not been previously submitted by him for a degree of any University.

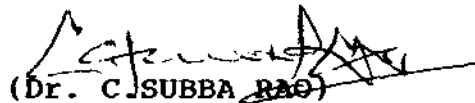
Date: 13.11.1984


(Dr. C. SUBBA RAO)
Major Advisor

CERTIFICATE

This is to certify that the thesis entitled **STUDIES ON THE POPULATION DYNAMICS OF MAJOR PESTS OF SORGHUM AND BIO-ECOLOGY AND CROP LOSS ASSESSMENT DUE TO THE SHOOTBUG, PEREGRINUS MAIDIS ASHMEAD** submitted in partial fulfilment of the requirements for the degree of **Doctor of Philosophy in Agriculture** of the Andhra Pradesh Agricultural University, Hyderabad is a record of the bonafide research work carried out by **Mr.P.Rajasekhar** under my guidance and supervision. The subject of the thesis has been approved by the Students' Advisory Committee.

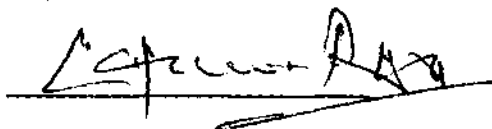
No part of the thesis has been submitted for any other degree or diploma or has been published. All the assistance and help received during the course of the investigation has been duly acknowledged by the author of the thesis.


(Dr. C. SUBBA RAO)

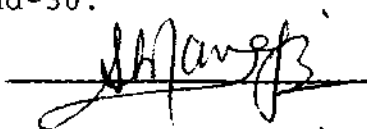
Chairman of the Advisory Committee

Thesis approved by the Student Advisory Committee.

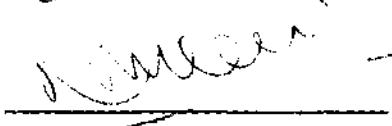
Chairman : (Dr.C.SUBBA RAO)
Professor & Head
Department of Entomology
College of Agriculture
Rajendranagar, Hyderabad-30.



Member : (Dr.S.L.TANEJA)
Sorghum Entomologist
ICRISAT
Patancheru.



Member : (Dr.NARENDRA KULKARNI)
Breeder
Agricultural Research Institute
Rajendranagar
Hyderabad



Member : (Dr. G. NAGESWARA RAO)
Professor & University Head
Department of Statistics & Mathematics
College of Agriculture
Rajendranagar, Hyderabad-30



LIST OF CONTENTS

Chapter	Title	Page No.
I	INTRODUCTION	
II	REVIEW OF LITERATURE	
III	MATERIALS AND METHODS	
IV	RESULTS	
V	DISCUSSION AND CONCLUSIONS	
VI	SUMMARY	
	LITERATURE CITED	

LIST OF TABLES

Table No.	Particulars	Page No.
1	Shoot fly oviposition and damage on sorghum planted during different months	
2	Shoot fly oviposition in various treatments at 14 DAE on sorghum planted during different months.	
3	Shoot fly deadhearts in various treatments at 21 DAE on sorghum planted during different months.	
4	Stem borer damage on sorghum planted during different months.	
5	Stem borer leaf damage in various treatments at 4 WAE on sorghum planted during different months	
6	Stem borer deadhearts at 35 DAE on sorghum planted during different months	
7	Stem borer population on sorghum planted during different months	
8	Stem borer population counts at boot leaf stage in various treatments on sorghum planted during different months	
9	Stem borer population counts at harvesting in various treatments on sorghum planted during different months	
10	Shoot bug and midge incidence on sorghum planted during different months	
11	Number of shoot bugs at 30 DAE in various treatments on sorghum planted during different months	

Contd..

Contd..

Table No.	Particulars	Page No.
12	Midge and head bug incidence on sorghum planted during different months	
13	Number of midge flies at 50 per cent flowering in various treatments on sorghum planted during different months	
14	Midge damage in various treatments on sorghum planted during different months	
15	Number of head bugs at milky stage in various treatments on sorghum planted during different months	
16	Head bugs damage rating at harvest in various treatments on sorghum planted during different months	
17	Number of armyworm larvae at 50 DAE in various treatments on sorghum planted during different months	
18	Correlation of insect population/damage in relation to abiotic factors	
19	Multiple linear regression model for insect population/damage in relation to abiotic factors	
20	Path coefficient analysis: climatological factors vs shoot fly deadhearts at 21 DAE.	
21	Path coefficient analysis: climatological factors vs stem borer leaf feeding (4 WAE)	
22	Path coefficient analysis: climatological factors vs stem borer deadhearts at 35 DAE	

Contd..

Contd..

Table No.	Particulars	Page No.
23	Path coefficient analysis: climatological factors vs stem borer counts at boot leaf stage.	
24	Path coefficient analysis: climatological factors vs stem borer counts at harvesting	
25	Path coefficient analysis: climatological factors vs number of shoot bugs at 30 DAE	
26	Path coefficient analysis: climatological factors vs number of midge flies	
27	Path coefficient analysis: climatological factors vs sorghum midge damage	
28	Path coefficient analysis: climatological factors vs number of head bugs.	
29	Duration and measurement of life stages of <u>P. maidis</u> during two generations	
30	Fecundity of <u>P. maidis</u> under laboratory conditions during two generations	
31	Fecundity of female during different mating intervals (times) with male during September to November, 1988	
32	Fecundity of <u>P. maidis</u> under different proportions of males to females during September to November, 1988	
33	The survival of different stages of shoot bug during development on sorghum (September to November, 1988)	
34	Age specific fecundity of shoot bug on sorghum	

Contd..

Contd..

Table No.	Particulars	Page No.
35	Calculation of corrected 'rm' (Trial and error method)	
36	Stable-age-distribution of shoot bug on sorghum (rm =0.085).	
37	Shoot bug population, grain and fodder yields, avoidable loss and cost benefit ratio under various protection levels (<u>kharif</u>)	
38	Shoot bug population, grain and fodder yields, avoidable loss and cost benefit ratio under various protection levels (<u>rabi</u>)	
39	Avoidable losses due to shoot bug infestation under caged conditions	
40	Shoot bug population on different genotypes during <u>kharif</u> and <u>rabi</u> seasons 1988-89	
41	Classification of genotypes based on mean and standard deviation of shoot bug population during <u>kharif</u> , 1988	
42	Classification of genotypes based on mean and standard deviation of shoot bug during <u>rabi</u> , 1988-89.	
43	Efficacy of different insecticides for the control of shoot bug during <u>kharif</u> 1988	
44	Shoot bug population, grain and fodder yields and cost benefit ratio in various treatments in <u>kharif</u> 1988	
45	Efficacy of different insecticides for the control of shoot bug during <u>rabi</u> 1988-89.	
46	Shoot bug population, grain and fodder yields and cost benefit ratio in various treatments in <u>rabi</u> 1988-89.	

LIST OF ILLUSTRATIONS

Figure No.	Particulars	Page No.
1	Seasonal occurrence of shoot fly oviposition at 14 DAE in relation to climatic factors during 1988-89.	
2	Per cent of shoot fly deadhearts at 21 DAE in relation to weather conditions during 1988-89.	
3	Per cent of stem borer deadhearts at 35 DAE in relation to weather factors during 1988-89	
4	Per cent of stem borer population at boot leaf stage in relation to weather factors during 1988-89	
5	Per cent of stem borer population at harvesting in relation to weather factors during 1988-89	
6	Seasonal incidence of shoot bugs at 30 DAE in relation to climatic factors during 1988-89	
7	Per cent of midge infested florets in relation to climatic factors during 1988-89	
8	Seasonal incidence of head bugs at milky grain stage in relation to climatic factors during 1988-89	
9	Egg of <u>P. maidis</u> A. Egg immediately after it is laid B. Egg before hatching	
10	First instar nymph of <u>P. maidis</u>	
11	Second instar nymph of <u>P. maidis</u>	
12	Third instar nymph of <u>P. maidis</u>	
13	Fourth instar nymph of <u>P. maidis</u>	

Contd..

Figure No.	Particulars	Page No.
14	Abdomen of fourth instar nymph of <u>P. maidis</u> showing the initiation of knob shaped external genitalia	
15	Fifth instar nymph of <u>P. maidis</u>	
16	External male genitalia of fifth instar nymph of <u>P. maidis</u>	
17	External female genitalia of fifth instar nymph of <u>P. maidis</u>	
18	Age specific survival and fecundity on sorghum	
19	Determination of the accurate intrinsic rate of increase (rm) on sorghum (Graphically)	

LIST OF PLATES

Plate No.	Particulars	Page No.
1	Egg of shoot fly, <u>A. soccata</u>	
2	Sorghum plant showing shoot fly damage symptom	
3	Carbofuran 3G treated and untreated plot	
4	Stem borer leaf damage on sorghum	
5	Stem borer infested and uninfested plants	
6	Stem borer larva feeding on sorghum stem	
7	Stem borer pupa and adults	
8	Sorghum grains showing head bug damage	
9	Shoot bug population in sorghum leaf whorl	
10	Different instars of <u>P. maidis</u>	
11	Macropterous adults of <u>P. maidis</u>	
12	General view of the experimental field	

ACKNOWLEDGEMENTS

I express my deep sense of gratitude and sincere regards to Dr.C. Subba Rao, Professor and Head, Department of Entomology and Chairman, Advisory Committee for his valuable guidance, constant encouragement and timely critical suggestions throughout the period of investigation.

I am highly indebted to Dr. S.L. Taneja, Entomologist, ICRISAT, Patanacheru and Co-Chairman of Advisory Committee, for helping me in planning out my research project and persistent and valuable guidance during the period of research work. I am also highly thankful to him and ICRISAT for providing necessary research material for smooth running of the research Project.

I wish to express my sincere thanks to Dr.G.Nageswara Rao, Professor and University head, Department of Statistics and Mathematics and Dr.Narender Kulkarni, Breeder, Agricultural Research Institute, Rajendranagar, Members of Advisory Committee for their marked advice and in going through the thesis.

I express my heartfelt gratitude and sincere regards to Mr.Kondal Rao, Farm-in-charge, Bayer

Agricultural Research Institute and Trial Farm, Medchal for providing field, laboratory and other facilities for conducting the research project smoothly.

I am immensely thankful to Dr. T. Ramesh Babu, Assistant Research Officer, AICRP on Biological Control and Mr. C. Kumar Naidu, Research Associate, ICRISAT for their help in statistical analysis, constant advice and encouragement throughout the period of investigation.

I also extend my thanks to the staff of Department of Entomology and my friends who helped me during the course of investigations.

Lastly, I greatly acknowledge the help received from Indian Council of Agricultural Research for extending financial assistance in the form of senior fellowship.

P. Raja Sekhar
(P. RAJA SEKHAR)

DECLARATION

I, P.RAJA SEKHAR, hereby declare that the thesis entitled STUDIES ON THE POPULATION DYNAMICS OF MAJOR PESTS OF SORGHUM AND BIOECOLOGY AND CROP LOSS ASSESSMENT DUE TO THE SHOOT BUG, Perigrinus maidis ASHMEAD, is a result of the 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.

Date: 13-11-89

P. Raja Sekhar
(P.RAJA SEKHAR)

Name of the author : P.RAJA SEKHAR

Title of the thesis : STUDIES ON THE POPULATION DYNAMICS OF MAJOR PESTS OF SORGHUM AND BIOECOLOGY AND CROP LOSS ASSESSMENT DUE TO THE SHOOT BUG, PEREGRINUS MAIDIS ASHMEAD.

Degree to which it is submitted : DOCTOR OF PHILOSOPHY IN AGRICULTURE

Faculty : AGRICULTURE

Major Advisor : Dr.C.SUBBA RAO

Major field of study : ENTOMOLOGY

University : ANDHRA PRADESH AGRICULTURAL UNIVERSITY

Year of submission : 1989

ABSTRACT

Studies on population dynamics and influence of abiotic factors on the major pests of sorghum from staggered plantings of two genotypes, namely, CSH-1 and ICSV1 at monthly intervals showed that the shoot fly was observed to be in its peak from July to December and the maximum temperature got a detrimental effect while relative humidity had a significant and positive relationship.

The damage by stem borer indicated, low level activity during February to April. The pest builds up with the first summer showers and reach peak levels in May to July plantings. The multiple regression analysis showed that an increase in relative humidity by one per cent would decrease the per cent of plants with leaf damage by 0.94%.

The shoot bug was active in June to October planted crop and the relationship between abiotic components and incidence revealed that the amount of rainfall, rainy days and relative humidity exhibited significant and positive relationship.

The highest population of midges (15.5 to 16.6 midges/ten panicles) was noticed in between July to September and multiple regression equation fitted with

weather factors predicted that an increase in number of rainy days by one day would increase adult midge population by 10.95 and an increase in rainfall by one unit would decrease per cent of midge damage by 0.76.

The crops which flowered during August to December suffered heavily due to higher population of head bugs and in general relative humidity and rainy days had a significant and positive influence while maximum temperature got a negative and direct effect.

In the studies on bioecology of shoot bug it was found that the average incubation and nymphal period was 8.2 and 16.6 days, respectively, the total life period being 24.8 days. Studies on life fecundity table revealed that the shoot bug would multiply 17.99 times on sorghum at the end of each generation with a mean generation length of 34.12 days. The stable age distribution revealed that the population would comprise 64.98% eggs, 30.82% nymphs and 4.18% adults.

Studies on assessment of crop losses due to shoot bug revealed that the vulnerable stage was 60 DAE and the avoidable loss was minimum when the crop was protected twice at 45 and 60 DAE. The EIL was found to be 3.73 bugs plant⁻¹.

The host plant resistance studies against shoot bug revealed that the promising genotypes were SPV 736, SPV858, SPV 756, SPV 775, SPV 741, SPV 678, SPV 475, SPV 819, CSV 10 and MSH 65 both in kharif and rabi season.

Four insecticides, namely, dimethoate, methyl demeton, methamidophos and endosulfan at two concentrations were tested against the shoot bug and the results revealed that all the insecticides were equally effective at higher concentrations. However, lower concentration of dimethoate 0.03% gave the highest cost-benefit ratio, even though higher additional yields were obtained with methyl demeton (0.05%) and methamidophos (0.1%).

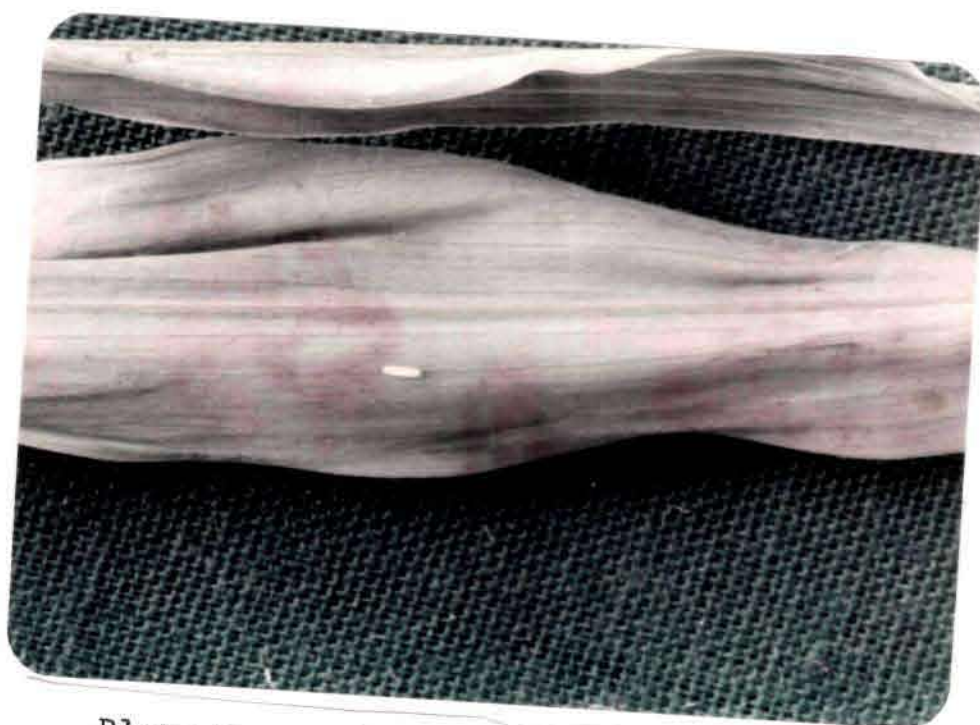


Plate No.1: Egg of shoot fly, A. soccata



Plate No.2: Sorghum symptom plant showing shoot fly damage

INTRODUCTION

CHAPTER I

INTRODUCTION

Sorghum (Sorghum bicolor (L.) Moench) popularly known as jowar, is one of the major staple cereal crops in the semi-arid tropics (SAT). The total world sorghum area is 50.2 million hectares with an annual production of 77.5 million tonnes (FAO, 1986). Over 55 per cent of the world sorghum production is in the SAT. In India, sorghum is the third important cereal after rice and wheat and is currently grown on 15.3 million hectares with an annual production of 10.3 million tonnes. In India, Andhra Pradesh is one of the important sorghum growing states and is currently grown on 1526.10 thousand hectares with an annual production of 1568.50 thousand tonnes.

Grain yields of sorghum on peasant farms are generally low (500 to 800 kg ha⁻¹) and one of the major yield limiting factors is insect pests (Seshu Reddy, 1982), which cause an average loss of about 12.2 per cent in the actual crop produce. Sorghum is vulnerable to over 150 insect species from sowing to the final crop harvest (Seshu Reddy and Davies, 1979).

Sharma (1985) has listed 31 insect species of which a few viz., shoot fly, (Atherigona soccata Rondani), stem borer (Chilo partellus Swinhoe), army

worm (Mythimna separata Walker), midge (Contarinia sorghicola Coquillett), head bug (Calocoris angustatus Lethierry) and shoot bug (Peregrinus maidis Ashmead) can be considered the major pests in India and in Andhra Pradesh. Krishnamurthy Rao et al. (1983) mentioned shoot fly, ear head caterpillar, midge, stem borer and earhead bug inflict an average loss of Rs.55.40 lakhs in Andhra Pradesh alone every year.

Recently the emphasis is being given on ecological basis of control based on suitable integrated pest management strategies. In this context, knowledge of the population dynamics of pests concerned becomes obligatory. Population dynamics strategy helps in planning need based application of insecticides as it clearly reveals the insect's peak activity as well as insect free periods during the crop growth.

Though a lot of work has been carried out on population dynamics of shoot fly, stem borer, midge and head bug detailed studies were not made earlier on population dynamics of shoot bug in particular, and the major pests in general in Telangana region, in relation to weather conditions. Hence, information on seasonal incidence, which were lacking for this particular region, were conducted during the present study.

Among the various sorghum pests, shoot bug causes serious losses to sorghum crop. It was considered once as a minor pest in South India but now it has become a major pest of sorghum. It is also responsible for the transmission of "Freckled yellow virus" of sorghum in India. Further, due to the sucking of sap from leaves, the feeding sites continue to exude the plant sap due to which the growth of plant gets stunted with sickly appearance. Further, they produce honey dew to which many ants are also attracted, consequently sooty mould develops and inhibits the photosynthetic activity of the plants.

Though preliminary reports were available for bionomics of shoot bug (Chelliah and Basheer, 1965) detailed bioecology studies were not carried out. Hence, life table studies have been initiated for the shoot bug on which information was lacking at present.

There is a felt need to assess the magnitude of crop losses caused by sorghum pests. Although losses for major pests of sorghum were reported from time to time, accurate estimates of losses for shoot bug are scanty. Most of the farmers operating under the stress of price cost squeeze in SAT can no longer carry out expensive pest control operations without a full knowledge of the economic benefits likely to be derived therefrom. Complete freedom from insect attack in most

cases for high yields is neither necessary nor appropriate in pest control programmes. To develop rational and economic control measures, the magnitude of loss must be evaluated, so that it can be related to the grain obtained. Only by pest loss appraisal it is possible to determine the economic loss due to different pest intensity levels.

Further, determination of economic thresholds is a complex and complicated procedure. Hence, a serious lacunae exists on this aspect. But at present the researchers are focussing their attention in fixing up the economic thresholds for the key pests of their location to pin point the timing of chemical control measures with the object of minimising the usage of toxic insecticides and thereby avoid their undesirable side effects. Further more, research efforts were intensified to find an effective control method against sorghum pests undertaking short and long term programmes.

Since sorghum is mainly grown by the resource-poor farmers in the SAT, host-plant resistance can offer an economic, efficient and a long term solution to manage the shoot bug either alone or in combination with other methods of control. It is also an essential component in an integrated pest management programme,

well suited to the environmental conditions of the SAT and involves no additional cost to the farmer.

Under the short-term programmes, chemical control was given more emphasis as it was expected to give immediate results. Because sorghum is a poor man's crop, emphasis should be on finding out cheaper and effective insecticides against the shoot bug.

The population increase of shoot bug in recurrent spells, season after season has exposed the gaps in our knowledge on bioecology, losses and pest management measures. Further, the population dynamics studies of major pests is an immediate felt need. Therefore, the possibility of the shoot bug further intensifying its activity in Andhra Pradesh and in SAT must be checked and calls for an all out effort to tackle the problem on scientific lines. Available information on shoot bug is very meagre with so many gaps, and the data found on population dynamics of major pests of sorghum, particularly, shoot bug is scattered and fragmentary and is not comprehensive enough to serve as a useful guide to overcome the pest and keep it within limits. Elaborate field and laboratory studies were undertaken to generate detailed information on major pests of sorghum with special reference to shoot bug, that has assumed importance in SAT with the following objectives.

1. To determine the incidence and peak activity of major pests of sorghum viz., shoot fly, stem borer, shoot bug, midge, head bug and armyworm.
2. To study the influence of abiotic factors which interact with the major pests of sorghum.
3. To study the bionomics of shoot bug along with life fecundity table studies.
4. To assess the avoidable losses in sorghum both in field and cage conditions due to shoot bug.
5. To determine economic injury level for shoot bug.
6. To screen different genotypes for shoot bug resistance and
7. To work out cost benefit ratios of the chemical control of shoot bug.

The results of the investigations presented in this thesis are envisaged to bridge the existing research gaps.

...

REVIEW OF LITERATURE

CHAPTER II

REVIEW OF LITERATURE

The literature pertaining to the major pests of sorghum related to the present investigations has been reviewed and presented below.

2.1 PESTS OF SORGHUM

Seshu Reddy and Davies (1979) reported more than 150 insect species attacking sorghum in India. Sharma (1985) has listed 31 insect species of economic importance of which a few viz., shoot fly, stem borer, armyworm, midge and head bug can be considered the major pests in India. According to Sharma (1985), shoot bug is a minor pest which becomes serious occasionally during dry periods.

2.1.1 The shoot fly, Atherigona soccata Rondani (Diptera : Muscidae)

In recent years, particularly after the introduction of certain hybrid varieties of jowar such as CSH-1 some insect pests like shoot fly have been found to appear in severe form. The genus, Atherigona consists of several species, but the only important pest of sorghum among them is A. soccata.

2.1.1.1 Seasonal activity - Abroad: Ritchie (1926) reported from Tanganyika that the sorghum maggot was

responsible for deadhearts in young sorghum which was noticeably severe on late planted sorghum and was also found to occur as a serious pest of Panicum milliaceum grown as a dry season or short rain crop.

Swaine and Wyatt (1954) from Nairobi mentioned that the shoot fly can be a troublesome pest in late planted sorghums and found in the drier territory.

2.1.1.2 South India: Ponnaiya (1951) in his studies on sorghum resistance to the insect pest, A. indica noted that the sorghum crop was very seriously damaged by this fly at siruguppa, in Mysore when raised as a second season crop under irrigated conditions. He observed that a good crop was obtained from sowings in the month of June as against the October sowings which often failed due to mass attack of this pest.

Ranga Rao et al. (1971) indicated that the limitations imposed by shoot fly on yields could be circumvented by adopting early sowings with the onset of first soaking rains in September using high seed rates and subsequent thinning of infested seedlings. They registered a phenomenal increase in the incidence of deadhearts to the extent of 155.8 per cent over September sown crop in CSH-1 and CSH-3 when compared to October sowings at Mysore.

Thimmiah et al. (1973) in their experiments conducted under Dharwar, Karnataka conditions reported that the incidence of shoot fly is severe (100 per cent) on the crops raised from late June to October.

In Karnataka, the sorghum sown early in September was less damaged, compared to October sown crop (Nadagouda et al., 1974).

According to Davies and Seshu Reddy (1981) the pest incidence is high particularly during post rainy season and very few plants escaped attack at Hyderabad.

2.1.1.3 North India: Jotwani et al. (1970) reported two peaks of shoot fly incidence in Delhi, one in March-April and the second in August-October.

Ram et al. (1976) conducted experiments on effects of planting dates of fodder sorghum on the incidence of shoot fly at Jhansi and found that crops sown before or in the first fortnight of July were protected from shoot fly attack and the yield was also high.

Firke and Kadam (1979) recorded less incidence of shoot fly on crops sown on 20th June (47 per cent) and 5th July (45.94 per cent) in kharif and 26th August (51.47 per cent) in rabi and the pest incidence was

higher on crops sown on subsequent dates in both seasons at Rahuri.

Several experiments conducted during kharif 1974 to 1976 at IARI, New Delhi revealed low incidence of shoot fly upto 19th July and increased thereafter (Samarjit Rai and Jotwani, 1979).

Dhaliwal and Sandhu (1981) studied the effect of the dates of sowing and seedrates on the infestation of fly at Ludhiana and observed that September sown crop recorded maximum number of eggs and minimum being in crops sown in May and June.

Premkishore et al. (1985) studied the response of 31 high yielding varieties and hybrids to A. soccata over a three year period in field studies in Delhi, under heavy infestations of the pest and found that mean percentage deadheart formation (42.5 per cent) was more in late sowings compared with normal sowings (24.8 per cent).

2.1.1.4 Western India: A peak incidence of 80 per cent in the third week of August was recorded by Rao deo et al. (1972) and the pest incidence was seen from June to October at Maharashtra.

In a field experiment trial at Maharashtra during kharif 1977 with five dates of sowing from 28th June to

31st July the per cent deadhearts gradually increased with delayed sowing (Gandhale et al., 1982).

**2.1.2 The sorghum stem borer, Chilo partellus Swinhoe
(Lepidoptera : Pyralidae)**

This pyralid is a key pest of sorghum in the Indian sub-continent and in East Africa. Adults are straw-coloured, which deposit scale like overlapping eggs on underside of leaves and on stems. The larvae are spotted and cream coloured which feed on the leaves and tunnel in the stalk thereby stunting the plants and sometimes killing the main shoot.

2.1.2.1 Seasonal activity - Abroad: Catches of Chilo in light traps and suction traps in a grain sorghum field in the Northern Transvaal, Southern Africa during 1973 to 1975 showed that adults were present throughout the year and there were two flight periods, one in spring and another in late summer (Van Hamburg, 1979).

2.1.2.2 South India: Fletcher and Ghosh (1920) observed absolute resting period extended from December to about March in C. simplex and the largest resting period noticed was from about September to about July or August.

Deshpande et al. (1982) selected ten sorghum stems randomly at weekly intervals to monitor the

presence of larvae and pupae of stem borer at Dharwar (Karnataka) and reported that the average number of diapausing larvae ranged from one in June to 7.4 per ten stems in December and no pupae were observed from October to March and larvae started pupating in April and gradually increased in May and June with the highest per cent of moth emergence in June.

2.1.2.3 North India: Hussaini (1929) reported from Lyallapur (Punjab) that the borer attack was decreased as the season progressed and it had become serious in September. He further observed that the damage in severe cases reaching as high as 73 per cent with a short hibernation in the stubbles during winter.

Sharma (1964) reported that the pest was active from June to November in Rajasthan and early planted crop was severely damaged in summer.

Fortnightly observations made on the infestation and incidence in an untreated Jowar field in North India by Singh (1964) revealed that the attack started as early as July and the percentage of infested plants gradually increased reaching cent per cent during October, after which the pest population decreased with a period of diapause after October.

Balraj Singh et al. (1975) reported from Punjab that the main source of infestation of the new crop was from the larvae hibernating inside the stubbles.

Firke and Kadam (1978) from Rahuri reported that the average number of larvae were greater in rabi than in kharif season but the average number of pupae, tunnels, per cent of stem length tunnelled and per cent of internodes attacked were greater in kharif season.

2.1.2.4 Western India: At Bombay, during December and January, only hibernating caterpillars are met and the adult emergence starts from these over-wintering larvae right from the end of March till early June and oviposition continued up to the end of October (Trehan and Butani, 1949).

2.1.2.5 Central India: Rawat (1967) in his studies on estimation of population of C. zonellus in sorghum stubbles at sehore (Madhya Pradesh) revealed that the pest has hibernation from November to February-March after which it resumes its activity on Charijowar, maize and sugarcane which are grown under irrigation. He concluded that a very large population of the pest tides over winter in stubbles.

2.1.3 The shoot bug, Peregrinus maidis Ashmead
(Homoptera : Delphacidae)

Peregrinus is one of the few delphacids occurring as crop pests in India. Hitherto, shoot bug was noted only as a minor pest but in recent years it is gaining importance since it occurs in large numbers effecting the crop seriously. It becomes serious when cloudy weather persists for longer durations. It is also known to be a vector of Dwarf Maize virus and Yellow streak virus and damages crops both through its normal phloem-feeding activities and through subsequent damage by viral infections.

2.1.3.1 Seasonal activity - South India: Khan and Rao (1956) studied the influence of black ant on the incidence of shoot bug at Hyderabad on six varieties of sorghum and observed highest percentage of attacked plants, that are adjacent to bunds harbouring nests of black ant.

Prabhakar et al. (1981) conducted experiments with CSV-4 sorghum variety at Hyderabad and indicated that the bug occurred largely in the whorls of young seedlings both in rainy season and winter season.

According to Sharma (1985) shoot bug which sucks sap from the whorl leaves and the earhead is a minor

pest which becomes serious during dry periods and particularly on the rabi crop.

2.1.3.2 North India: Agarwal et al. (1981) reported the presence of shoot bug from mid July to the end of December with a population peak in September.

2.1.3.3 Central India: According to Rawat and Saxena (1967), the shoot bug first appeared in July and was observed until March with a population peak in August to October at Sehore. Hot and dry conditions were found unfavourable to the pest.

2.1.4 The sorghum midge, Contarinia sorghicola Coquillett (Diptera : Cecidomyiidae)

The sorghum midge, one of the most important pests attacking grain sorghum has received increasingly much attention in recent years. It is a serious problem in Asia, Africa, Australia, Europe and America.

2.1.4.1 Seasonal incidence : Abroad: Midge emergence was recorded from sorghum, Dekalb BR-64, planted on four dates in Oktibbeha county by Roth and Pitre (1973), who observed 311 midges per head in the July 13th planting followed by 192 in June 23rd planting, 167 in May 19th planting and no midges during April 28th sowing.

Barral et al. (1974) observed active adults throughout the year in the central region of Chaco

(Argentina) with peak numbers in spring and in summer-autumn.

Roth and Pitre (1975) studied the emergence of midge adults from over wintering sites in Mississippi and reported that sorghum bloomed during August and September was damaged extensively, the adults coming from Johnson grass which was in full bloom during April-May.

Virtually all plantings made after 22nd June risk severe infestation and yield reduction in the San Joaquin valley as reported by Summers et al. (1976).

Busoli et al. (1979) recorded more midge larvae in late plantings and in plots flowering in December with highest diapausing individuals in November and March - April at Brazil.

2.1.4.2 South India: Examination of sorghum heads collected at various sites in Karnataka in 1970-72 revealed that the incidence of midge was high from June to October reaching a peak in August or September but decreased thereafter being lowest in January (Gowda and Thontadarya, 1977).

Maximum population was observed during November at Dharwar, May to June at Bhavanisagar and during rainy season at Hyderabad (ICRISAT, 1985).

2.1.4.3 Western India: Taley et al. (1971) noticed maximum incidence of midge during November followed by December and January with maximum number of diapausing maggots during December and January from Nagpur.

Chundurwar et al. (1976) observed the increase in midge population from the first week of October to the end of November reaching a peak in mid October and declined sharply during the first week of December. They opined that sowing of the grain sorghum should not be later than the third week of July in the monsoon season and not earlier than the third week of September for post monsoon season.

Mogal et al. (1980) on examination of aborted ears of the sorghum variety CSH-1 collected at harvest from kharif, rabi and summer crops from fields heavily infested with midge at Dhule in 1977-78, revealed that diapausing maggots were present in the ears from the kharif and rabi crops but not in those from the summer crop.

**2.1.5 The sorghum head bug, Calocoris angustatus
Lethierry (Hemiptera : Miridae)**

Mirid head bugs are one of the most important pests of sorghum in Asia and Africa. Species belonging to the four genera namely Calocoris, Campylomma, Creontiades and Eurystylus are known to attack sorghum.

Of the various mirid species damaging sorghum earheads, Calocoris angustatus Le. is the most important in India.

2.1.5.1 Seasonal activity - South India: Thimmiah et al. (1972) reported maximum bug activity (77 to 78 bugs per head) in sorghum planted on 12th and 19th August at Dharwar (Karnataka) than on June and July sowings.

Balasubramanian et al. (1979) observed more number of bugs in compact earheads than in open type.

Natarajan et al. (1989) studied the seasonal occurrence of earhead bug in main and ratoon crops of two hybrids, CSH-5 and K-Tall by sowing the crop at fortnightly intervals during 1984 at Tamilnadu. According to them severe infestations were recorded in early April, July, February and March first fortnight sowings with cultivar CSH-5 which was always more attacked than K-Tall. Finally they concluded that those crops, either as main or ratoon, which flowered during April, June, September, October and December suffered heavily due to the higher population than crops coming to flowering in January, February, March, May, August and November which had low populations of bug, and as such little bug damage.

2.1.6 The oriental armyworm, Mythimna separata Walker
(Lepidoptera : Noctuidae)

2.1.6.1 Seasonal Incidence - South India: The armyworm incidence at Hyderabad was severe in September and low from October to November and in August (ICRISAT, 1985).

2.1.6.2 North India: Ram Singh et al. (1987) reported that the larval population was at its peak in September and February with sugarcane and Napier grass acting as a link between rainy season and winter cereals at Haryana.

**2.2 INFLUENCE OF ABIOTIC FACTORS ON POPULATION
BUILD UP AND DAMAGE**

2.2.1 The shoot fly

Hussaini and Rao (1967) have observed that the mean minimum daily temperature and the mean relative humidity per day during the first 15 days from sowing are important factors affecting the shoot fly infestation.

Usman (1968) in his studies, recorded zero per cent incidence of deadhearts in crops sown in April-May to 89.6 per cent in late July sown crop. Further, he reported that a mean maximum temperature of 30 to 33°C, with a mean minimum temperature of 21°C and 80 to 90 per cent relative humidity (RH) during the first four weeks

from sowing are most favourable conditions for the activity of the shoot fly.

The shoot fly had a peak period of abundance during July, August and September and continued till mid October with little fluctuations and its activity is mainly affected by extreme temperatures and continuous or heavy rains as observed by Shivpuje et al. (1976).

According to Doharey et al. (1977), who studied the development of shoot fly under different combinations of temperature and relative humidity, a temperature of 25 to 30°C and a relative humidity between 60 and 90% were best for development in the laboratory. Further, they concluded that a temperature of 30°C and 90% RH is very ideal for its emergence.

Murthy et al. (1977) reported that the shoot fly was found to breed practically throughout the year at Rahuri, though its incidence varied considerably in different seasons with a low incidence during November and December, when the temperature and relative humidity were 21 to 29°C and 40 to 50 per cent, respectively.

The infestation of shoot fly increased from July 15th sowing and continued to increase until February 1st sowing and declined thereafter (Venugopal and Mani, 1978). Further, it was also found that increase of RH by one per cent resulted in an increase of 3.78 per cent

in infestation while a rise of 1°C in maximum temperature decreased the damage by 3.65 per cent.

Ogwaro (1979) conducted experiments on adult fly emergence fluctuations in Kenya and he found that immediately after peaks in rainfall there was peak emergence of adults as determined by sweeping and he concluded that shoot fly survives the dry season mainly in the pupal stage and rapid build up in density is due both to immediate adult emergence from pupae after rain starts and oviposition on the new crop.

Dubey and Yadav (1980) studied the effect of temperature and humidity and inferred that the maximum temperatures (30 to 34°C) are conducive to egg-laying and larval activities causing severe attack while higher relative humidity (86 to 88 per cent) is conducive to reduction in the intensity of attack.

Abdin (1981) recorded highest incidence of shoot fly in August which coincided with peak of the rainy season and lower temperatures and the number of insects in the field showed a remarkable decrease as rains ceased. The same observation was also recorded by Adesiyun (1981) in Samaru (Nigeria).

Delobel (1983) studied the temperature - time and temperature - velocity equations in Kenya and reported that pre-imaginal development on sorghum CSH-1

seedlings lasted 19.5, 26.3, 33.8 and 76.8 days at 30, 25, 20 and 15°C, respectively. Further, he reported that shoot fly had optimal development and survival at 30°C with the lower threshold temperatures being 13.8, 10.2 and 11.8°C for the egg, larva and pupa, respectively. He concluded that condition of food plant affects the larval development and survival, indicating that lower mortality and higher pupal weight was achieved in insects reared on fertilised and normally watered seedlings than on unfertilised and water stressed seedlings.

Chundurwar et al. (1984) recorded positive and significant correlation between shoot fly incidence and average temperature and relative humidity. According to them the incidence increased by 5.2 units with an increase in temperature by 1°C over an average temperature of 24.9°C and by 1.6 units for each unit increase in the relative humidity above the average RH of 63.6 per cent.

The effect of rainfall on survival of shoot fly was studied in Nairobi, Kenya during 1981 rainy season by Delobel and Lubega (1984) who by multiple regression analysis showed that rain fall and in particular, heavy rains occurring at the beginning of the rainy season, caused substantial mortality among adults of the pest,

with no adverse affect on survival of egg, which were protected on the underside of leaves.

Naitam and Sukhani (1985) studied the ovipositional behaviour of shoot fly under different soil, plant growth and weather conditions and showed that oviposition was significantly and negatively correlated with soil moisture followed by atmospheric temperature and RH and concluded that the soil moisture, which plays a significant role affects seedling growth resulting in differential oviposition during different seasons.

Mote and Kadam (1986) conducted experiments on shoot fly during 1982 - 1983 using traps baited with fish meal and reported that deadheart formation and the adult population were significantly correlated. According to them conditions of 25 to 27°C and 68 to 75% RH favoured the build up of population.

Gahukar (1987) used water traps baited with fish meal for assessing abundance and species of shoot fly from five regions in Senegal during 1978 and 1979. He collected 23 species of Atherigona with greatest abundance in August - September with positive correlation between rainfall, temperature and RH which interacted. The sorghum planted just after the first rains passes the growth stage susceptibility because the

first rain showers enhance fly ability to increase in abundance during the first month or so after the first showers and he concluded that temperature and RH are the critical factors in the survival of shoot fly eggs.

2.2.2 The stem borer

Population density studies were carried at Maharashtra by Chundurwar (1978) revealed that an average of 12.6% stubbles exhibited hibernation of Chilo larvae in January as against 11.07% by February. He opined that high temperature and low RH might induce pupation of hibernating larvae and subsequent emergence of moths to commence normal life.

Taley and Thakare (1980) studied the population dynamics in carry over of C. partellus under laboratory conditions in Nagpur and indicated that moth emergence started from March to August and peaked in July when the maximum temperature, minimum temperature and RH ranged from 30.7 to 38.7°C, 23.6 to 25.9°C and 70 to 90%, respectively.

Bernays et al. (1983) studied the behaviour of newly hatched larvae associated with their establishment in the host-plant, sorghum and opined that the success of reaching the whorl by larvae will depend on high winds, rain and by some physical features of the plants.

The hibernation preference of the pyralid in sorghum, maize and pearl millet and the influence of environmental factors on moth emergence was investigated in field studies in Madhya Pradesh during 1981 - 82 by Singh et al. (1985). They found that the larvae hibernated in the stems and stubbles of all three crops, sorghum being the preferred host. According to them, the adult emergence started in the last week of February and continued until the end of April with a peak at the end of March following rainfall in the third week of March and finally they concluded that adult emergence is dependent on rainfall.

Mahadevan and Chelliah (1986) studied the influence of season and weather factors on the occurrence of stem borer and the results indicated that the attack varied significantly on sorghum sown in different fortnights ranging from 4.7 to 24% at 30 days after sowing and from 9.5 to 37.4% at 45 days after sowing. In terms of damaged plants, damage rating, percentage deadhearts and per cent stem tunnelling, crops sown in the first fortnight of March were mostly affected followed by crops sown in the second fortnight of February with the lowest damage in crops sown in the second fortnight of June or of October. Every 1°C reduction in temperature appeared to be associated with 1.69% reduction in damage at 30 DAS as observed by them,

who concluded that fertility and fecundity were higher in summer than in winter.

The effect of sowing date on the incidence of stem borer was studied by Mote (1986), who observed that highest percentage of stem tunnelling occurred in the crops sown on 1st June, while the lowest was observed in the crops sown on 15th August. The incidence was greatest in crops sown between 1st April and 1st June and then declined while the larvae tended to enter diapause in January - March when the temperature was low and pupated in April - May.

2.2.3 The armyworm

The influence of climatic factors on outbreaks of this polyphagous pest on sorghum, Bajra and rice was examined by Moray et al. (1983) in Maharashtra and the results indicated, that heavy rainfall during the first two weeks of August (coinciding with the vegetative phases of the crops) followed by prolonged break monsoon conditions favoured out breaks.

2.2.4 The sorghum midge

Hardas et al. (1972) observed the incidence of midge on three hybrids viz., CSH-1, CSH-2 and PSH-2 and reported that the first midge infestation appeared in August with the rise in RH (70 to 80 per cent) and

population seemed to buildup from third week of September reaching the peak in first week of October and subsequently with the fall in RH and temperature, it declined sharply in the first week of December.

Akola (1973) reported the incidence of midge in August with a range of temperatures from 25 to 27°C and RH from 75 to 80% and population gradually increased during September and October with the increase in humidity. Further, he concluded, that if humidity continued to be higher, the winter crop might have high incidence.

Lara et al. (1975) found the occurrence of diapausing midge larvae from February to July with no relationship between climatic factors and the number of larvae in diapause.

Jotwani et al. (1976) conducted experiments on effect of date of sowing on the incidence and damage by midge at IARI, New Delhi and reported that the most favourable conditions for infestations were a mean temperature of 25 to 30°C and a RH of more than 60 per cent and sudden fluctuations in the populations were found to result from continuous drought or heavy rainfall during the peak of midge incidence.

Garg and Taley (1978) reported the trends in population fluctuation of midge at Nagpur where they have recorded an average of 3.1 flies ear⁻¹ between 27th September and 2nd October, increased steadily to reach a maximum of 54.8 flies ear⁻¹ between 28th November and 2nd December and gradually declined thereafter falling to 2.7 flies ear⁻¹ from 17th to 20th February who attributed the population decline to parasites and not by climatic factors.

Moisture is the most important climatic factor in terminating diapause in midge larvae as reported by Thontadarya et al. (1979).

Fisher and Teetes (1982) conducted laboratory and field experiments in Texas (USA) and proved that higher RH (90 per cent) was conducive for emergence of adults and increased adult emergence occurred during periods of high RH before and after heavy rainfall under field conditions.

According to Baxendale and Teetes (1983) differences in emergence times and distribution among years was a function of soil temperature and rainfall and no midge terminated diapause and emerged as adult in the same season that diapause was initiated in Texas during 1979 to 1981.

Chundurwar et al. (1984) studied the relationship between the average temperature and midge density and RH and midge density and found positive and significant relationship. The incidence increased by 6.2 per cent over the average incidence 9.56 per cent with an increase in temperature by 1°C over the average temperature (24.7°C) and density increased by 1.7 per cent over the average incidence 9.56 with an increase of one per cent in RH over an average of 56.4 per cent.

Kulkarni (1985) reported lowest midge incidence on 1st June sown crop and highest on 15th August sown crop which coincided with a minimum temperature of 18.5°C , maximum of 27.7°C and a RH of 76 per cent.

Mote and Ghule (1986) noticed midge attack on 1st May sown Crop and peaked during September 25th to October 1st bloomed crop with mean temperature of 27°C and 65% RH and they observed positive and highly significant correlation between increase in temperature, RH and rainfall and midge population and damage.

2.2.5 The sorghum head bug

Balasubramanian and Balasubramanian (1979) studied the effect of weather factors at Bhavanisagar and Coimbatore in Tamilnadu and reported that the population build up was not influenced by the temperature, sunshine hours, RH and rainfall. Further,

they concluded that the bugs were more abundant in the summer season than in kharif due to less amount of rainfall and less number of rainy days in summer.

Seasonal incidence of the sorghum earhead bug was studied by sowing the crop once in 10 days, throughout the year by Hiremath and Thontadarya (1984) at Dharwad. According to their studies, the bug was found throughout the year except for a few weeks during March, April and May. The computed seasonal indices were higher during August (230), September (222), October (224) and January (214) and the correlation studies between the bug population at the milky stage, which is the most preferred stage, and maximum temperature indicated negative and significant relationship and positive and significant relationship with relative humidity.

2.3 BIOECOLOGY OF SHOOT BUG

Otanés and Kargavilla (1940) reported that egg laying was in groups in longitudinal slits on the upper surface of the leaves, near the stalks and the nymphal period lasted for 16 days.

Ayyar (1950) reported that the bug was greyish brown and found in colonies inside tender shoots.

Khan and Rao (1956) observed 31 to 181 eggs per leaf, with the nymphs and adults attacking leaves, leaf whorls and leaf sheaths.

Chelliah and Basheer (1965) studied the life history in detail and observed the total life cycle to be 18 to 31 days with an average of 24.45 days. The biometric studies showed that the size increased from 1.00 mm x 0.277 mm in the first instar to 3.804 mm x 1.468 mm in the adult. The conducive period for the multiplication of bug was from September to January.

According to Rawat and Saxena (1967) both macropterous and brachypterous forms were found among adults of both sexes. The observations by the workers revealed that the lifespan from egg to death of adults being 14 to 53 days in macropterous males and 19 to 71 days in macropterous females: the corresponding figures for brachypterous males and females were 17 to 41 and 22 to 62 days, respectively. The number of eggs laid per female were 18 to 98 and 5 to 64, respectively of the two forms.

Namba and Higa (1971) carried out tests in Hawaii on the suitability of different species as food plants for P. maidis and proved that sorghum is the most favourable food-plant after maize in that region.

2.4 ASSESSMENT OF CROP LOSSES

Plant pests have been extensively studied because they damage cultivated crops. It is strange, but a fact, that even today there are few reliable estimates of losses caused by the pests.

Khan and Rao (1956) observed that when the flag leaf was infested, it adhered to the ear and interfered with grain development. Further, they reported that bugs attacked the roots and stilt roots causing severe clipping and the plants lodged readily and dried up causing whole loss of plant.

Chelliah and Basheer (1965) studied the extent of damage and reported that large number of nymphs and adults cause unhealthy yellow appearance, combined with stunted growth and in severe cases, top leaves started drying first and some times resulted in the complete death of the plant, besides the bug also known to secrete honey dew which favoured Capnodium fungal growth causing sooty mold, thus affecting the plant with reduced yield.

Rawat and Saxena (1967) observed infested plants to present sickly appearance with stunted growth, yellowish leaves and underdeveloped ears or cobs.

Agarwal et al. (1981) reported the damage to be two fold, one being failure of emergence of the earhead due to death of top leaves and secondary damage results from sooty mold besides acting as a vector of the freckled yellow virus.

Expect for these few reports not much information has been accumulated on crop loss due to shoot bug on sorghum.

2.5 MANAGEMENT OF SHOOT BUG

2.5.1 Varietal resistance

Khan and Rao (1956) studied the incidence on six varieties of sorghum during 1953 - 54 at Hyderabad and observed that PJ - 7 R was severely infested (upto 65.7%) followed by M 35-1 (49.5%), Ellis sorgho (33.7%), PJ - 4 R (30.2%), dwarf Hagari (14.9%) and Kafir Suma (11.0%).

127 varieties or hybrids of sorghum were screened by Agarwal et al. (1981) and came out with five varieties, I 753, H - 109, G I B, 3677 B and B P 53, which remained completely free from infestation and 14 others had low infestation rates, the remaining varieties hosting more numbers. They concluded that resistant varieties were found to have leaves that were very tightly wrapped round the stem and afforded no

space for the bug to shelter, while susceptible varieties had more loosely attached leaves.

2.5.2 Chemical Control

Sarup et al. (1960) tested several insecticides in the laboratory and observed Sevin, malathion, parathion, gamma BHC, endrin, chlordane, isodrin, DDT and aldrin to be effective against the shoot bug.

Rathore et al. (1970) tested eight chemicals for control of shoot bug and reported that endosulfan 0.03 per cent and malathion 0.05 per cent had better knock down effect, while phosphomidon 0.025 per cent and endrin 0.025 per cent were effective upto two weeks.

Jabhar Khan (1984) tried indigenous plant extracts in laboratory trials with the oil extracted from seeds of Eruca sativa (Taramira oil) and from leaves and shoots of Artemisia kurramensis (Artemisia oil) and reported that their insecticidal effects are slightly less than those of DDT and lindane. Their effects were considerably improved when the oils were mixed with DDT and Lindane for which they were good solvents.

The insecticides, 0.02 per cent demeton-S-methyl, 0.02 per cent monocrotophos, 0.03 per cent dimethoate and 0.02 per cent formothion are most

efficient treatments for controlling shoot bug and in increasing the grain yield over control than other insecticides like 0.02 per cent endosulfan, 0.03 per cent quinalphos and other dust treatments as reported by Gandhale et al. (1986).

MATERIALS AND METHODS

CHAPTER III

MATERIALS AND METHODS

Studies on the incidence and peak activity of major pests of sorghum, influence of abiotic factors on the population build up of major pests of sorghum, bioecology of sorghum shoot bug, crop loss assessment due to bug and management of shoot bug were conducted during the years 1988 to 1989 on the Bayer Agricultural Research Institute, and Trial Farm at Medchal (Medak district), near Hyderabad, Andhra Pradesh, India. The field experiments were conducted on Alfisol. Materials used and the techniques employed during the course of investigations for conducting each experiment are presented below.

The research farm is situated at 17-19°N latitude and 78-23°E longitude and at an elevation of 542.3 meters above mean sea level.

3.1 SEASONAL INCIDENCE OF MAJOR PESTS OF SORGHUM

Two susceptible sorghum cultivars, CSH 1, a hybrid, and a variety, ICSV 1 were sown at monthly intervals commencing from 28th April 1988 and continued up to 25th March, 1989. The experiment was conducted in a split plot design with a plot size of 5 x 4 m, replicated twice with a spacing of 45 x 15 cm. The main treatments consisted of two genotypes (CSH 1 and ICSV 1)

sub treatments being four protection treatments viz., (i) Carbofuran 3G Soil application at the time of sowing (ii) Carbofuran 3G whorl application at 30 days after germination (iii) Endosulfan 35 EC spray at flowering stage and (iv) Endosulfan 35 EC spray at milky stage to control shoot fly, stem borer, midge and Head bugs, respectively. Normal agronomic practices were followed except plant protection methods for raising the crop.

Shoot fly egg counts were taken at 14 days after emergence (DAE) and deadheart count was taken at 21 DAE. In the subtreatment (T_1) carbofuran 3G was applied at the rate of 1.5 g per metre row at the time of sowing to control the shoot fly and shoot fly observations were compared with other subtreatments statistically. Egg counts were expressed in actual count. The deadheart count was expressed in percentage over the total plants observed. For recording eggs and deadhearts, 100 plants were selected at random from five spots in a plot leaving two rows on either side.

The stem borer infestation was assessed at 35 DAE besides observing leaf feeding damage at four weeks after emergence (WAE). The percentage of deadhearts was based on the number of plants showing deadhearts on 35 DAE. Finally stem borer counts were taken from 100 randomly selected plants in five spots during boot leaf stage and at harvest.

The number of midge flies at 50 per cent flowering was recorded from 10 randomly selected earheads during the morning hours when they are very active between 8 AM to 10 AM. The larval and midge population infesting the earheads was estimated by selecting 500 spikelets at random (50 from each of the ten earheads per plot from top, middle and lower one third portion of earhead) and squeezing them in between fingers, 15 days after panicle emergence to know the midge damage.

The population of earhead bug was recorded from 10 earheads at the milky stage. The panicle was covered with a polythene bag and closed at the peduncle region. The plant was slightly bent and panicle tapped four or five times. The insects fallen in the bag were counted after anaesthisizing them with chloroform.

The shoot bug counts were taken at 30 DAE on 10 randomly selected plants in a plot and the army worm larval counts were taken at 50 DAE from 100 randomly selected plants in a plot.

3.1.1 Statistical analysis

The statistical tools employed during the present investigations are as follows:

3.1.1.1 Simple correlations: The correlation coefficient is the coefficient measuring the closeness

of relation between two variables (x and y). It was calculated by using the formula

$$r = \frac{\frac{\sum x_i y_i}{n} - \left(\frac{\sum x_i}{n} \right) \left(\frac{\sum y_i}{n} \right)}{\sqrt{\left\{ \sum x_i^2 - \frac{(\sum x_i)^2}{n} \right\} \left\{ \sum y_i^2 - \frac{(\sum y_i)^2}{n} \right\}}}$$

3.1.1.2 Multiple linear regression: The study of simultaneous variation of two or more characters when a relationship exists is the study of multiple regression. The coefficients a , b_1 , b_2 are estimated by a set of equations as given by Nageswara Rao (1983).

3.1.1.3 Path coefficient analysis: In order to have a clear understanding of the abiotic factors which have directly or indirectly contributed to incidence of the pest either individually or in concert path-coefficient analysis, using the dependent and independent variables has been worked out. Moreover, simple correlations does not take into consideration the complex relationship among various factors, which are related to dependent variables. In such situations path coefficient analysis provides an effective means of finding out direct and indirect effects of such associations.

The influence of weather elements on the shoot fly, stem borer, midge, head bugs and shoot bug incidence was analysed statistically by simple

different months (i.e., there will be two main treatments (CSH 1 and ICSV 1) and twelve subtreatments (different monthly sowings) with six replications by excluding the particular protection subtreatment..

3.2 BIOECOLOGY OF SHOOT BUG

P. maidis was multiplied in the laboratory throughout the bionomics studies on caged sorghum, ICSV 1 plants from the adults collected from the field. The biology was studied for two generations during 1988 to 1989 in the months of September to January.

Five pairs were introduced into five separate caged plants and then the end was covered with the muslin cloth. The observations were recorded every day both for oviposition and hatching. For the study of the nymphal development and the adult longevity, a small petridish with a maximum diameter of one and half inch was used which enclosed the nymph and the dish was fastened to the lamina of the leaf with a small cardboard strip kept on the ventral side of the lamina to give stability.

Number of eggs laid every day till the death of female bugs, number of days covered by each nymphal instar and longevity of adults were studied. The length and width of each instar and adults was measured by using ocular and millimetre scale.

The males are allowed to mate for 4 hours, 8 hours, 16 hours, 24 hours, 48 hours and 72 hours with the female and its effect on fecundity was studied along with sex ratio and fertility of eggs.

In another experiment different proportions of male and females (1 : 1, 1 : 1.5, 1 : 2, 1.5 : 1, and 2 : 1) were released and the above said parameters was studied.

The average temperature and relative humidity that prevailed during the investigation was also recorded.

3.3 LIFE FECUNDITY TABLES

Freshly emerged bugs from the pure culture were paired and kept in cages. The first day oviposited eggs were kept individually in the cages for studying the development. Soon after hatching, the bugs were supplied with fresh tender leaves by enclosing them in one and half inch petridish cage. The position of the cage was changed daily in the morning till the nymphs became adults. The adults emerged on a particular day, after sexing, were paired and kept for egg laying in separate cages. Observations were made daily in the morning on hatching, nymphal development, successful adult emergence, fecundity and death of the female. As the sex ratio was approximately 1 : 1 the number of eggs

laid by the individual female were divided by two to get the number of female births (mx). The egg counts were made according to a technique suggested by Chattarjee and Ram (1970). The life tables were prepared according to the method of Birch (1948), as elaborated by Howe (1953) and Atwal and Bains (1974). The innate capacity for increase (rc) was worked out from the data on life tables. The intrinsic rate of increase (rm), net reproductive rate (Ro) and mean generation time (T) were the basic population parameters used to assess the population growth in the laboratory. The true values of 'rm' was calculated from three trial values arbitrarily selected on either side of it differing in second decimal place by interpolation with the formula,

$$rm = e^{7--rmx} \quad lx.mx = 1097 \quad \text{where } e = 2.71828$$

Stable-age-distribution (percentage distribution of various age groups) was worked out by calculating the population schedule of birth rate and death rate (mx and lx), when grown in a limited space. All the tests were performed under laboratory conditions on caged plants and the mean temperature and relative humidity were recorded.

The growth Index is calculated by using the formula,

$$\text{Growth Index} = \frac{\text{Per cent of nymphs becoming adults}}{\text{Average developmental period (days)}}$$

3.4 ESTIMATION OF CROP LOSS DUE TO THE SORGHUM SHOOT BUG UNDER FIELD CONDITIONS

The crop loss under field conditions was estimated by protecting the crop at different stages of crop growth.

A field trial was laid out in a randomised block design, replicated thrice, with seven treatments including control. The net plot size was 32.4 sq.m. The different treatments are as follows :

- T₁ : spraying demeton-S-methyl at 30 DAE
- T₂ : spraying demeton-S-methyl at 45 DAE
- T₃ : spraying demeton-S-methyl at 60 DAE
- T₄ : spraying demeton-S-methyl at 30 and 45 DAE
- T₅ : spraying demeton-S-methyl at 45 and 60 DAE
- T₆ : complete protection (i.e. spraying at 30, 45 and 60 DAE)
- T₇ : Untreated control.

The variety chosen was ICSV 1 which was grown according to standard package of practices during late kharrif, 1988-89 and early rabi, 1988-89 and the studies were conducted for two seasons.

Widely recommended and effective insecticide, methyl demeton 25 EC at 0.03 per cent concentration with 600 litres of spray fluid per hectare was used as per the treatment.

To estimate the crop losses due to the pest ten plants were selected at random from the middle rows leaving the peripheral rows and labelled for all subsequent observations.

As the incidence of the pest started, three counts were taken at fortnightly intervals starting from 30 DAE. Average of the three observations were taken for assessing the bug incidence. At maturity the tagged plants were harvested separately from each plot in each treatment and the yield was computed per hectare.

The avoidable or per cent loss in yield was calculated by comparing the yields of completely protected treatment with those exposed to pest damage during crop growth using the formula,

$$\text{Avoidable loss (per cent)} = \frac{\text{Mean yield of protected plot} - \text{Mean yield of unprotected plot}}{\text{Mean yield of protected crop}} \times 100$$

3.4.1 Economics of treatments

The economics of insecticidal spray was worked out by taking the cost of the chemical required to spray

the crop of one hectare and the operational charges and the yield obtained over control and its value, the cost-benefit ratio of additional value obtained and profit over control.

3.5 ESTIMATION OF CROP LOSS UNDER GREENHOUSE CONDITIONS

Assessment of sorghum crop loss in yield reduction due to artificial infestation of the shoot bug was made by raising the plants in pots in the glass house. The experiment consisted of seven treatments which were replicated thrice and are as follows.

- T₁ : Infestation by releasing 15 nymphs per plant
- T₂ : Infestation by releasing 20 nymphs per plant
- T₃ : Infestation by releasing 25 nymphs per plant
- T₄ : Infestation by releasing 30 nymphs per plant
- T₅ : Infestation by releasing 35 nymphs per plant
- T₆ : Infestation by releasing 40 nymphs per plant
- T₇ : No infestation (control)

Recommended dose of fertilizer was applied to the pots before sowing. When the plants were 30 days old 1st instar nymphs were released on all potted plants as per the treatment and allowed to feed till harvest. Plants were harvested individually, threshed and yield of seed per plant was recorded.

3.6 ECONOMIC INJURY LEVEL (EIL)

Based on the level of infestation, yield per plant, cost of insecticide used and the average market price of sorghum grain and fodder per quintal, the EIL was computed by utilising the procedure of Stone and Pedigo (1972) and modified by Ogunlana and Pedigo (1974).

The EIL was computed by the following formula

$$\text{EIL} = \frac{\text{Gain threshold}}{\text{Yield reduction per bug}}$$

$$\text{where Gain threshold} = \frac{\text{Cost of pest control (Rs/ha)}}{\text{Market price of grain plus fodder (Rs./q)}}$$

In calculating the cost of pest control, the chemical cost and application cost including labour were considered.

3.7 VARIETAL SCREENING

Thirty eight genotypes were selected to study their relative susceptibility to shoot bug. The genotypes were collected from National Research Centre for Sorghum (NRCS), Rajendranagar, Hyderabad except for one variety, ICSV 1 which was obtained from ICRISAT, Patancheru. Each genotype was sown in a single row of

6 m with a spacing of 15 cm between plants & replicated thrice.

The screening was done for two seasons during 1988 and 1989 in late kharif and early rabi seasons. Commencing from 30th day after emergence, average bug population per ten plants was recorded at 10 day interval and the mean number for the total crop period was noted.

3.7.1 Grouping of varieties

The mean ($\bar{X}$) and standard deviation (S.D.) of average population count was computed. A preliminary classification of the genotypes was done considering the mean population count as follows.

1. Promising genotypes with bug population less than $\bar{X} - S.D.$
2. Susceptible genotypes with bug population between $\bar{X} - S.D.$ and $\bar{X} + S.D.$
3. Highly susceptible genotypes with bug population more than $\bar{X} + S.D.$

3.8 CHEMICAL CONTROL

An experiment was laid out in a randomised block design at Bayer Agricultural Research Institute and Trial farm during the kharif 1988 and rabi, 1988-89, to

test the efficacy of different insecticides for the control of shoot bug. ICSV 1 variety of sorghum was used for the studies. Normal package of practices were followed for raising the crop except the plant protection measures. There were nine treatments which were replicated thrice and each plot size was 32.4 sq.m. The treatments and the concentration used are as follows.

S.NO.	Treatment	Formulation	Concentration used
1.	Dimethoate	30 EC	0.03 per cent
2.	Dimethoate	30 EC	0.05 per cent
3.	Demeton-S-methyl	25 EC	0.03 per cent
4.	Demeton-S-methyl	25 EC	0.05 per cent
5.	Endosulfan	35 EC	0.05 per cent
6.	Endosulfan	35 EC	0.07 per cent
7.	Methamidophos	60 SC	0.05 per cent
8.	Methamidophos	60 SC	0.10 per cent
9.	Control	-	Untreated

The initial count of shoot bug was taken on ten randomly selected plants in each plot before application of insecticides. A total of three sprays were given at 30, 45 and 60 days after emergence. Observations were made after 24 hours, 48 hours and 7 days on ten plants selected and tagged in each plot after the chemical application.

The per cent reduction in population was calculated with the modified Abbott's formula as given by Fleming and Arthur (1985) giving due weightage to the untreated check (control) also.

$$\text{Per cent population reduction} = \left[1 - \frac{\left[\frac{\text{Post treatment population in treatment}}{\text{Pretreatment population in treatment}} \times \frac{\text{pretreatment population in check}}{\text{Post treatment population in check}} \right]}{\left[\frac{\text{Post treatment population in treatment}}{\text{Pretreatment population in treatment}} \right]} \right] \times 100$$

The per cent reduction after calculating with the above formula was transformed to angular values and analysed statistically. When the crop matured, the tagged plants were harvested, threshed and the yield of grain and fodder were recorded.

The economics of treatments was calculated by the method as described earlier under crop loss estimation.

...

ANGRAU
Central Library
Hyderabad



003251

RESULTS

CHAPTER IV

RESULTS

Investigations have been carried out with a view to find out 1. Seasonal incidence of major pests of sorghum 2. Influence of abiotic factors on population build up 3. Bionomics of shoot bug 4. Crop loss assessment due to shoot bug 5. Varietal screening and 6. Cost-benefit ratio of chemical control of shoot bug. The results of the investigations carried out are presented in this chapter.

4.1 SEASONAL INCIDENCE

The data on seasonal incidence of major pests of sorghum was recorded from staggered sowings of sorghum at monthly intervals. The incidence of major pests was recorded as described in materials and methods in the plots with different sowing dates.

4.1.1 The shoot fly

Seasonal activity of shoot fly was studied on sorghum planted at monthly intervals by recording oviposition (number of eggs laid) (Plate 1) and damage symptoms (number of deadhearts) (Plate 2) at 14 and 21 days after emergence (DAE), respectively.

4.1.1.1 Oviposition: Shoot fly oviposition was very low (ranged between 0.0 to 33.37 eggs/100 plants), on

sorghum planted between January and June (Table 1). No oviposition was recorded in April planted crop. Maximum egg laying was observed on July planted crop (110 eggs/100 plants), followed by August, October, November, September and December plantings which were at par.

Oviposition was similar on both the genotypes (CSH 1 and ICSV 1) during all the plantings and the difference between the genotypes was non-significant (Table 1). Both genotypes received maximum eggs during July planted crop and no eggs in April planted crop.

Shoot fly oviposition on sorghum crop receiving four different treatments (Table 2) was non-significant on crop planted during April to October and December. However, significant differences were observed on November and January to March planted crop. In the planting where significant differences were observed, higher number of eggs were laid on crop receiving carbofuran at sowing time (T_1), while the other three treatments (T_2 , T_3 and T_4) were at par with each other.

When the analysis was carried out by excluding the carbofuran soil application (T_1) treatment, all the other treatments were at par for shoot fly oviposition during all the plantings, indicating that these treatments had no effect on shoot fly oviposition. Similar to the data presented in Table 1, here also very

Table 1: Shoot fly Oviposition and damage on Sorghum planted during different months

Planting month	Number of eggs per 100 plants at 14 days after emergence			Percent of dead hearts at 21 DAE		
	CSH1	ICSV1	Mean	CSH1	ICSV1	Mean
April	0.00 (0.71)	0.00 (0.71)	0.00 (0.71)	0.00 (0.71)	0.00 (0.71)	0.00 (0.71)
May	3.22 (1.93)	4.20 (2.17)	3.70 (2.05)	2.18 (1.64)	3.42 (1.98)	2.77 (1.81)
June	6.68 (2.68)	6.15 (2.58)	6.41 (2.63)	6.15 (2.58)	14.47 (3.87)	9.86 (3.22)
July	110.80 (10.55)	110.17 (10.52)	110.59 (10.54)	98.30 (9.94)	95.54 (19.80)	96.91 (9.87)
August	78.71 (8.90)	80.14 (8.98)	79.42 (8.94)	89.56 (9.49)	87.67 (9.39)	88.61 (9.44)
September	74.32 (8.65)	73.46 (8.60)	73.97 (8.61)	82.31 (9.10)	87.10 (9.36)	84.69 (19.23)
October	77.99 (8.86)	77.64 (8.84)	77.82 (8.85)	93.39 (9.69)	96.52 (9.85)	94.95 (9.77)
November	75.01 (8.69)	77.99 (8.86)	76.41 (8.77)	97.31 (9.89)	97.11 (9.88)	97.11 (9.88)
December	73.11 (8.58)	74.49 (8.66)	73.80 (8.62)	96.52 (9.85)	76.94 (8.80)	86.54 (9.33)
January	10.32 (3.29)	10.19 (3.27)	10.25 (3.28)	11.26 (3.43)	13.56 (3.75)	12.38 (3.59)
February	32.21 (5.72)	34.54 (5.92)	33.37 (5.82)	27.80 (5.32)	28.55 (5.39)	28.12 (5.35)
March	13.48 (3.74)	14.24 (3.84)	13.86 (3.79)	14.09 (3.82)	8.20 (2.95)	10.99 (3.39)
Mean	35.74 (6.02)	36.46 (6.08)	36.10 (6.05)	39.06 (6.29)	39.56 (6.33)	39.31 (6.31)
C.D (month) (P. 0.05)			0.25			0.76
C.D (main treatment)			NS			NS

Figures in parentheses are $\sqrt{x+0.5}$ transformation

Table 2: Shootfly Oviposition in various treatments at 14 DAE on Sorghum planted during different months

Treatment	Number of eggs/100 plants on crop planted during											
	April	May	June	July	August	September	October	November	December	January	February	March
CSH 1	T1 0	2.50	7.50	109.50	81.70	78.67	80.00	84.33	73.67	11.00	35.00	18.50
	T2 0	4.50	6.50	113.00	76.70	76.33	78.66	74.00	73.00	10.00	30.50	14.50
	T3 0	2.50	7.00	108.50	83.30	73.67	77.33	72.00	74.33	11.50	34.50	11.50
	T4 0	3.00	7.00	111.50	77.00	73.66	78.33	80.00	73.00	10.00	32.00	15.00
Mean (All treatments)	-	3.13	7.00	110.63	79.70	75.58	78.58	77.58	73.50	10.63	33.00	14.87
Mean (Excluding T1)	-	3.33	6.83	111.00	79.00	74.55	78.10	75.33	73.44	10.50	32.33	13.66
ICSV 1	T1 0	6.00	4.00	111.50	74.00	73.67	78.00	85.67	71.33	12.00	44.50	20.00
	T2 0	4.00	5.00	109.50	87.70	74.00	79.00	81.00	75.00	10.50	33.00	13.50
	T3 0	5.00	9.00	110.00	77.00	73.66	83.33	76.66	74.66	10.00	34.00	14.00
	T4 0	4.00	6.00	111.50	76.70	73.00	79.66	76.67	75.00	10.50	37.00	16.00
Mean (All treatments)	-	4.75	6.00	110.63	78.80	73.58	80.00	80.00	74.00	10.75	37.12	15.82
Mean (Excluding T1)	-	4.33	6.66	110.33	80.46	73.55	80.66	78.11	74.88	10.33	34.66	14.50
C.D. (All subtreatments) (P = 0.05)	NS	NS	NS	NS	NS	NS	NS	6.79	NS	0.82	5.11	4.10
C.D. (Excluding T1)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
C.D. (Main treatments)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

T1 : Carbofuran 3G soil application at sowing time for shootfly control
T2 : Carbofuran 3G whorl application at 30 DAE for stem borer control
T3 : Endosulfan 35 EC spray at flowering stage for midge control.
T4 : Endosulfan 35 EC spray at milky stage for headbug control.

APAU Central Library
Acc. No: D3251
Date: 22-2-90

few eggs were laid in all the treatments (T_2 , T_3 and T_4) when the crop was planted between January to June and the maximum egg laying was recorded on July planted crop.

4.1.1.2 Damage: The extent of shoot fly damage (per cent of deadhearts) was similar to the intensity of oviposition (number of eggs laid). The percentage deadhearts were low (ranged between 0.0 to 28.12) on sorghum planted between January and June (Table 1). No deadhearts were observed on April planted crop. There was steep increase in the deadheart formation in July planted crop (from 9.86% in June to 96.91% in July) and this high infestation was maintained upto December planted crop. Again there was steep decrease in infestation on January planting (86.54% in December and 12.38% in January). Infestation on crop planted during July to December ranged between 84.69 and 97.11%, however, the differences being non-significant.

Shoot fly infestation was similar in both the genotypes in all the plantings and no significant differences were observed (Table 1). Both the genotypes recorded higher infestation during July to December planting and low infestation during rest of the period. No infestation was observed in any of the genotypes on April planted crop.

Table 3: Shoot fly deadhearts in various treatments at 21 DAE on Sorghum planted during different months

Treatment	Per cent of deadhearts on crop planted during											
	April	May	June	July	August	September	October	November	December	January	February	March
CSH 1	T1 0	0.25	1.00	5.33	3.00	5.33	8.33	5.33	9.66	3.00	8.50	3.50
	T2 0	3.00	5.50	94.33	86.30	83.00	93.33	96.67	98.33	11.50	29.50	15.00
	T3 0	3.50	6.50	98.30	88.70	85.33	90.67	96.33	95.66	11.50	26.50	15.00
	T4 0	1.50	6.50	98.33	94.30	82.33	94.00	98.66	96.33	11.00	30.00	17.50
Mean (All treatments)	-	2.06	4.88	74.07	68.10	64.00	71.58	74.25	75.00	9.25	23.62	12.75
Mean (Excluding T1)	-	2.66	6.16	96.98	89.76	83.55	92.66	97.22	96.77	11.33	28.66	15.83
ICSV 1	T1 0	1.00	1.50	7.00	3.70	5.67	4.87	4.66	6.66	1.00	5.50	4.00
	T2 0	3.00	4.00	98.66	84.00	76.66	98.00	97.66	97.33	11.00	30.00	9.50
	T3 0	3.50	9.00	97.33	88.00	88.00	94.66	97.00	98.00	10.50	32.00	11.50
	T4 0	2.50	7.50	98.33	91.70	90.67	98.33	96.33	95.33	12.00	29.50	14.00
Mean (All treatments)	-	2.50	5.50	75.33	66.80	65.25	73.96	73.91	74.33	8.63	24.25	9.75
Mean (Excluding T1)	-	3.00	6.83	98.10	87.90	85.11	96.99	96.99	96.88	11.16	30.50	11.66
C.D. (All subtreatments) (P=0.05)	NS	1.93	3.66	3.05	7.98	6.78	4.01	2.89	1.82	3.41	6.64	5.78
C.D. (Excluding T1)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
C.D. (Main treatments)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
T1 : Carbofuran 3G soil application at sowing time for shootfly control												
T2 : Carbofuran 3G whorl application at 30 DAE for stem borer control												
T3 : Endosulfan 35 EC spray at flowering stage for midge control.												
T4 : Endosulfan 35 EC spray at milky stage for headbug control.												

In contrast to the data on oviposition, there were significant differences in deadhearts among the four treatments on all the plantings, except in the April planting, when the infestation was nil (Table 3). In other plantings, the carbofuran soil application (T_1), recorded significantly low infestation. The trend was similar during high (July to December planting) as well as during low infestations (January to June planting). Control of shoot fly using carbofuran soil application (T_1) was dramatic particularly during high infestation period when the infestation was below 10% as against more than 80% in other treatments (Plate 3).

When carbofuran soil application treatment was excluded from the analysis, no significant differences were observed in other three treatments (T_2 , T_3 and T_4) during all the plantings (Table 3). The incidence ranged between 83.00% and 98.10% during the high infestation period (July to December) and between 0.0 and 30.5% during the low infestation period (January to June).

4.1.2 The stem borer

Seasonal activity of stem borer was studied on sorghum planted at monthly intervals by recording leaf damage (Plate 4), deadhearts (Plate 5), population counts at bootleaf and harvesting stage (Plate 6 and 7).



Plate No.3: Carbofuran 3G treated and untreated plot



Plate No.4: Stem borer leaf damage on sorghum



Plate No.5: Stem borer infested and uninfested plants

4.1.2.1 Leaf damage: The stem borer leaf feeding was very low (ranged between 1.54 to 8.56 per cent of plants) on sorghum planted during July to September, November-December and February to April (Table 4). Maximum leaf feeding was observed on October planted crop (17.81 per cent of plants) followed by May planting (16.14 per cent of plants) which were on par with each other. Next in the order of highest leaf feeding was in June planting (12.74 per cent of plants) which differed significantly from all other plantings. The January (10.39%) and February plantings (8.56%) were on par and similarly, the September (7.52%), March (6.73%) and December (6.26%) plantings were on par with regard to leaf feeding. The November sowing recorded 4.16% of plants with leaf damage followed by April sowing (2.95%), which in turn was on par with August planting (2.63%). The lowest per cent of plants with leaf feeding was observed in July planting (1.54) which differed significantly from all other sowings.

Leaf feeding was similar on both the genotypes during all the plantings and the differences between the genotypes was non-significant (Table 4). Both genotypes recorded maximum leaf feeding during October planted crop and the lowest in July planted crop.

Stem borer leaf feeding on sorghum crop receiving four different treatments (Table 5) was non

Table 4 : Stem borer damage on Sorghum planted during different months, 1988-89.

Planting Month	Per cent plants with leaf damage at 4 WAE			Per cent plants with dead hearts at 35 DAF		
	CSH 1	ICSV 1	Mean	CSH 1	ICSV 1	Mean
April	5.40 (2.43)	3.42 (1.98)	4.34 (2.20)	3.07 (1.89)	2.84 (1.83)	2.95 (1.86)
May	8.38 (2.98)	9.74 (3.20)	9.04 (3.09)	15.50 (4.00)	16.72 (4.15)	16.14 (4.08)
June	17.73 (4.27)	18.16 (4.32)	17.99 (4.30)	11.26 (3.43)	14.24 (3.84)	12.74 (3.64)
July	7.34 (2.80)	5.40 (2.43)	6.31 (2.61)	1.72 (1.49)	1.40 (1.38)	1.54 (1.43)
August	3.62 (2.03)	3.74 (2.06)	3.66 (2.04)	3.14 (1.91)	2.18 (1.64)	2.63 (1.77)
September	3.11 (1.90)	2.09 (1.61)	2.59 (1.76)	8.32 (2.97)	6.73 (2.69)	7.52 (2.83)
October	15.66 (4.02)	12.17 (3.56)	13.86 (3.79)	15.18 (3.96)	20.66 (4.60)	17.81 (4.28)
November	4.47 (2.23)	3.86 (2.09)	4.16 (2.16)	3.62 (2.03)	4.74 (2.29)	4.16 (2.16)
December	6.95 (2.73)	7.22 (2.78)	7.06 (2.75)	5.50 (2.45)	7.06 (2.75)	6.26 (2.60)
January	17.64 (4.26)	14.09 (3.82)	15.82 (4.04)	10.72 (3.75)	10.06 (3.25)	10.39 (3.30)
February	4.79 (2.30)	3.46 (1.99)	4.07 (2.14)	8.74 (3.04)	8.32 (2.97)	8.56 (3.01)
March	2.77 (1.81)	2.59 (1.76)	2.70 (1.79)	9.74 (3.20)	4.25 (2.18)	6.73 (2.69)
Mean	7.39 (2.81)	6.41 (2.63)	6.90 (2.72)	7.39 (2.81)	7.34 (2.80)	7.36 (2.80)
C.D. (month) (P < 0.05)			0.409			0.312
C.D. (main treatments)			0.164			NS

* Figures in parentheses are $\sqrt{x + 0.5}$ transformation

significant on crop planted during April and June and August to March. However, significant differences were observed in May and July planted crop. In May planting, where significant differences were observed, significantly less leaf feeding was observed on crop receiving carbofuran at 30 DAE (T_2), while the other three treatments (T_1 , T_3 and T_4) were at par with each other. In July planting, the treatments, carbofuran whorl application (T_2), endosulfan spray at flowering (T_3) and milky (T_4) stages were on par with each other.

When the second treatment (carbofuran whorl application - T_2) was excluded from the analysis, all the other three treatments (T_1 , T_3 and T_4) were at par for stem borer leaf feeding except in July planting when the treatments endosulfan spray at flowering and milky stage were on par and differed significantly from carbofuran soil application treatment, which recorded more per cent of plants with leaf feeding (4.0% for CSH 1 and 4.5% for ICSV 1). Similar to the data presented in Table 4, here also maximum leaf feeding was observed in all the treatments when the crop was planted in October and May and the lowest leaf feeding was observed on July planted crop in all the treatments. In March planting, the ICSV 1 recorded less leaf feeding than CSH 1 (Table 5).

Table 5: Stem borer leaf damage in various treatments at 4 weeks after emergence on Sorghum planted during different months

Treatment	Percent plants with lower leaf feeding marks on crop planted during												
	April	May	June	July	August	September	October	November	December	January	February	March	
CSM 1	T1	3.5	16.0	10.5	4.0	3.5	9.5	13.0	3.0	6.0	12.0	8.5	10.0
	T2	1.5	7.0	12.0	1.5	2.0	10.0	14.0	4.5	4.5	10.5	13.0	10.5
	T3	3.5	18.5	13.0	1.0	3.5	6.5	18.0	4.0	5.0	10.5	8.0	10.5
	T4	3.0	12.5	10.5	1.0	3.0	9.5	15.0	4.5	6.0	10.0	10.0	8.5
Mean (All treatments)		2.9	13.5	11.5	1.9	3.0	8.9	15.3	4.0	5.4	10.8	9.9	10.0
Mean (Excluding T2)		3.3	15.7	11.3	2.0	3.3	8.5	19.5	3.8	5.7	10.8	8.8	9.8
ICSV 1	T1	2.5	17.0	11.0	4.5	3.0	6.5	21.0	3.5	7.0	10.0	9.0	5.0
	T2	3.0	9.5	17.5	0.5	1.0	9.0	21.5	2.5	6.5	10.0	7.5	4.5
	T3	4.0	16.0	16.5	0.5	1.5	8.5	21.0	6.5	7.0	12.0	7.5	4.0
	T4	2.5	17.5	16.0	0.5	2.5	5.5	20.8	5.0	7.5	8.5	9.0	4.0
Mean (All treatments)		3.0	15.0	15.3	1.5	2.0	7.4	20.7	4.4	7.0	10.1	8.3	4.4
Mean (Excluding T2)		3.0	16.8	14.5	1.8	2.3	6.8	97.0	5.0	7.2	10.2	8.5	4.3
C.D. (All subtreatments)	NS	5.52	NS	1.47	NS	NS	NS	NS	NS	NS	NS	NS	NS
(P = 0.05)													
C.D. (Excluding T2)	NS	NS	NS	2.07	NS	NS	NS	NS	NS	NS	NS	NS	NS
C.D. (Main treatments)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	1.58
T1 : Carbofuran 3G soil application at sowing time for shootfly control													
T2 : Carbofuran 3G whorl application at 30 DAE for stem borer control													
T3 : Endosulfan 35 EC spray at flowering stage for midge control.													
T4 : Endosulfan 35 EC spray at milky stage for headbug control.													

4.1.2.2 Damage : Deadhearts at 35 DAE

The percentage deadhearts in different sowings as observed from Table 4 showed that the mean deadheart formation ranged from 2.59 in September to 17.99% in June planting. The percentage deadhearts was low (ranged between 2.59 to 9.04) on sorghum planted during April, May, July, August, September, November, December, February and March. There was steep increase in the deadheart formation in June planted crop (from 9.04% in May to 17.99% in June) followed by a steep decrease in infestation on July planted crop (6.31%). The mean percentage of deadheart formation in September and March; August, February, November and April; July and December; December and May; October and January and January and June plantings were on par with each other.

The stem borer damage was significantly more in the genotype CSH 1 in April, July, September, October, January and February plantings where as the genotype, ICSV 1 recorded more per cent of deadhearts in May planting.

A perusal of the data (Table 6) reveals significant treatmental difference in July to October and December to March plantings. In the remaining plantings viz., April to June and November the treatmental differences were non-significant. In the

Table 6: Stem borer deadhearts in various treatments at 35 DAE on Sorghum planted during different months

Treatment	Per cent of deadhearts on crop planted during												
	April	May	June	July	August	September	October	November	December	January	February	March	
CSH 1	T1	5.50	7.00	23.50	9.00	5.50	2.50	17.00	4.50	4.00	16.00	5.00	1.87
	T2	2.00	5.00	14.50	5.00	2.00	1.50	2.50	1.50	1.50	3.50	2.00	1.22
	T3	7.00	9.50	14.00	7.50	4.00	3.00	15.00	5.00	8.00	19.00	5.00	1.81
	T4	4.50	9.00	19.00	6.00	2.00	4.00	15.50	4.50	10.00	18.50	4.50	1.72
Mean (All treatments)	4.75	7.63	17.80	6.88	3.38	2.75	12.50	3.88	5.88	14.30	4.12	1.66	
Mean (Excluding T2)	5.66	8.50	11.80	7.50	3.83	3.16	15.83	7.33	7.33	17.83	4.83	1.80	
ICSV 1	T1	3.50	10.00	13.50	11.50	4.50	1.50	14.00	3.50	5.50	9.50	3.50	1.99
	T2	2.50	7.50	10.50	1.50	1.00	0.25	2.50	1.50	1.50	3.00	1.00	1.44
	T3	3.50	9.50	23.50	3.00	2.50	2.50	11.00	4.00	7.00	20.00	4.00	1.58
	T4	3.50	10.00	20.50	3.50	4.50	2.50	12.00	4.50	10.00	15.00	3.00	1.72
Mean (All treatments)	3.25	9.25	16.90	4.88	3.13	1.68	9.88	3.38	6.00	11.90	2.87	1.61	
Mean (Excluding T2)	3.50	9.83	19.16	6.00	3.83	2.16	12.33	4.00	7.50	14.83	3.50	1.76	
C.D. (All subtreatments)	NS	NS	NS	3.79	1.36	0.66	2.99	NS	3.03	9.49	1.17	0.47	
(P= 0.05)													
C.D. (Excluding T2)	NS	NS	NS	4.5	1.55	NS	NS	NS	NS	2.75	NS	NS	NS
C.D. (Main treatments)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

T1 : Carbofuran 3G soil application at sowing time for shootfly control													
T2 : Carbofuran 3G whorl application at 30 DAE for stem borer control													
T3 : Endosulfan 35 EC spray at flowering stage for midge control.													
T4 : Endosulfan 35 EC spray at milky stage for headbug control.													

July planting, the treatments, carbofuran whorl application (T_2), endosulfan spray at flowering (T_3) and milky stage (T_4) were on par with each other. During the August planting, the treatments, endosulfan spray at flowering and milky stage were on par while in September planting all the treatments differed significantly while in December planting, the carbofuran whorl application treatment differed significantly from other three treatments.

In January planting, the carbofuran whorl application and soil application were on par whereas the remaining two treatments were on par (i.e., T_3 and T_4). However, during February and March plantings, the treatments, carbofuran soil application, endosulfan spray at flowering and milky stage were on par with each other.

When carbofuran whorl application treatment was excluded from the analysis, significant differences were observed in other three treatments during July, August and December plantings (Table 6). In the July planting, the treatments endosulfan spray at flowering and milky stage were on par and differed from carbofuran soil application treatment and the same pattern was observed in August planting also. While in December planting, the treatments, carbofuran soil application (T_1) and endosulfan spray at flowering stage (T_3) were on par.

However, endosulfan spray at flowering stage (T_3), in turn, was on par with endosulfan spray at milky stage (T_4).

4.1.2.3 Stem borer population at boot leaf stage: The stem borer population counts at boot leaf stage was very low (ranged between 1.60 to 6.15 per cent of plants with borer) on sorghum planted between July to December (Table 7). Maximum population was observed on June planted crop (21.87), followed by February, January, April, May and March plantings. Significantly higher population was recorded on June planted crop, however, it was on par with February planting (18.94). Next in the order of largest mean stem borer population counts were the January (17.47) and April (14.39) plantings which were on par with each other. Similarly, the January and February; May and March; December and October; and November, July and September plantings were on par, while the lowest mean number of stem borer population was observed in August planting (1.60) which differed significantly from all other plantings.

The stem borer population differed significantly in the two genotypes during different plantings (Table 7). The genotype, CSH 1 recorded significantly more number of population in April, July, October and January to March planting, the only exception

being June planting where the ICSV 1 recorded more number of population.

Stem borer population on sorghum crop at boot leaf stage receiving four different treatments (Table 8) showed significant difference in all the plantings with no exception. In all the plantings where significant difference were observed, significantly lower population counts were recorded on crop receiving, carbofuran at 30 DAE (T_2), while the other three treatments (T_1 , T_3 and T_4) were at par with each other in majority of plantings. During the July and August planting, the treatments, carbofuran whorl application (T_2), endosulfan spray at flowering (T_3) and milky stage (T_4) were on par. During the November planting, the treatment, carbofuran whorl application (T_2) and soil application (T_1) were on par with each other.

When the second treatment (Carbofuran whorl application) was excluded from the analysis, significant treatment difference was observed in July and December plantings (Table 7). In July planting, the treatments, endosulfan spray at flowering and milky stage were on par and differed significantly from carbofuran soil application (T_1). In December planting, the treatments carbofuran soil application and endosulfan spray at milky stage were on par with each other. However, the treatment, endosulfan spray at flowering stage in turn

Table 7 : Stem borer population counts on sorghum planted during different months, 1988-89

Planting Month	Per cent plants with borer at Boot leaf stage			Per cent plants with borer at harvesting		
	CSH 1	ICSV 1	Mean	CSH 1	ICSV 1	Mean
April	17.22 (4.21)	11.75 (3.50)	14.39 (3.86)	25.71 (5.12)	19.48 (4.47)	22.44 (4.79)
May	10.32 (3.29)	12.03 (3.54)	11.12 (3.41)	10.65 (3.34)	8.98 (3.08)	9.80 (3.21)
June	18.94 (4.41)	25.00 (5.05)	21.87 (4.73)	12.60 (3.62)	13.63 (3.76)	13.11 (3.69)
July	4.34 (2.20)	2.56 (1.75)	3.38 (1.97)	3.62 (2.03)	2.06 (1.60)	2.81 (1.82)
August	1.72 (1.49)	1.51 (1.42)	1.60 (1.45)	1.90 (1.55)	2.52 (1.74)	2.22 (1.65)
September	3.18 (1.92)	3.58 (2.02)	3.38 (1.97)	11.82 (3.51)	16.88 (4.17)	14.24 (3.84)
October	6.36 (2.62)	4.42 (2.22)	5.35 (2.42)	16.72 (4.15)	11.82 (3.51)	14.16 (3.83)
November	3.38 (1.97)	3.91 (2.10)	3.62 (2.03)	3.99 (2.12)	6.26 (2.60)	5.60 (2.36)
December	6.15 (2.58)	6.20 (2.59)	6.15 (2.58)	4.92 (2.33)	6.26 (2.60)	5.06 (2.36)
January	19.66 (4.49)	15.50 (4.00)	17.47 (4.24)	22.44 (4.79)	21.12 (4.65)	21.77 (4.72)
February	23.21 (4.87)	15.10 (3.95)	18.94 (4.41)	9.42 (3.15)	4.60 (2.26)	6.84 (2.71)
March	14.24 (3.84)	5.35 (2.42)	9.29 (3.13)	23.51 (4.90)	15.10 (3.95)	19.03 (4.42)
Mean	9.48 (3.16)	7.79 (2.88)	8.63 (3.02)	10.92 (3.38)	9.74 (3.20)	10.33 (3.29)
C.D. (month) (P = 0.05)			0.433			0.469
C.D. (main treatments)			0.263			NS

* Figures in parentheses are $\sqrt{x + 0.5}$ transformation

Table 8: Stem borer population counts at Bootleaf stage in various treatments on Sorghum planted during different months												
Treatment	Percent of plants with stem borer population on crop planted during											
	April	May	June	July	August	September	October	November	December	January	February	March
CSH 1	T1 21.50	13.00	24.50	10.00	3.00	4.00	7.00	3.50	4.00	20.00	24.50	15.00
	T2 2.50	1.50	2.00	2.50	0.25	0.50	1.50	1.50	0.50	2.00	2.00	1.50
	T3 18.00	6.00	14.50	2.00	2.00	5.00	7.00	3.00	6.50	18.50	20.00	14.00
	T4 14.50	13.50	21.50	3.00	1.00	3.50	7.50	4.00	8.50	21.00	26.00	14.00
Mean (All treatments)	14.10	8.50	15.60	4.38	1.56	3.25	5.75	3.00	4.88	15.38	18.12	11.12
Mean (Excluding T2)	18.00	10.83	20.16	5.00	2.00	4.16	7.16	3.50	6.33	19.83	23.50	14.33
ICSV 1	T1 12.00	9.50	26.00	8.00	2.50	4.00	4.50	3.00	5.00	13.00	17.00	5.00
	T2 2.00	2.50	3.50	0.25	0.25	0.25	2.50	1.00	0.50	2.00	1.50	2.00
	T3 12.00	13.00	24.00	1.00	0.50	3.00	5.50	4.00	6.00	15.50	13.00	5.00
	T4 11.50	14.00	29.50	1.00	2.00	4.00	3.50	5.00	8.50	20.00	15.50	6.50
Mean (All treatments)	9.40	9.75	20.80	2.56	1.31	2.81	4.00	3.25	5.00	12.63	11.75	4.62
Mean (Excluding T2)	11.83	12.16	26.50	3.33	1.66	3.66	4.50	4.00	6.50	16.16	15.16	5.50
C.D. (All sub treatments)	9.16	3.569	13.56	2.10	1.5	2.5	2.45	2.12	3.73	6.73	6.48	3.44
(P = 0.05)												
C.D. (Excluding T2)	NS	NS	NS	2.90	NS	NS	NS	NS	2.56	NS	NS	NS
C.D. (Main treatments)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	3.17
T1 : Carboturan 36 soil application at sowing time for shootfly control T2 : Carbofuran 36 whorl application at 30 DAE for stem borer control T3 : Endosulfan 35 EC spray at flowering stage for midge control. T4 : Endosulfan 35 EC spray at milky stage for head borer control.												



Plate No.6: Stem borer larva feeding on sorghum stem

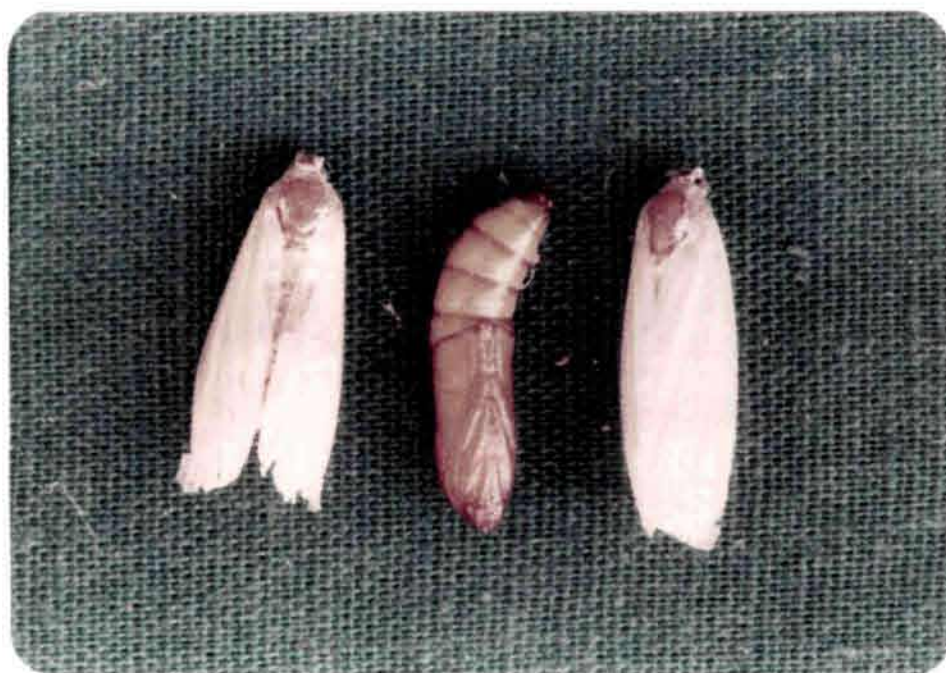


Plate No.7: Stem borer pupa and adults

was on par with endosulfan spray at milky stage. Significant main treatmental difference was observed during March planting with the genotype CSH-1 recording more infestation than ICSV 1.

4.1.2.4 Stem borer population at harvesting: The mean stem borer population at harvesting in different plantings ranged from 2.22 in August to 22.44 in April planting (Table 7). Maximum population was observed in April (22.44) followed by January (21.77) and March (19.03) planting which were on par with each other. Similarly the September, October and June sowings recorded 14.24, 14.16 and 13.11 mean stem borer population per 100 plants, respectively and were on par with each other. The May planting recorded mean stem borer population of 9.80, which differed significantly from all other sowings. Next in the order of highest mean total count was in February (6.84) followed by December (5.60) and November (5.06) plantings which were on par with each other. The lowest population was recorded in August (2.22) which was on par with July (2.81) planting.

Stem borer population was similar in both the genotypes in all the plantings and no significant differences were observed between them in any of the plantings (Table 7).

The population counts on sorghum crop receiving four different treatments (Table 9) showed significant differences. In May planting, endosulfan spray at flowering stage and milky stage were on par. During July planting, the treatments, carbofuran whorl application (T_2), endosulfan spray at flowering stage (T_3) and at milky stage (T_4) were on par with each other. In August and October plantings, the treatments, carbofuran soil application (T_1) and endosulfan spray at flowering stage, and endosulfan spray at flowering stage and at milky stage were on par with each other. In the remaining plantings viz., April, June, September, November, December, January, February and March the treatments, carbofuran soil application, endosulfan spray at flowering stage and at milky stage were on par and differed significantly from carbofuran whorl application treatment.

When the data was analysed by excluding carbofuran whorl application (T_2) treatment, significant treatment differences were observed in May, July, August and October plantings (Table 9). In May and July plantings, carbofuran soil application differed from other two treatments which were on par while in August and October plantings the endosulfan spray treatments were on par with each other. However, the endosulfan

Table 9: Stem borer population counts at harvesting in various treatments on Sorghum planted during different months

Treatment	Planting month (Percent of plants with stem borer population)											
	April	May	June	July	August	September	October	November	December	January	February	March
CSH 1	T1	26.50	16.50	13.50	11.00	1.50	12.50	14.50	3.50	5.50	22.00	10.00 (3.22)*
	T2	3.50	2.50	2.00	1.00	0.50	1.00	1.50	1.00	1.50	1.50	1.00
	T3	29.50	6.00	11.00	3.00	2.00	11.50	14.50	6.00	4.50	21.00	9.50 (3.16)
	T4	22.00	11.00	15.00	0.50	2.50	16.00	22.00	3.00	5.00	24.50	9.00 (3.08)
Mean (All treatments)		20.40	9.00	10.40	3.88	1.63	10.30	13.13	3.38	4.00	17.25	7.37 (2.65)
Mean (Excluding T2)		26.00	11.16	13.16	4.83	2.00	13.33	17.00	4.16	5.00	22.50	9.50 (3.15)
ICSV 1	T1	13.00	12.00	12.00	9.50	1.50	16.00	9.00	6.50	5.50	25.00	4.50 (2.23)
	T2	3.00	2.50	4.00	0.25	1.00	2.00	2.00	1.00	1.50	2.50	0.50 (0.96)
	T3	23.50	7.50	12.00	0.50	3.00	18.50	13.50	6.00	7.00	21.00	6.00 (2.51)
	T4	23.00	8.00	17.50	0.25	3.50	17.00	13.50	6.50	6.50	18.00	4.00 (2.10)
Mean (All treatments)		15.60	7.50	11.40	2.63	2.25	13.40	9.50	5.00	5.13	16.63	3.75 (1.95)
Mean (Excluding T2)		19.83	9.16	13.83	3.42	2.66	17.16	12.00	6.33	6.33	21.33	5.00 (2.28)
C.D. (All sub-treatments) (P= 0.05)		10.48	1.87	7.80	3.83	1.47	7.2	3.15	1.98	1.08	3.63	0.51
C.D. (Excluding T2)	NS	2.29	NS	NS	3.78	1.27	NS	3.08	NS	NS	NS	NS
C.D. (Main treatments)	1.07	NS	NS	NS	NS	NS	NS	NS	1.59	NS	NS	0.14

T1 : Carbofuran 36 soil application at sowing time for shootfly control
T2 : Carbofuran 36 whorl application at 30 DAE for stem borer control
T3 : Endosulfan 35 EC spray at flowering stage for midge control.
T4 : Endosulfan 35 EC spray at milky stage for headbug control.

* : Figures in paranthesis are $\sqrt{x+0.5}$ transformation

spray at flowering stage in turn was on par with the treatment, carbofuran soil application.

In different plantings, the main treatment difference was observed in April, November and February sowings. During April and February, CSH-1 recorded more incidence while in November it was ICSV 1 which has recorded more incidence (5.00).

4.1.3 The shoot bug

The incidence of shoot bug at 30 DAE was nil in April and May plantings. There was steep increase in the incidence in June planting (from 0.0 in May to 140.87 bugs/10 plants) and this high incidence was maintained upto August sowings (Table 10). Again there was a decrease in incidence on September planted crop (44.25 bugs per ten plants) followed by October planting (17.05 bugs per ten plants). Also there was a steep decrease in incidence and no infestation can be observed in November to March plantings. Incidence in crop planted during June to August ranged between 127.19 to 151.28 bugs per ten plants, however, the differences were not significant (Table 10).

Shoot bug incidence was similar in both the genotypes in all the plantings and no significant differences were observed in any of the plantings (Table 10). Both the genotypes recorded higher infestation

Table 10 : Shoot bug and midge incidence on sorghum planted during different months, 1988-89

Planting Month	Number of shoot bug per ten plants at 30 DAE			No. of midge flies at 50% flowering per ten panicles		
	CSH 1	ICSV 1	Mean	CSH 1	ICSV 1	Mean
April	0 (0.707)	0 (0.707)	0 (0.707)	0.0 (0.707)	0.0 (0.707)	0.0 (0.707)
May	0 (0.707)	0 (0.707)	0 (0.707)	16.55 (4.13)	16.63 (4.14)	16.63 (4.14)
June	148.09 (12.19)	134.06 (11.60)	140.87 (11.89)	15.26 (3.97)	16.06 (4.07)	15.66 (4.02)
July	126.73 (11.28)	127.41 (11.31)	127.19 (11.30)	15.82 (4.04)	15.10 (3.95)	15.50 (4.00)
August	146.39 (12.12)	156.00 (12.51)	151.28 (12.32)	3.66 (2.04)	6.95 (2.73)	5.16 (2.38)
September	51.05 (7.18)	37.94 (6.20)	44.25 (6.69)	3.42 (1.98)	2.92 (1.85)	3.18 (1.92)
October	16.63 (4.14)	17.47 (4.24)	17.05 (4.19)	0.0 (0.707)	0.0 (0.707)	0.0 (0.707)
November	0	0		4.60 (2.26)	5.26 (2.40)	4.92 (2.33)
December	0	0		2.22 (1.65)	1.37 (1.37)	1.78 (1.51)
January	0	0		2.09 (1.61)	1.75 (1.50)	1.93 (1.56)
February	0	0		0.0 (0.707)	0.0 (0.707)	0.0 (0.707)
March	0	0		0	0	0
Mean	18.16 (4.32)	17.39 (4.23)	17.77 (4.27)	3.66 (2.04)	3.78 (2.07)	3.72 (2.05)
C.D. (month) ($P=0.05$)			1.67			0.2802
C.D. (main treatments)			NS			NS

* Figures in parentheses are $\sqrt{x + 0.5}$ transformation

Table 11: Number of shoot bugs at 30 DAE in various treatments on Sorghum planted during different months

Treatment	Number of shoot bugs per ten plants on crop planted during											
	April	May	June	July	August	September	October	November	December	January	February	March
CSH 1	T1	0	0	158	425	197.5	59.5	15	0	0	0	0
	T2	0	0	127.5	42	126.5	47.5	24	0	0	0	0
	T3	0	0	138	36	112.0	52.5	20	0	0	0	0
	T4	0	0	149	52	137.5	43	16	0	0	0	0
Mean (All treatments)				143.10	138.90	143.40	50.60	18.75	0	0.00	0	0
ICSV 1	T1	0	0	121	394.5	215	39	13	0	0	0	0
	T2	0	0	131	39	113	36	12	0	0	0	0
	T3	0	0	147	41	128.5	31	24	0	0	0	0
	T4	0	0	136	59	141	43	22	0	0	0	0
Mean (All treatments)				133.8	133.4	149.4	37.3	17.8				
C.D. (subtreatments)				NS	36.83	47.42	NS	NS				
C.D. (Main treatments)				NS	NS	NS	NS	NS				

T1 : Carbofuran 3G soil application at sowing time for shootfly control
T2 : Carbofuran 3G whorl application at 30 DAE for stem borer control
T3 : Endosulfan 35 EC spray at flowering stage for midge control.
T4 : Endosulfan 35 EC spray at milky stage for headbug control.

during June to August plantings and low infestation during September and October plantings. During rest of the period, no infestation was observed in both the genotypes.

During July and August planting the treatments, carbofuran whorl application (T_2), endosulfan spray at flowering (T_3) and milky stage (T_4) were on par and differed significantly from the carbofuran soil application treatment (T_1). During June, September and October plantings, all the treatments were on par with each other in recording shoot bug incidence (Table 11).

4.1.4 The sorghum midge

Seasonal activity of midge was studied on sorghum planted at monthly intervals by recording adult population and damage symptoms (midge infested florets).

4.1.4.1 Population: The observation of the data regarding the incidence of midge at 50 per cent flowering during different plantings (Table 10) indicated that the mean incidence was nil in April, October, February and March plantings. The maximum mean number of midges were highest in May (16.63 midges/ten panicles) followed by June (15.66) and July plantings (15.50) however, the differences being non-significant. There was a steep decrease in midge population (from 15.50 in July to 5.16 in August) in August planting

followed by September planting (3.18 midges per ten panicles), which were on par with each other. The September planting recorded a mean of 3.18 midge flies and differed significantly from all other sowings. Similarly, the January and December plantings recorded a mean of 1.93 and 1.78 midge flies/ten panicles, respectively and were on par with each other.

A perusal of the data (Table 10) clearly shows that there was no significant difference between the two genotypes in all the plantings with regard to midge incidence.

A perusal of the data (Table 13) regarding the number of midge flies in various treatments during different plantings shows no significant differences except in January planting where the treatments, endosulfan spray at flowering (T_3) and milky stage (T_4) were on par with each other. Similarly, the carbofuran treatments were on par with each other.

When the data was analysed by excluding the treatment, endosulfan spray at flowering (T_3), the differences between the remaining three treatments were non-significant in almost all the plantings except in January planting where the carbofuran treatments were on par and differed from endosulfan spray at milky stage (T_4).

4.1.4.2 Damage: The extent of midge damage (per cent of midge infested florets) was similar to the intensity of population (Table 12). The mean per cent of midge infested florets were low in September (8.44), December (8.86) and January (10.85) planted crop with no damage during April, October, February and March plantings (Table 12). The maximum damage was observed in May planting (47.52 per cent of midge infested florets) and this high infestation was maintained upto August planted crop. Suddenly there was a decrease in infestation on September planting (8.44 per cent of midge infested florets) followed by October planting with no midge damage at all. Again there was steep increase in midge damage in November (31.87) planted crop followed by a decline in all other plantings subsequently. The infestation on crop planted during May and June was on par and similarly the infestation on crop planted during July, November and August was on par with each other (Table 12).

Damage was similar in both the genotypes (CSH 1 and ICSV 1) during all the plantings and the difference between the genotypes was non-significant (Table 12). Both genotypes recorded maximum damage during May planted crop and no damage in April, October, February and March planted crop.

Table 12 : Midge and Head bug incidence on sorghum planted during different months, 1988-89

Planting	Per cent of florets with midge damage		Number of head bugs per ten panicles		Damage rating (due to bugs)	
	CSH 1	ICSV 1	Mean	CSH 1	ICSV 1	Mean
April	0.0 (0.707)	0.0 (0.707)	0.0 (0.707)	0.0 (0.707)	0.0 (0.707)	0.0 (0.707)
May	44.52 (6.71)	50.62 (7.15)	47.52 (6.93)	345.81 (18.69)	2.63 (1.77)	2.70 (1.79)
June	38.81 (6.27)	42.66 (6.57)	40.71 (6.42)	447.66 (21.17)	4.12 (2.15)	3.95 (2.11)
July	33.14 (5.80)	34.54 (5.92)	33.83 (5.86)	124.71 (11.19)	2.81 (1.82)	2.45 (1.72)
August	29.09 (5.44)	33.37 (5.82)	31.19 (5.63)	55.30 (7.47)	1.99 (1.58)	1.99 (1.58)
September	7.22 (2.78)	9.74 (3.20)	8.44 (2.99)	34.42 (5.91)	1.99 (1.58)	1.99 (1.58)
October	0.0 (0.707)	0.0 (0.707)	0.0 (0.707)	7.73 (2.87)	0.776 (1.13)	0.776 (1.13)
November	31.30 (5.64)	32.33 (5.73)	31.87 (5.69)	16.31 (4.30)	1.63 (1.46)	1.63 (1.46)
December	9.54 (3.17)	8.14 (2.94)	8.86 (3.06)	6.79 (2.70)	0.27 (0.88)	0.34 (0.92)
January	10.45 (3.31)	11.19 (3.42)	10.85 (3.37)	12.67 (3.63)	0.776 (1.13)	0.868 (1.17)
February	0.0 (0.707)	0.0 (0.707)	0.0 (0.707)	0.916 (1.19)	0.0 (0.707)	0.0 (0.707)
March	0.0 (0.707)	0.0 (0.707)	0.0 (0.707)	0.0 (0.707)	0.0 (0.707)	0.0 (0.707)
Mean	11.68 (3.49)	12.67 (3.63)	12.17 (3.56)	44.25 (6.69)	1.19 (1.30)	1.18 (1.299)
C.D. (month)						
C.D. (main treatments)			0.5241			0.1082
(P.D.O.S)			NS			NS

* Figures in parentheses are $\sqrt{x + 0.5}$ transformation

Table 13: Number of midge flies at 50 per cent flowering in various treatments on Sorghum planted during different months

Treatment	Number of midgeflies per ten panicles on crop planted during									
	April	May	June	July	August	September	October	November	December	January February March
CSH 1	T1 0	17.00	18.50	16.00	2.00	3.00	0	5.00	3.00	2.50 0 0
	T2 0	17.00	12.50	13.50	5.00	6.00	0	4.50	1.00	2.50 0 0
	T3 0	13.00	13.50	12.50	6.50	1.50	0	7.50	1.00	1.00 0 0
	T4 0	16.00	15.50	18.50	5.50	2.00	0	5.00	3.50	1.50 0 0
Mean (All treatments)	-	15.75	15.00	15.10	4.75	3.13	0	5.50	2.13	1.80 0 0
Mean (Excluding T3)	-	16.66	15.50	16.00	4.16	3.66	0	4.83	2.50	2.16 0 0
ICSV 1	T1 0	18.50	16.00	16.50	6.00	2.50	0	5.50	2.00	2.50 0 0
	T2 0	15.00	16.50	15.00	2.50	3.00	0	4.00	1.00	2.00 0 0
	T3 0	15.00	12.50	14.00	3.00	3.50	0	4.50	1.00	0.50 0 0
	T4 0	17.00	16.00	14.50	8.50	3.50	0	4.50	1.50	1.00 0 0
Mean (All treatments)	-	16.38	15.25	15.00	5.00	3.13	0	4.63	1.38	1.50 0 0
Mean (Excluding T3)	-	16.83	16.16	15.33	5.66	3.00	0	4.66	1.50	1.83 0 0
C.D. (All subtreatments)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS NS
C.D. (Excluding T3)	NS	NS	NS	NS	NS	NS	NS	NS	NS	0.70 NS NS
C.D. (Main treatments)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS NS

T1 : Carbofuran 3G soil application at sowing time for shootfly control
T2 : Carbofuran 3G whorl application at 30 DAE for stem borer control
T3 : Endosulfan 35 EC spray at flowering stage for midge control.
T4 : Endosulfan 35 EC spray at milky stage for shootfly control

Table 14: Midge damage in various treatments on Sorghum planted during different months

Treatment	Number of midgeflies per ten panicles on crop planted during											
	April	May	June	July	August	September	October	November	December	January	February	March
CSW 1	0.00						0.00				0.00	0.00
	T1 (0.71)	46.00	40.50	24.50	28.00	10.50	(0.71)	34.50	10.50	12.00	(0.71)	(0.71)
	0.00						0.00				0.00	0.00
	T2 (0.71)	40.00	37.50	52.00	27.00	6.50	(0.71)	29.00	9.50	13.00	(0.71)	(0.71)
T3	0.00						0.00				0.00	0.00
	T3 (0.71)	60.00	4.50	75.00	5.00	1.50	(0.71)	3.50	0.25	0.50	(0.71)	(0.71)
	0.00						0.00				0.00	0.00
	T4 (0.71)	50.00	43.50	28.00	33.00	8.00	(0.71)	33.50	9.00	7.50	(0.71)	(0.71)
Mean (All treatments)	0.00						0.00				0.00	0.00
	(0.71)	35.50	31.50	28.00	23.30	6.63	(0.71)	25.10	7.31	8.25	(0.71)	(0.71)
	0.00						0.00				0.00	0.00
	(0.71)	45.33	40.50	34.83	29.33	8.33	(0.71)	32.33	9.66	10.83	(0.71)	(0.71)
ICSW 1	0.00						0.00				0.00	0.00
	T1 (0.71)	45.00	35.00	32.50	34.50	10.00	(0.71)	33.50	8.50	14.50	(0.71)	(0.71)
	0.00						0.00				0.00	0.00
	T2 (0.71)	52.00	44.00	32.00	33.00	10.00	(0.71)	33.00	7.50	12.00	(0.71)	(0.71)
T3	0.00						0.00				0.00	0.00
	T3 (0.71)	4.50	2.50	4.50	2.00	1.50	(0.71)	3.00	1.50	1.50	(0.71)	(0.71)
	0.00						0.00				0.00	0.00
	T4 (0.71)	55.50	50.50	42.00	35.00	9.50	(0.71)	31.00	9.00	8.00	(0.71)	(0.71)
Mean (All treatments)	0.00						0.00				0.00	0.00
	(0.71)	39.30	33.00	27.80	26.10	7.75	(0.71)	25.10	6.63	9.00	(0.71)	(0.71)
	0.00						0.00				0.00	0.00
	(0.71)	50.83	43.16	35.50	34.16	9.83	(0.71)	32.50	8.33	11.50	(0.71)	(0.71)
C.D. (All subtreatments)	NS	10.10	18.63	25.03	17.61	2.39	NS	9.24	2.58	4.56	NS	NS
C.D. (Excluding T3)	NS	NS	NS	NS	NS	NS	NS	NS	NS	4.21	NS	NS
C.D. (Main treatments)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

T1 : Carbofuran 3G soil application at sowing time for shootfly control
T2 : Carbofuran 3G whorl application at 30 DAE for stem borer control
T3 : Endosulfan 35 EC spray at flowering stage for midge control.
T4 : Endosulfan 35 EC spray at milky stage for headbug control.

Midge damage on sorghum crop receiving four different treatments (Table 14) was non significant in those plantings where no midge incidence was observed. However, significant differences were observed on May to September and November to January planted crop. Significantly lower damage was observed on crop receiving endosulfan spray at flowering stage, while the other three treatments were at par with each other in most of the plantings with few exceptions. In July planting, the endosulfan spray at flowering stage (T_3) and carbofuran soil application were on par with each other. However, the latter treatment, in turn was on par with the treatments, carbofuran whorl application and endosulfan spray at milky stage (T_4). During January planting, the carbofuran treatments were on par while the endosulfan spray treatments formed another group.

When the third treatment (endosulfan spray at milky stage) was excluded from the analysis, all the treatments were at par in recording midge damage during all the plantings (Table 14) except in January planting where the carbofuran treatments were on par and differed from endosulfan spray at milky stage.

4.1.5 The sorghum head bug

Seasonal activity of head bugs was studied on sorghum planted at monthly intervals by recording

population per ten panicles at milky stage and damage rating at harvesting (Plate 8).

4.1.5.1 Population: Head bug population was very low (ranged between 0.0 to 32.44 bugs per ten panicles) on sorghum planted between September and April (Table 12). No population was observed in March and April planted crop. Maximum population was observed on June planted crop (411.59 bugs per ten panicles), followed by May (346.94), July (105.79) and August (55.30) plantings and all these plantings differed significantly from one another. Even though the February planting recorded a mean of 0.56 bugs per ten panicles, it was on par with March and April plantings which recorded no incidence.

The population was similar on both the genotypes during all the plantings and the differences between them was non-significant (Table 12).

The head bug population on sorghum crop receiving four different treatments (Table 15) showed significant treatmental differences on the crop planted between May to February. In February sowing, the treatments, endosulfan spray at milky stage (T_4) and carbofuran whorl application (T_2) were on par and the latter treatment in turn was on par with endosulfan spray at flowering stage (T_3) and carbofuran soil application (T_1).

Table 15: Number of head bugs at milky stage in various treatments on Sorghum planted during different months

Treatment	Number of head bugs per ten panicles on crop planted during											
	April	May	June	July	August	September	October	November	December	January	February	March
CSH 1	T1 0.00										1.00	0.00
	(0.71)	379.00	440.00	80.00	55.50	36.50	7.00	19.50	8.50	15.00	(1.22)	(0.71)
	T2 0.00										0.50	0.00
	(0.71)	339.00	454.50	167.50	50.00	33.50	8.50	16.00	5.50	11.50	(0.96)	(0.71)
	T3 0.00										1.50	0.00
Mean (All treatments)	(0.71)	359.50	450.00	137.00	63.50	34.00	8.50	14.00	7.00	12.50	(1.40)	(0.71)
	T4 0.00										0.00	0.00
	(0.71)	12.00	8.00	2.00	6.00	3.00	1.00	3.50	0.25	1.50	(0.71)	(0.71)
	0.00										0.75	0.00
	(0.71)	272.40	338.10	96.60	43.80	26.75	6.25	13.25	5.31	10.13	(1.08)	(0.71)
Mean (Excluding T4)	(0.71)	359.16	448.16	128.16	56.33	34.66	8.00	16.50	7.00	13.00	(1.22)	(0.71)
	T1 0.00										1.00	0.00
	(0.71)	425.00	277.50	99.50	52.00	30.00	5.50	15.50	5.00	15.00	(1.22)	(0.71)
	T2 0.00										0.00	0.00
	(0.71)	320.00	430.50	94.50	62.00	32.00	3.00	19.00	7.00	12.00	(0.71)	(0.71)
ICSV 1	T3 0.00										0.00	0.00
	(0.71)	300.00	462.50	73.50	53.00	29.50	7.00	19.00	7.50	11.00	(0.71)	(0.71)
	T4 0.00										0.00	0.00
	(0.71)	12.50	5.50	2.50	5.00	3.50	2.00	3.50	0.50	0.50	(0.71)	(0.71)
	0.00										0.25	0.00
Mean (All treatments)	(0.71)	264.40	294.00	67.50	43.00	23.75	4.38	14.25	5.00	9.63	(0.84)	(0.71)
	0.00										0.33	0.00
	(0.71)	348.33	390.16	89.16	55.66	30.50	5.16	17.83	6.50	12.66	(0.88)	(0.71)
	C.D. (All subtreatments)	NS	131.43	121.65	68.87	24.97	4.21	3.73	4.47	2.78	0.22	NS
	C.D. (Excluding T4)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
C.D. (Main treatments)	(t _{5, 0.05})	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

T1 : Carbofuran 3G soil application at sowing time for shootfly control

T2 : Carbofuran 3G whorl application at 30 DAE for stem borer control

T3 : Endosulfan 35 EC spray at flowering stage for midge control.

T4 : Endosulfan 35 EC spray at milky stage for headbug control.

* : Figures in parenthesis are $\sqrt{x+0.5}$ transformation



Plate No.8: Sorghum grains showing head bug damage

During the May to January planted crop, the carbofuran treatments and endosulfan spray at flowering stage (T_3) were on par with each other. The only significant main treatment difference was observed in October sowing with CSH 1 recording more incidence (6.25 bugs per ten panicles) than ICSV 1 (4.78 bugs per ten panicles).

When the fourth treatment (endosulfan spray at milky stage) was excluded from the analysis, all the other treatments were at par for head bug incidence during all the plantings (Table 15).

4.1.5.2 Damage: The extent of head bug damage (Damage rating) was similar to the intensity of population. The damage rating was low (ranged between 0.0 to 1.99) on the crop, planted between August and March (Table 16). No damage was observed on April, February and March planted crop. The highest damage rating was observed in June sowing (3.95) followed by May (2.70) and July (2.45). The damage was identical and was on par in May and July; August and September; and October and January plantings.

The damage rating was similar in both the genotypes in all the plantings and no significant differences were observed between them in any of the plantings (Table 12). Both the genotypes recorded

Table 16: Head bugs damage rating at harvest in various treatments on Sorghum planted during different months

Treatment		Head bug damage rating in the crop planted during											
		April	May	June	July	August	September	October	November	December	January	February	March
CSH 1		0.00						0.50		0.50	1.00	0.00	0.00
	T1 (0.71)		2.50	3.50	2.50	2.00	2.00	(1.00)	2.00	(1.00)	(1.41)	(0.71)	(0.71)
		0.00						1.00		0.00	0.50	0.00	0.00
	T2 (0.71)		2.50	4.50	3.00	2.00	2.00	(1.42)	1.50	(0.71)	(1.00)	(0.71)	(0.71)
		0.00						1.00		0.50	1.00	0.00	0.00
	T3 (0.71)		3.00	4.50	3.00	2.00	2.00	(1.42)	1.50	(1.00)	(1.41)	(0.71)	(0.71)
		0.00						0.00		0.00	0.00	0.00	0.00
	T4 (0.71)		1.00	0.50	1.00	0.50	0.50	(0.71)	0.50	(0.71)	(0.71)	(0.71)	(0.71)
		0.00						0.63		0.25	0.62	0.00	0.00
	Mean (All treatments)	(0.71)	2.25	3.33	2.38	1.63	1.63	(1.12)	1.38	(0.85)	(1.13)	(0.71)	(0.71)
		0.00						0.83		0.33	0.83	0.00	0.00
	Mean (Excluding T4)	(0.71)	2.66	4.16	2.83	2.00	2.00	(1.28)	1.66	(0.90)	(1.27)	(0.71)	(0.71)
		0.00						1.00		0.00	1.00	0.00	0.00
	T1 (0.71)		3.00	3.50	2.50	2.00	2.00	(1.42)	1.00	(0.71)	(1.41)	(0.71)	(0.71)
		0.00						0.50		0.50	1.00	0.00	0.00
	T2 (0.71)		2.50	4.00	2.00	2.00	2.00	(1.00)	2.00	(1.00)	(1.41)	(0.71)	(0.71)
		0.00						1.00		1.00	1.00	0.00	0.00
	T3 (0.71)		3.00	4.00	2.00	2.00	2.00	(1.42)	2.00	(1.42)	(1.41)	(0.71)	(0.71)
		0.00						0.00		0.00	0.00	0.00	0.00
	T4 (0.71)		1.00	0.50	0.50	0.50	0.50	(0.71)	0.50	(0.71)	(0.71)	(0.71)	(0.71)
		0.00						0.63		0.37	0.75	0.00	0.00
	Mean (All treatments)	(0.71)	2.37	3.00	1.75	1.62	1.63	(1.13)	1.38	(0.96)	(1.23)	(0.71)	(0.71)
		0.00						0.83		0.50	1.00	0.00	0.00
	Mean (Excluding T4)	(0.71)	2.83	3.83	2.16	2.00	2.00	(1.28)	1.66	(1.04)	(1.41)	(0.71)	(0.71)
	C.D. (All subtreatments)	NS	0.66	0.94	0.83	0.43	0.43	0.61	0.83	NS	0.43	NS	NS
	C.D. (Excluding T4)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
		NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
	C.D. (Main treatments)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
	(P=0.05)							1.59	NS	NS	NS	NS	NS
T1 : Carbofuran 3G soil application at sowing time for shootfly control?		Damage rating											
T2 : Carbofuran 3G whorl application at 30 DAT for stem borer control		1: Grains fully developed											
T3 : Endosulfan 35 EC spray at flowering stage for midge control.		2: Grains showing slight shrivelling and browning											
T4 : Endosulfan 35 EC spray at milky stage for headbug control.		3: Grains half shrivelled											
* : Figures in parenthesis are $\sqrt{x+0.5}$ transformation		4: Highly shrivelled grains											

highest damage rating during June planting and no damage during February to April planted crop.

The different treatments on sorghum planted during different months showed significant treatment differences except in April, December, February and March plantings. In the remaining plantings, the carbofuran treatments (T_1 , T_2) and endosulfan spray at flowering stage (T_3) were on par and differed from the treatment, endosulfan spray at milky stage (T_4) (Table 16).

When the treatment, endosulfan spray at milky stage was excluded from the analysis, all the other three treatments were on par in all the plantings with no exception (Table 16).

4.1.6 The oriental armyworm

A perusal of the data (Table 17) on the incidence of armyworm larvae at 50 DAE reveals that the incidence was more in August planting (16.5 to 19.00 larvae per 100 plants) than in July planting (15.63 to 16.00 larvae per 100 plants) and in the remaining plantings there was no incidence.

The incidence was similar in both the genotypes in July and August plantings. The endosulfan treatments (T_3 , T_4) were on par and differed from the carbofuran

Table 17: Number of armyworm larvae at 50 DAE in various treatments on sorghum planted during different months

Treatment		Number of larvae per 100 plants on crop planted during						
		April	May	June	July	August	September	October
CSH 1	T1	0	0	0	28.50	25.00	0	0
	T2				4.00	4.50		
	T3				15.00	16.00		
	T4				15.00	20.50		
	Mean				15.63	16.50		
ICSV 1	T1				28.50	30.50		
	T2				4.00	9.50		
	T3				14.00	18.50		
	T4				17.50	17.50		
	Mean				16.00	19.00		
C.D. (Sub treatments)					6.77	9.96		
C.D. (Main treatments)					NS	NS		

T1 : Carbofuran 3 G soil application at sowing for shoot fly control
 T2 : Carbofuran 3 G whorl application at 30 DAE for stem borer control
 T3 : Endosulfan 35 EC spray at flowering stage for midge control
 T4 : Endosulfan spray at milky stage for head bug control.

treatments (T_1 , T_2) in the July and August plantings with the treatment, carbofuran soil application recording more number of larvae than the other three treatments (Table 17).

4.2 INFLUENCE OF ABIOTIC FACTORS ON POPULATION BUILD UP AND DAMAGE

4.2.1 The shoot fly

In order to find out the interaction of date of sowing and climatic factors, namely, maximum and minimum temperatures, morning and evening relative humidities, rainfall, number of rainy days and the incidence of the pest as indicated by the oviposition and dead hearts, correlation between each of the above parameters and the incidence of the pest were worked out.

4.2.1.1 Population: A negative and significant correlation was observed between oviposition and maximum temperature ($r=-0.710$). All the remaining abiotic factors were found to be non-significant (Table 18).

The data on oviposition when subjected to multiple linear regression analysis gave the following equation:

$$Y = 431.74 - 12.87 x_1 + 4.71 x_2 - 1.54 x_3 + 2.66 x_4 + 0.56 x_5 - 19.86 x_6$$

Table 18 : Correlation of insect population / damage in relation to abiotic factors

Population / Damage	Temperature °C		Relative Humidity (%)		Rain fall (mm)	No.of rainy days
	Maximum	Minimum	Morning	Evening		
Shootfly oviposition (14 DAE)	-0.710**	-0.320	0.550	0.500	0.330	0.270
Shootfly deadhearts (21 DAE)	-0.720**	-0.340	0.720**	0.550	0.370	0.280
Stem borer leaf feeding (4 WAE)	0.070	0.010	-0.160	-0.310	0.010	-0.060
Stem borer dead hearts (35 DAE)	-0.240	-0.270	0.110	0.130	0.400	0.310
Stem borer counts (Boot leaf stage)	0.380	0.630*	-0.110	0.040	0.350	0.370
Stem borer counts (Harvesting)	0.100	0.410	0.180	0.300	0.290	0.280
Shoot bug population (30 DAE)	-0.460	0.370	0.700**	0.870**	0.900**	0.910**
Number of midge flies	-0.510	0.210	0.580*	0.630*	0.640*	0.830**
Midge damage	-0.440	-0.140	0.260	0.330	0.160	0.350
Head bug population	-0.440	0.170	0.600*	0.740**	0.470	0.610*

* Significant at 5% level

** Significant at 1% level

Table 19 : Multiple linear regression model for insect population / damage in relation to abiotic factors

Population / Damage	A	Temperature °C		Relative Humidity (%)		Rain fall (mm)	Rainy days	R ²
		°		%				
		Maximum	Minimum	Morning	Evening			
Shootfly oviposition (14 DAE)	431.74	-12.87 (0.6051)	4.7164 (0.2831)	-1.5471 (0.4088)	2.6609 (0.4326)	0.5613 (0.4966)	-19.8637 (0.9850)	0.616
Shootfly deadhearts (21 DAE)	6.81	-2.0784 (0.1314)	-1.0094 (0.0867)	1.1229 (0.3991)	1.3304 (0.4821)	0.3845 (0.7309)	-8.3194 (0.6350)	0.663
Stem borer leaf feeding (4 WAE)	41.89	-1.8634 (0.9942)	1.6047 (1.2197)	0.4314 (0.9048)	-0.9404* (2.7360)	0.1543 (1.4373)	-1.2612 (0.8056)	0.652
Stem borer dead hearts (35 DAE)	-59.64	2.4764 (1.4535)	-2.1521 (1.7937)	0.3512 (0.5547)	-0.0638 (0.1034)	0.0635 (0.6851)	0.3678 (0.2573)	0.656
Stem borer counts (Boot leaf stage)	-80.66	0.3825 (0.1684)	1.3053 (1.0714)	1.2566 (1.6840)	-1.1683 (2.0739)	0.1393 (0.8079)	-0.8537 (0.4642)	0.702
Stem borer counts (Harvesting)	-160.92	3.7256 (0.8184)	-0.8485 (0.1475)	0.8968 (0.5996)	0.0071 (0.0063)	0.2989 (0.8467)	-2.8577 (0.7753)	0.369
Shoot bug population (30 DAE)	351.45	-8.150 (0.5174)	2.6275 (0.2507)	-3.1633 (0.3790)	2.9038 (0.3113)	0.1929 (0.3494)	2.1264 (0.2155)	0.874
Midge population	26.09	0.9638 (0.7072)	-1.7249 (1.5222)	-0.5594 (1.988)	0.3803 (1.6280)	-0.3625 (1.7153)	10.9475* (2.9949)	0.878
Midge damage	241.80	-2.9161 (0.6897)	-0.7932 (0.2661)	-2.8275 (2.0843)	2.5115 (1.4456)	-0.7577* (2.9189)	8.8760 (2.4991)	0.751
Head bug population	3406.88	-88.288 (2.0285)	41.0164 (1.7448)	-17.5263 (1.7410)	1.3286 (0.1706)	-1.9708 (1.5431)	36.0188 (1.7177)	0.865

* Significant at 5% level.

Figures in parenthesis indicate 't' value

It was observed that the coefficient of determination for shoot fly oviposition was 0.616 which shows that the climatic factors together are able to explain the variation in the oviposition to the extent of 61.6 out of 100. However, the partial regression coefficients were found to be non-significant (Fig.1).

4.2.1.2 Damage: A perusal of the data (Table 18) regarding correlation indicates that deadheart formation was positive and significantly correlated with morning relative humidity ($r = 0.720$), and negative and significantly correlated with maximum temperature ($r=-0.720$).

The regression model for dead heart formation was given as (Table 19),

$$Y = 6.81 - 2.07 x_1 - 1.00 x_2 + 1.12 x_3 + 1.33 x_4 + 0.38 x_5 - 8.31 x_6$$

It was observed that the coefficient of determination ($R^2=0.663$) was able to explain the variation in the damage to the extent of 66.3 out of 100 but all the partial regression coefficients were found to be non-significant (Fig.2).

In order to have a clear understanding of the climatological factors, which have directly contributed to incidence of the pest either individually or in concert, path coefficient analysis was carried out in

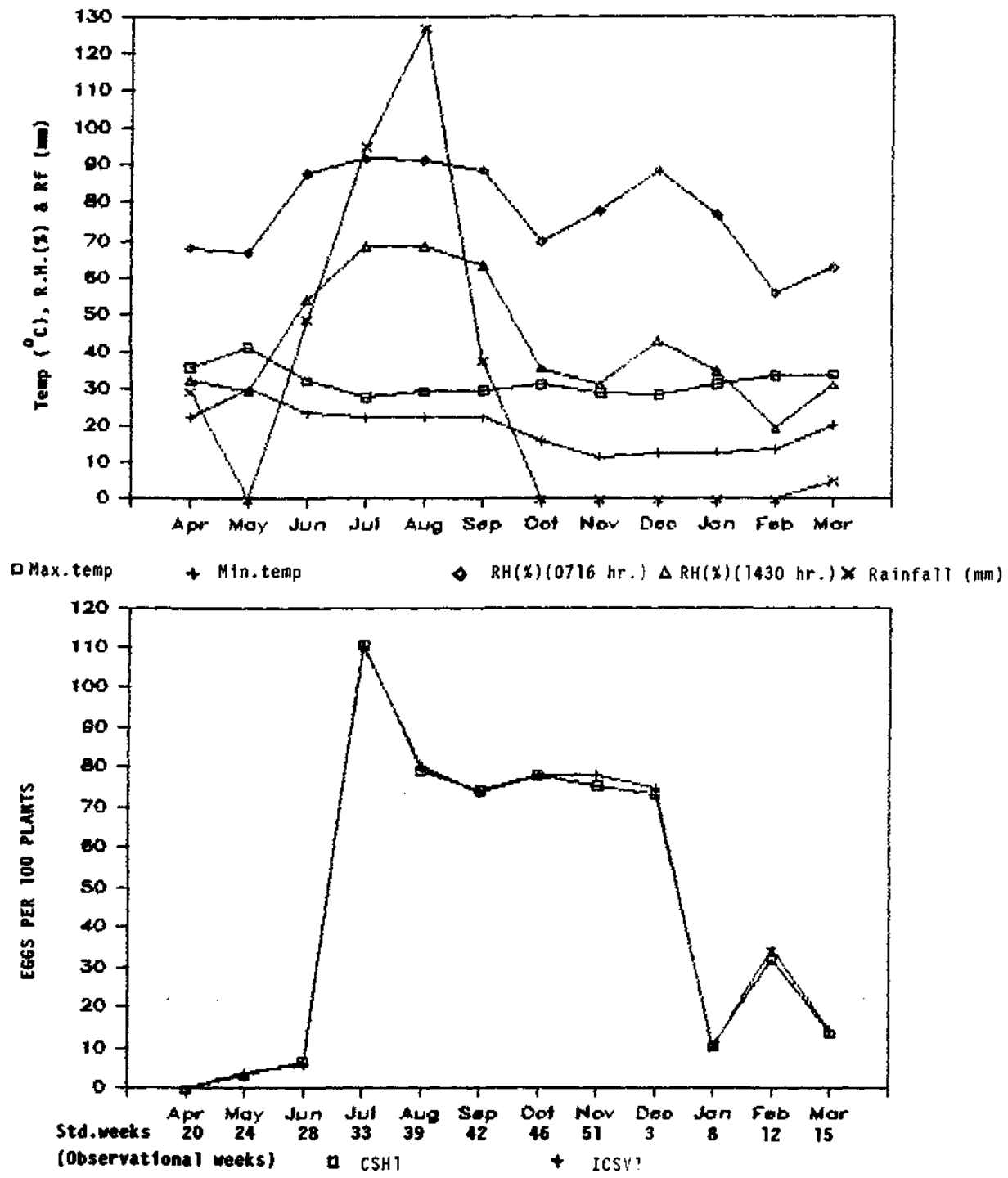


FIG.1: SHOOT FLY OVIPOSITION AT 14 DAE IN RELATION TO CLIMATIC FACTORS DURING 1988-89

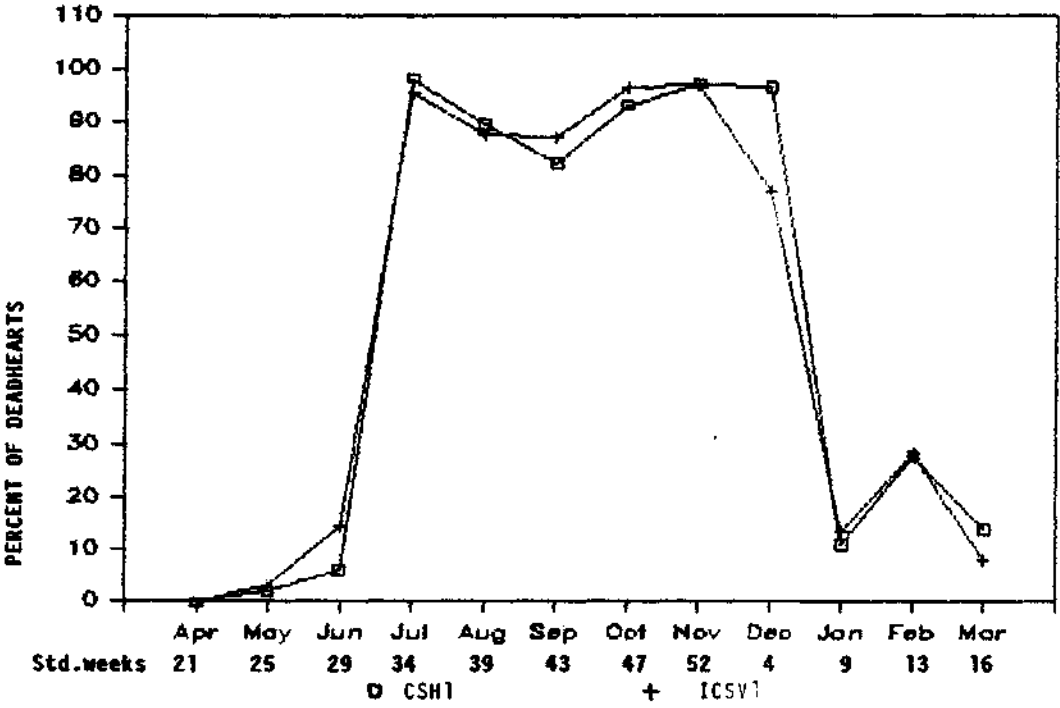
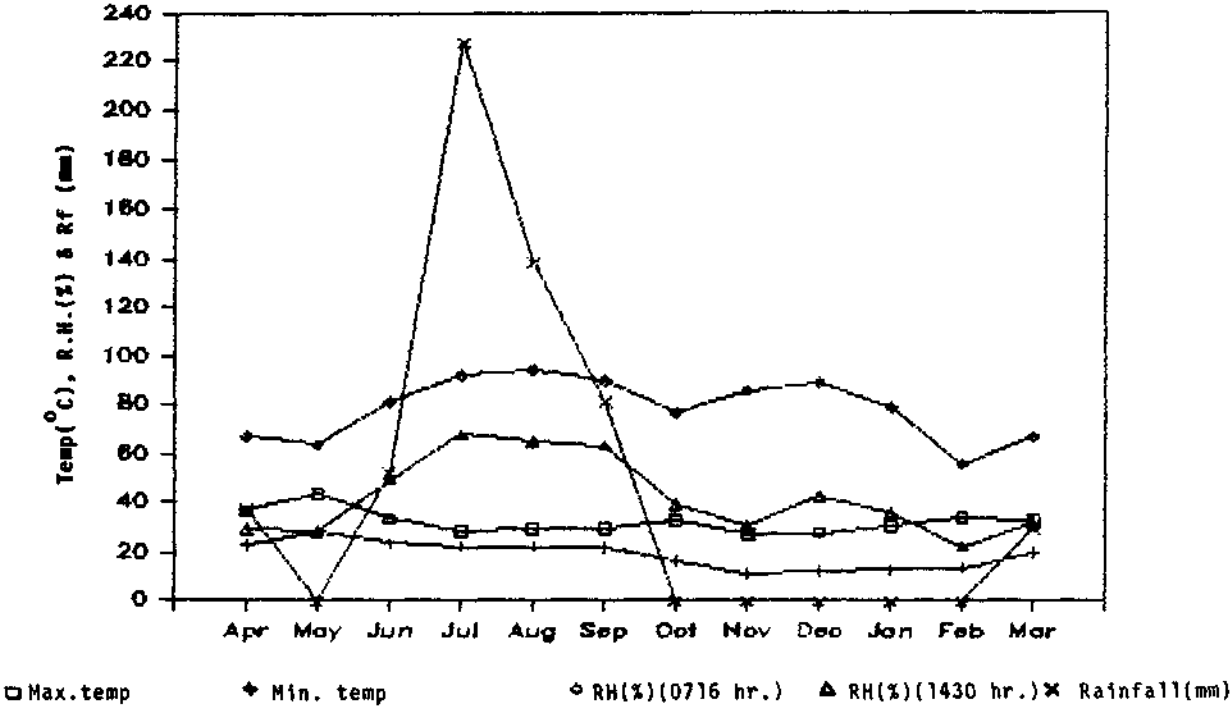


Fig.2 :PERCENT OF SHOOT FLY DEADHEARTS AT 21 DAE IN RELATION TO WEATHER CONDITIONS DURING 1988-89.

order to estimate the direct and indirect effects of different independent variables ($X_1, X_2 \dots X_6$) on the dependent variable (Y) and presented in Table 20.

The results indicated that there was highest negative and direct effect of rainy days on deadheart formation (-0.8974) followed by maximum temperature (-0.2081) and minimum temperature (-0.1280). However, there is direct and positive effect of morning and evening relative humidities on deadheart formation (0.3203 and 0.4756), respectively. It was also observed that rainfall had positively influenced the deadheart formation with a direct effect (0.6245).

Eventhough the number of rainy days got a positive and non-significant correlation with deadheart formation, the path-coefficient analysis has proved that it has got negative direct effect and that morning and evening relative humidities and rainfall were positively influencing deadheart formation indirectly as they got the highest positive and indirect effect in each case. The results also indicated that the residual path made significant contribution towards deadheart formation (Table 20).

4.2.2 The stem borer

Table 20 : Path Coefficient analysis : Climatological factors vs shoot fly deadhearts at 21 days after emergence.

Parameters	Temperature (°C)		Relative Humidity (%)		Rain Fall (mm)	Rainy days	Correlation with dead heart formation.
	Maximum	Minimum	0716 hrs.	1416 hrs.			
Maximum temperature °C	<u>-0.2081</u>	-0.0786	-0.2388	-0.2446	-0.2095	0.2621	-0.720**
Minimum temperature °C	-0.1278	<u>-0.1280</u>	-0.0243	0.1491	0.2694	-0.4751	-0.340
Morning Relative Humidity (per cent)	0.1551	0.0097	<u>0.3203</u>	0.3969	0.3530	-0.5126	0.720**
Evening Relative Humidity (per cent)	0.1070	-0.0401	0.2673	<u>0.4756</u>	0.5214	-0.7786	0.550
Rain Fall (mm)	0.0698	-0.0552	0.1881	0.3971	<u>0.6245</u>	-0.8492	0.370
Rainy days	0.0608	-0.0677	0.1830	0.4126	0.5909	<u>-0.8974</u>	0.280

Residual effect = 0.5802
 Under lined values have direct influence, others indirect
 * Significant at 5% level.
 ** Significant at 1% level

4.2.2.1 Leaf feeding: The leaf feeding at four weeks after emergence was correlated with abiotic factors and the results were presented in Table 18.

A perusal of the data from Table 18 reveals that none of the abiotic factors were significant at 5% level of significance.

The multiple linear regression model for stem borer leaf feeding was (Table 19)

$$Y = 41.89 - 1.86 x_1 + 1.60 x_2 + 0.43 x_3 - 0.94 x_4 + 0.15 x_5 - 1.26 x_6$$

It was observed from Table 19 that the coefficient of determination ($R^2=0.652$) was able to explain the variation in the population to the extent of 65.2 out of 100.

Among the abiotic factors the only significant partial regression coefficient was evening relative humidity, indicating for every one per cent increase in evening relative humidity, there was a decrease of about 0.94 per cent in stem borer leaf feeding at 4 WAE.

A perusal of the result of (Table 21) path-coefficient analysis reveals that there was highest negative and direct effect of evening relative humidity (-2.8909) followed by maximum temperature (-1.7532) and rainy days (-1.2047). However, there was direct and

Table 21 : Path Coefficient analysis : Climatological factors vs stem borer leaf feeding (4 weeks after emergence)

Parameters	Temperature (°C)		Relative Humidity (%)		Rain Fall (mm)	Rainy days	Correlation with leaf feed- ing marks 4 WAE
	Maximum	Minimum	0716 hrs.	1416 hrs.			
Maximum temperature °C	<u>-1.7532</u>	1.2194	-1.0064	1.8287	-0.5458	0.3313	0.070
Minimum temperature °C	-1.3803	<u>1.5488</u>	-0.3956	0.2006	0.3912	-0.3571	0.010
Morning Relative Humidity (per cent)	1.4324	-0.4974	<u>1.2318</u>	-2.6871	1.1781	-0.8167	-0.160
Evening Relative Humidity (per cent)	1.1091	-0.1075	1.1449	<u>-2.8909</u>	1.4202	-0.9837	-0.310
Rain Fall (mm)	0.5365	0.3397	0.8136	-2.3020	<u>1.7835</u>	-1.1686	0.010
Rainy days	0.4821	0.4591	0.8350	-2.3606	<u>1.7301</u>	-1.2047	-0.060

Residual effect = 0.5899
under lined values have direct influence, others indirect

positive effect of rain fall (1.7835), minimum temperature (1.5488) and morning relative humidity ($r = 1.2318$). It was also observed that number of rainy days were negatively influencing leaf feeding indirectly through other factors (evening RH) as it has exerted highest negative indirect effect.

4.2.2.2 Deadhearts : 35 DAE

A perusal of the data (Table 18) shows that none of the abiotic components were significant when correlated with deadheart formation.

The multiple linear regression model for deadheart formation was (Table 19).

$$Y = -59.64 + 2.47 x_1 - 2.15 x_2 + 0.35 x_3 \\ - 0.06 x_4 + 0.06 x_5 + 0.36 x_6$$

The path coefficient analysis (Table 22) revealed that minimum temperature had negative and direct influence (-1.9861) followed by evening relative humidity (-0.1754). A positive and direct influence was observed with maximum temperature (1.9826), rainfall (0.9714), morning relative humidity (0.7607) and rainy days (0.4270) (Fig.3).

4.2.2.3 Stem borer counts at Boot leaf stage:

Significant and positive correlation was observed only with minimum temperature ($r = 0.630$) and non significant

Table 22 : Path Coefficient analysis : Climatological factors vs Stem borer deadhearts at 35 DAE.

Parameters	Temperature (°C)		Relative Humidity (%)		Rain Fall days (mm)	Rainy days with deadhearts
	Maximum	Minimum	Morning	Evening		
Maximum temperature °C	<u>1.9826</u>	-1.3126	-0.5900	0.1054	-0.3032	-0.1216 -0.240
Minimum temperature °C	1.3102	<u>-1.9861</u>	-0.0809	-0.0293	0.3355	0.1772 -0.270
Morning Relative Humidity (per cent)	-1.5377	0.2113	<u>0.7607</u>	-0.1633	0.5802	0.2636 0.110
Evening Relative Humidity (per cent)	-1.1915	-0.3324	0.7084	<u>-0.1754</u>	0.7694	0.3505 0.130
Rain Fall (mm)	-0.6187	-0.6860	0.4543	-0.1389	<u>0.9714</u>	0.4179 0.400
Rainy days	-0.5645	-0.8242	0.4697	-0.1440	0.9508	<u>0.4270</u> 0.310

Residual effect = 0.5864
under lined values have direct influence, others indirect

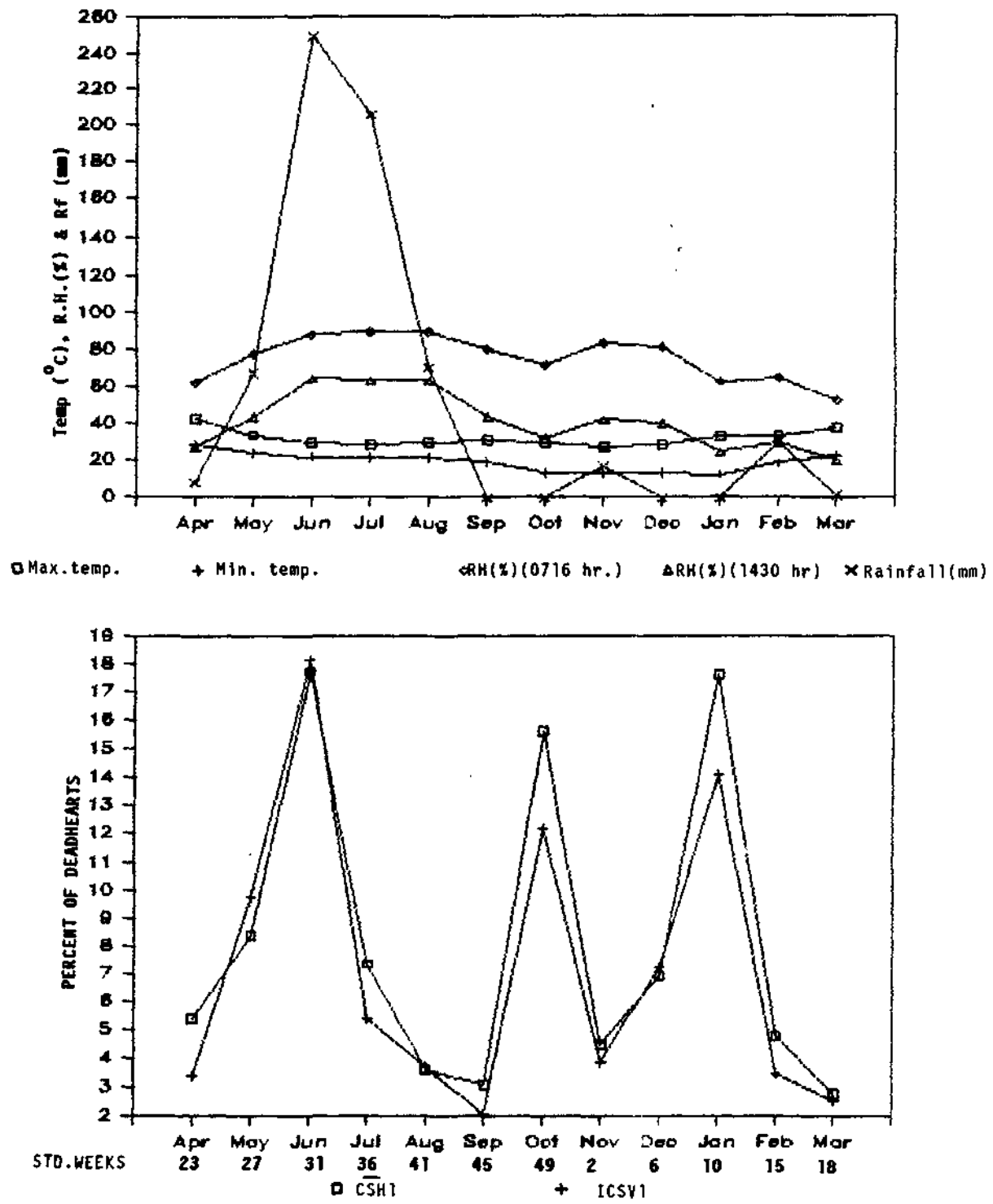


Fig.3: PERCENT OF STEM BORER DEADHEARTS AT 35 DAE IN RELATION TO WEATHER FACTORS DURING 1988-89.

correlations were observed with maximum temperature, evening relative humidity, rain fall and rainy days (Table 18).

The multiple linear regression model resulting from data in Table 19 was

$$Y = -80.66 + 0.38 x_1 + 1.30 x_2 + 1.25 x_3 - 1.16 x_4 + 0.13 x_5 - 0.85 x_6$$

and the path coefficient analysis data (Table 23) revealed highest negative and direct influence of evening relative humidity (-3.5237) followed by rainy days (-1.0028). The highest positive and direct effect was observed with morning relative humidity (3.1178) followed by rainfall (1.7660) and minimum temperature (1.2790) (Fig.4).

4.2.2.4 Stem borer counts at harvesting: All the abiotic factors were positively correlated with stem borer counts at harvesting but none of them were significant (Table 18). The regression model as obtained from Table 19 is:

$$Y = -160.92 + 3.72 x_1 - 0.84 x_2 + 0.89 x_3 + 0.007 x_4 + 0.29 x_5 - 2.85 x_6$$

The path coefficient analysis for stem borer counts at harvesting indicated highest positive and direct effect with rainfall (2.7533) and highest

Table 23 : Path Coefficient analysis : Climatological factors vs Stem borer count at Boot leaf stage.

Parameters	Temperature (°C)		Relative Humidity (%)		Rain Fall (mm)	Rainy days	Correlation with Stem borer count.
	Maximum	Minimum	Morning	Evening			
Maximum temperature °C	<u>0.2942</u>	0.7429	-2.6655	2.3299	-0.6348	0.3085	0.380
Minimum temperature °C	0.1709	<u>1.2790</u>	-0.3981	-0.6900	0.7488	-0.4773	0.630*
Morning Relative Humidity (per cent)	-0.2515	-0.1633	<u>3.1178</u>	-3.2885	1.0373	-0.5622	-0.110
Evening Relative Humidity (per cent)	-0.1945	0.2504	2.9096	<u>-3.5237</u>	1.3475	-0.7537	0.040
Rain Fall (mm)	-0.1057	0.5423	1.8313	-2.5888	<u>1.7660</u>	-0.9944	0.350
Rainy days	-0.0905	0.6088	1.7481	-2.6486	<u>1.7513</u>	<u>-1.0028</u>	0.370

Residual effect = 0.5451
 Underlined values have direct influence, others indirect
 Significant at 5% level.

Table 24 : Path Coefficient analysis : Climatological factors vs Stem borer counts at Harvesting

Parameters	Temperature (°C)		Relative Humidity (%)		Rain Fall (mm)	Rainy days	Correlation with Stem borer at Harvest.
	Maximum	Minimum	Morning	Evening			
Maximum temperature °C	<u>2.0822</u>	-0.3510	-1.3824	-0.0102	-0.9896	0.7505	0.100
Minimum temperature °C	1.2094	<u>-0.2064</u>	-0.2064	0.0030	1.1674	-1.1613	0.410
Morning Relative Humidity (per cent)	-1.7802	0.0771	<u>1.6170</u>	0.0145	1.6172	-1.3678	0.180
Evening Relative Humidity (per cent)	-1.3768	-0.1183	1.5090	<u>0.0155</u>	2.1009	-1.8337	0.300
Rain Fall (mm)	-0.7484	-0.2562	0.9498	0.0118	<u>2.7533</u>	-2.4192	0.290
Rainy days	-0.6406	0.2876	0.9066	0.0116	2.7302	<u>-2.4396</u>	0.280

Residual effect = 0.7940
Underlined values have direct influence, others indirect

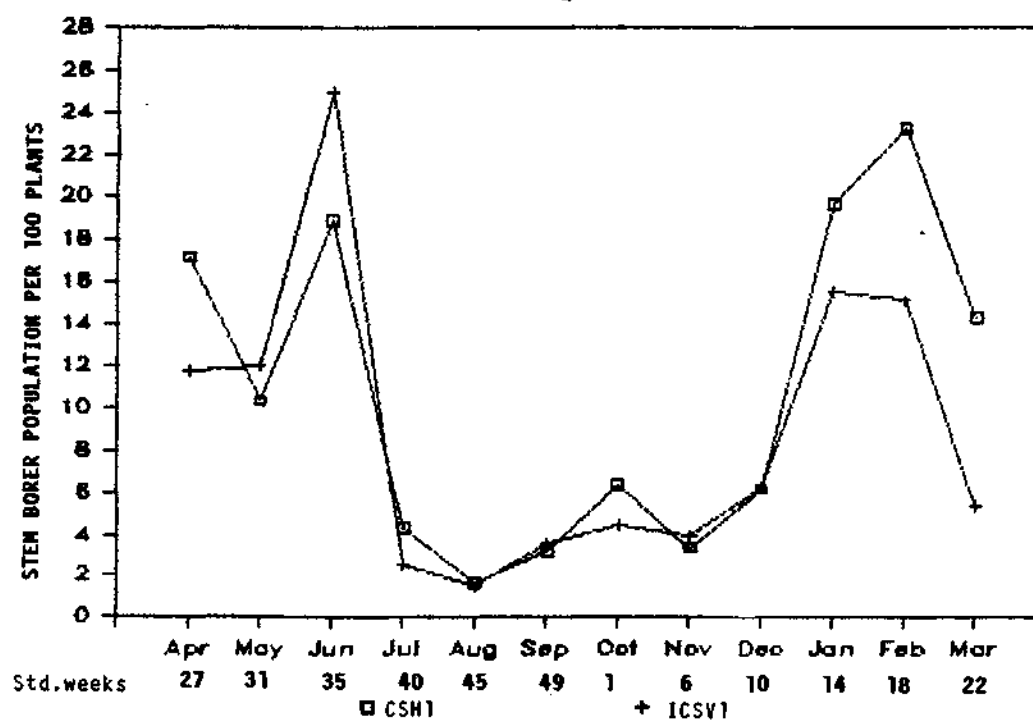
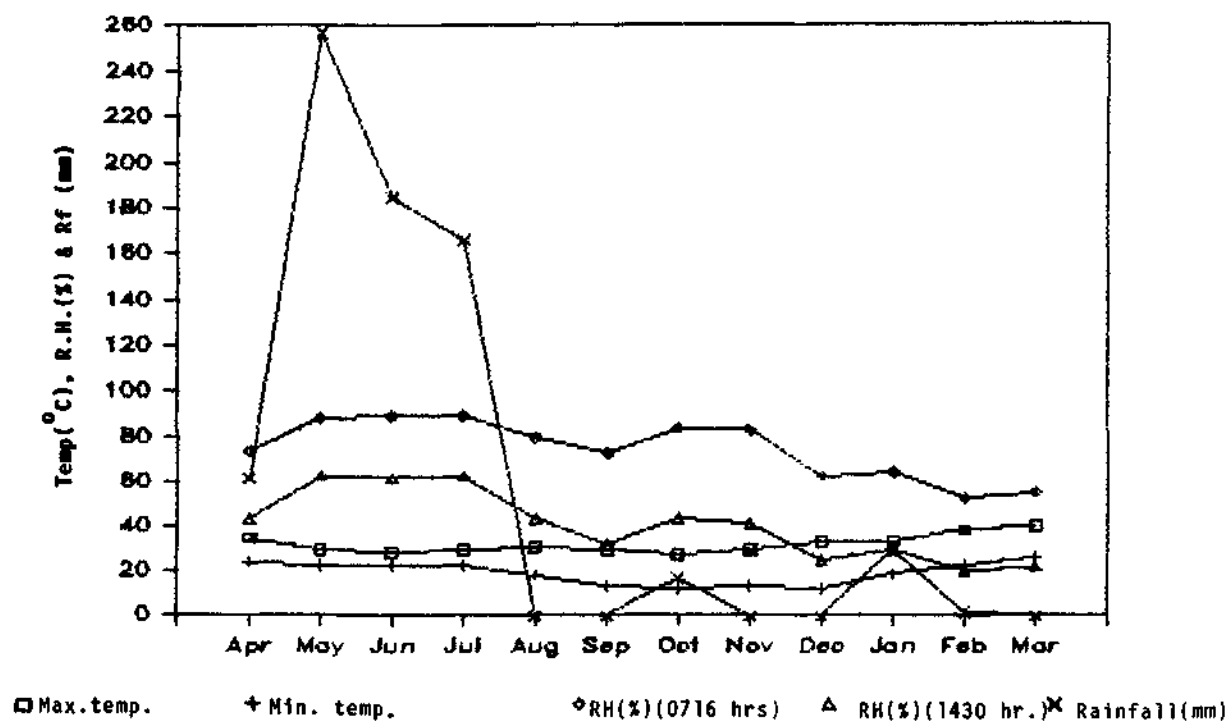


Fig.4: STEM BORER POPULATION AT BOOT LEAF STAGE IN RELATION TO WEATHER FACTORS DURING 1988-89.

negative and direct effect with rainy days (-2.4396) (Table 24 and Fig.5).

4.2.3 The shoot bug

A positive correlation was observed between shoot bug incidence at 30 DAE and minimum temperature ($r = 0.370$), morning relative humidity ($r = 0.700$), evening relative humidity ($r = 0.870$), rainfall ($r = 0.900$) and rainy days ($r = 0.910$). Negative correlation was observed with maximum temperature ($r = -0.460$). Except for maximum and minimum temperatures all other abiotic factors were found to be significant at 1% level (Table 18).

Multiple regression analysis was carried out to find out the relationship among the several climatological factors and the model obtained is: (Table 19).

$$Y = 351.45 - 8.15 x_1 + 2.62 x_2 - 3.16 x_3 + 2.90 x_4 + 0.19 x_5 + 2.12 x_6$$

The result indicated that all the partial regression co-efficients were non-significant even though, the climatic factors collectively were able to explain the variation in the shoot bug incidence to the extent of 87.45 out of 100.

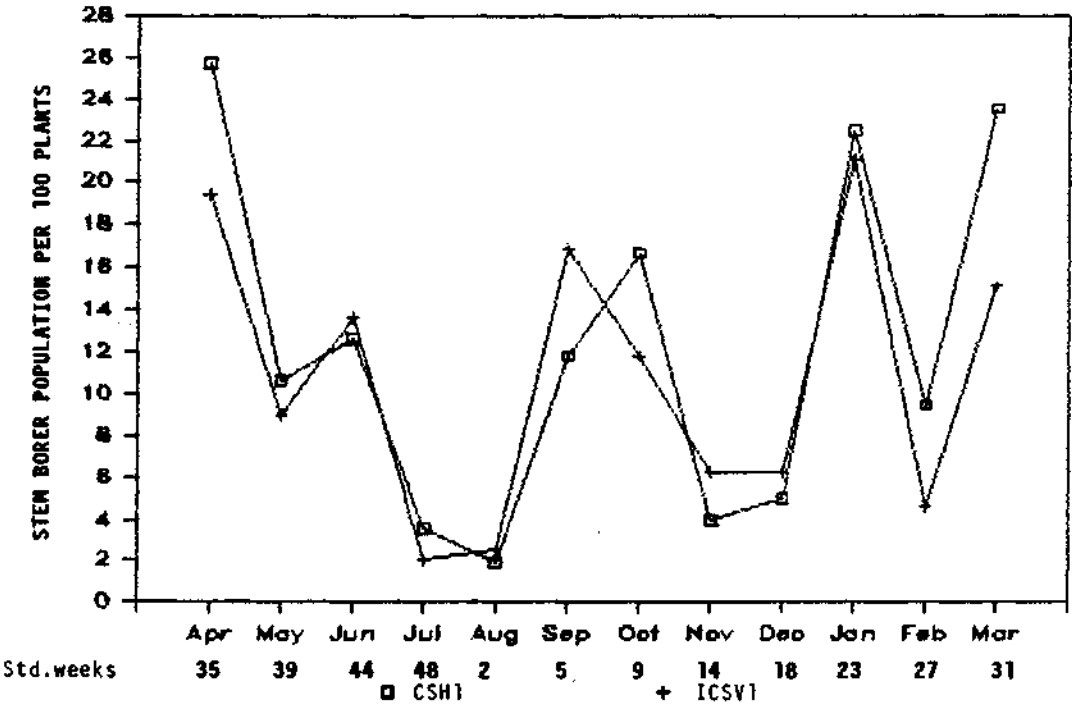
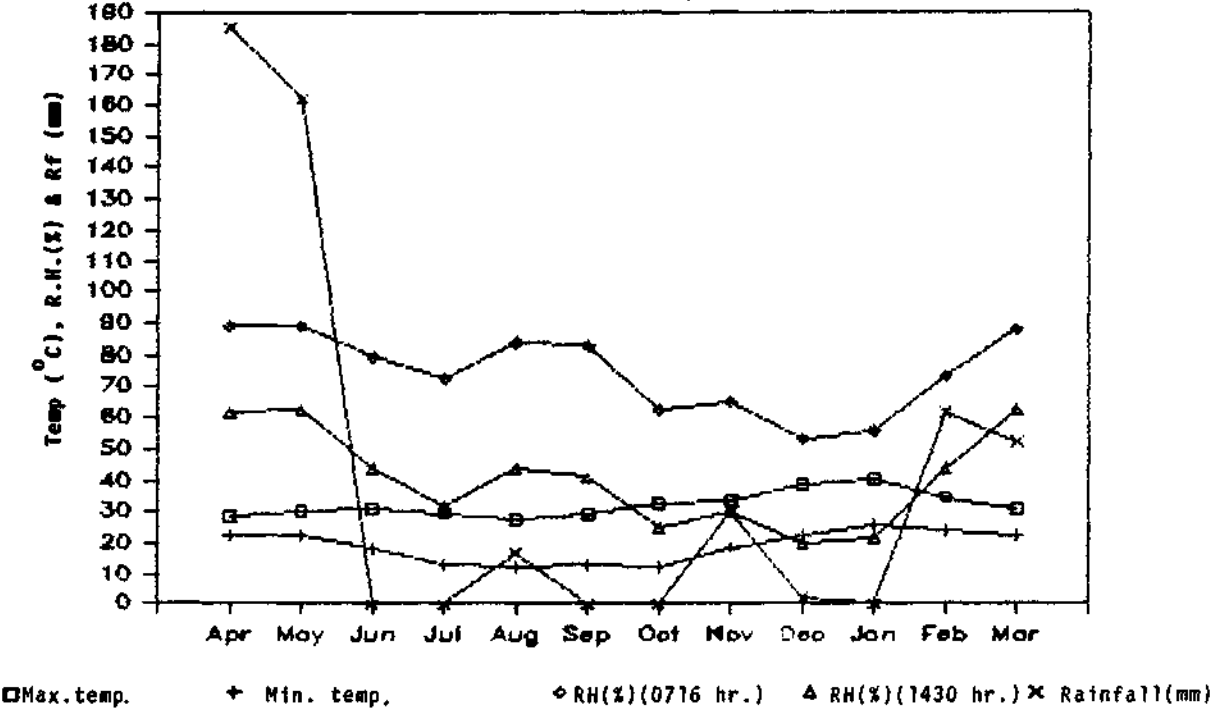


Fig.5 :STEM BORER POPULATION AT HARVESTING IN RELATION TO WEATHER FACTORS DURING 1988-89.

A perusal of the data indicates that there was highest positive and direct effect of evening relative humidity (0.6416) on incidence followed by rainfall (0.2504), rainy days (0.2189) and minimum temperature (0.1967). However, there is direct and negative effect of morning relative humidity (-0.5714) and maximum temperature (-0.4815) on shoot bug incidence (Table 25 and Fig.6).

4.2.4 The sorghum midge

4.2.4.1 Population: It was observed that midge incidence had a positive correlation with morning relative humidity, ($r=0.500$), evening relative humidity ($r=0.630$), rainfall ($r=0.640$) and rainy days ($r=0.830$) while the maximum and minimum temperatures were proved to be non significant (Table 18).

The linear regression model for midge incidence as obtained from Table 19 is:

$$Y = 26.09 + 0.96 x_1 - 1.72 x_2 - 0.55 x_3 + 0.38 x_4 - 0.36 x_5 + 10.94 x_6$$

It may be observed from the Table 19 that majority of the partial regression coefficients were found to be non significant except rainy days which was significant at 5% level. If there was an increase in one rainy day, there will be an increase of about 10.94

Table 25 : Path Coefficient analysis : Climatological factors vs Number of shoot bugs at 30 DAE

Parameters	Temperature (°C)		Relative Humidity (%)		Rain Fall (mm)	Rainy days	Correlation with shoot bug numbers
	Maximum	Minimum	Morning	Evening			
Maximum temperature °C	<u>-0.4815</u>	0.1100	0.4791	-0.4210	-0.0808	-0.0664	-0.460
Minimum temperature °C	-0.2693	<u>0.1967</u>	0.0490	0.1503	0.1258	0.1210	0.370
Morning Relative Humidity (per cent)	0.4038	-0.0169	<u>-0.5714</u>	0.5974	0.1555	0.1360	0.700**
Evening Relative Humidity (per cent)	0.3160	0.0461	-0.5321	<u>0.6416</u>	0.2101	0.1865	0.870**
Rain Fall (mm)	0.1553	0.0989	-0.3548	0.5382	<u>0.2504</u>	0.2130	0.900**
Rainy days	0.1460	0.1088	-0.3549	0.5464	<u>0.2437</u>	<u>0.2189</u>	0.910**

Residual effect = 0.3561
 Underlined values have direct influence, others indirect
 ** Significant at 1% level

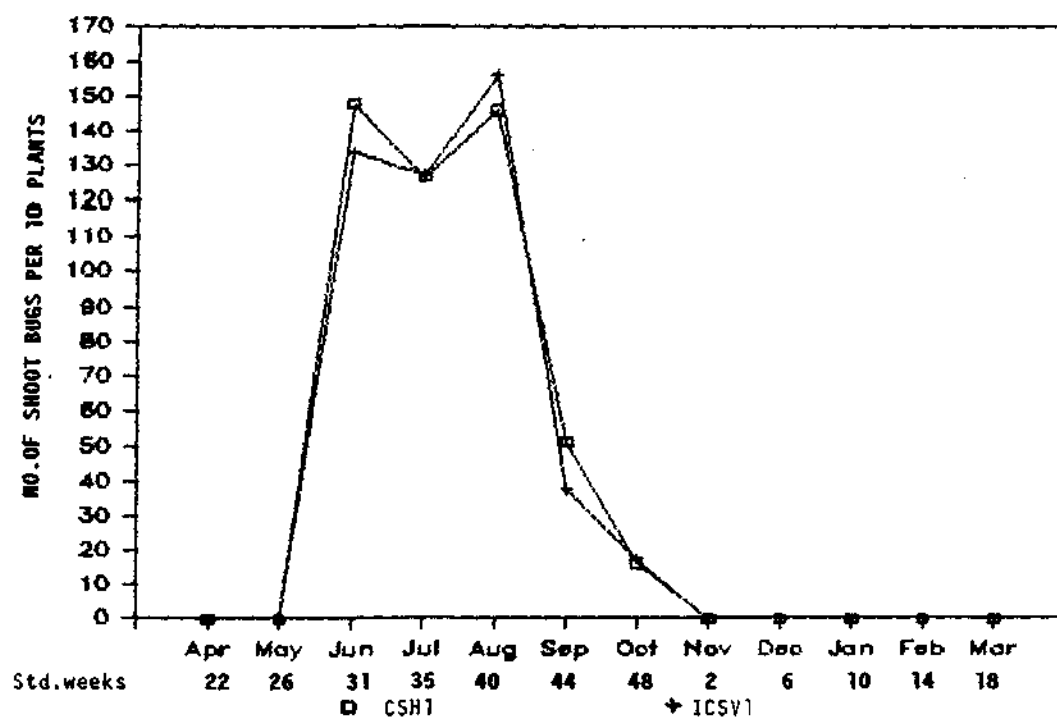
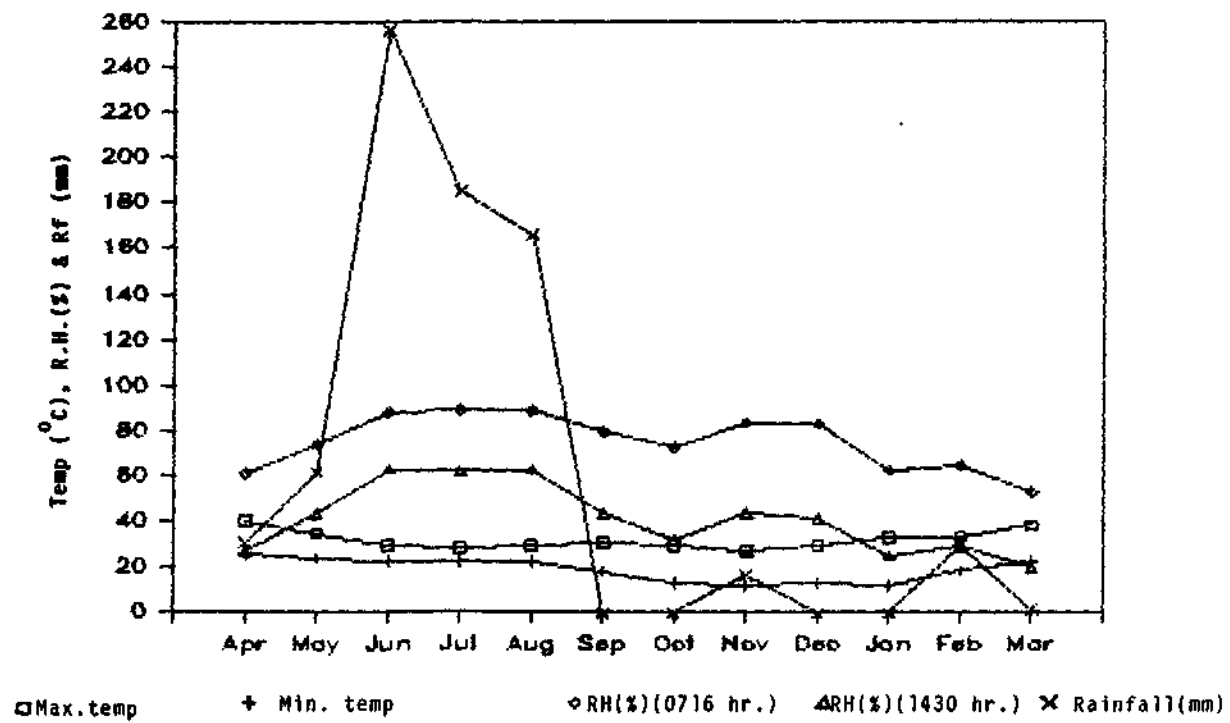


Fig.6: SEASONAL INCIDENCE OF SHOOT BUGS AT 30 DAE IN RELATION TO CLIMATIC FACTORS DURING 1988-89.

in midge incidence and the climatic factors were able to explain the variation in the population to the extent of 87.8 out of 100.

The path coefficient analysis results indicated (Table 26) that there was highest negative and direct effect of minimum temperature (-1.3145) followed by morning relative humidity (-1.0159) and rainfall (-0.6420). However, there was direct and positive effect of rainy days (2.2169), with evening relative humidity (1.0106) and maximum temperature (0.6206) on midge incidence. It was also observed that rainy days were positively influencing midge incidence indirectly as they had the highest positive and indirect effect in majority of cases.

4.2.4.2 Damage: A perusal of the data (Table 18) reveals that none of the correlations were significant at 5% level.

However, the midge damage was negatively significant with the partial regression coefficient, the rainfall and all other abiotic factors were observed to be non-significant (Table 19). The regression equation obtained is ;

$$Y = 241.80 - 2.91 x_1 - 0.79 x_2 - 2.82 x_3 + 2.51 x_4 - 0.75 x_5 + 8.87 x_6$$

Table 26 : Path Coefficient analysis : Climatological factors vs Number of midge flies

Parameters	Temperature (°C)		Relative Humidity (%)		Rain Fall (mm)	Rainy days	Correlation with Midge flies.
	Maximum	Minimum	0716 hrs.	1416 hrs.			
Maximum temperature °C	<u>0.6206</u>	-0.6808	0.8087	-0.5520	0.2131	-0.9196	-0.510
Minimum temperature °C	0.3214	<u>-1.3145</u>	0.0079	0.3639	-0.2309	1.0639	0.210
Morning Relative Humidity (per cent)	-0.4940	0.0103	<u>-1.0159</u>	0.8742	-0.3588	1.5621	0.580*
Evening Relative Humidity (per cent)	-0.3390	-0.4733	-0.8708	<u>1.0106</u>	-0.3803	1.6938	0.630*
Rain Fall (mm)	-0.2060	-0.4727	-0.5678	0.5986	<u>-0.6420</u>	1.9302	0.640*
Rainy days	-0.2574	-0.6308	-0.7158	0.7722	-0.5590	<u>2.2169</u>	0.830**

Residual effect = 0.3561
 Underlined values have direct influence, others indirect
 * Significant at 5% level
 ** Significant at 1% level

Table 27 : Path Coefficient analysis : Climatological factors vs Sorghum midge damage

Parameters	Temperature (°C)		Relative Humidity (%)		Rain Fall (mm)	Rainy days	Correlation with Midge damage
	Maximum	Minimum	0716 hrs.	1416 hrs.			
Maximum temperature °C	<u>-0.6610</u>	-0.1231	1.6095	-1.4937	0.8555	-0.6245	-0.440
Minimum temperature °C	-0.3816	<u>-0.2132</u>	0.2416	0.2580	-0.8353	0.7902	-0.140
Morning Relative Humidity (per cent)	0.5196	0.0252	<u>-2.0477</u>	1.9838	-1.2647	1.0450	0.260
Evening Relative Humidity (per cent)	0.4630	-0.0258	-1.9047	<u>2.1328</u>	-1.7124	1.3765	0.330
Rain Fall (mm)	0.2650	-0.0834	-1.2135	1.7114	<u>-2.1340</u>	1.6184	0.160
Rainy days	0.2372	-0.0968	-1.2298	1.6872	-1.9849	<u>1.7400</u>	0.350

Residual effect = 0.4988

Underlined values have direct influence, others indirect

An increase in rainfall by one millimetre will decrease the midge damage by 0.757 per cent. The climatic factors in concert were able to explain the variation in the population to the extent of 75.11 out of 100.

A perusal of the data (Table 27) revealed that evening relative humidity (2.1328) and rainy days (1.740) had direct and positive influence, whereas rainfall (-2.1340), morning relative humidity (-2.0477), maximum temperature (-0.6610) and minimum temperature (-0.2132) had negative and direct effect on midge damage. It was also observed that intensity of rainfall was negatively influencing midge damage, as it had the highest negative and indirect effect in majority of cases (Fig.7).

4.2.5 The sorghum head bugs

The head bug incidence was positively correlated with morning relative humidity ($r = 0.600$), evening relative humidity ($r = 0.740$) and rainy days ($r = 0.610$) which were significant (Table 18).

The partial regression coefficients were observed to be non-significant for head bug incidence and the equation was given as (Table 19).

$$Y = 3406.88 - 88.28 x_1 + 41.01 x_2 - 17.52 x_3 + 1.32 x_4 - 1.97 x_5 + 36.01 x_6$$

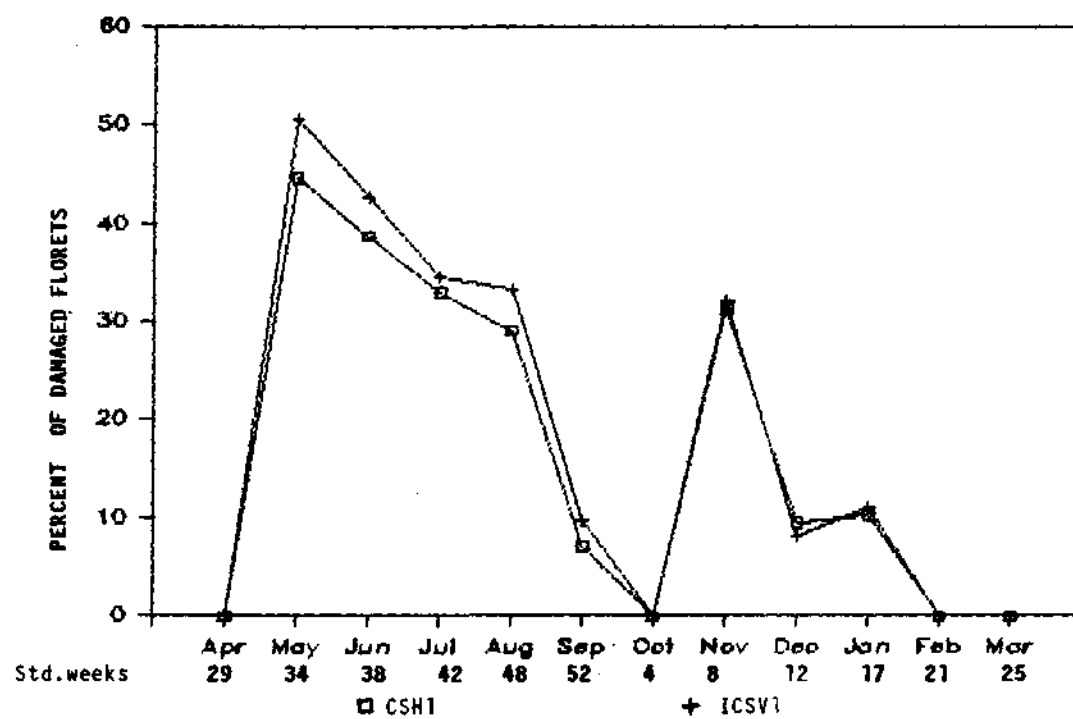
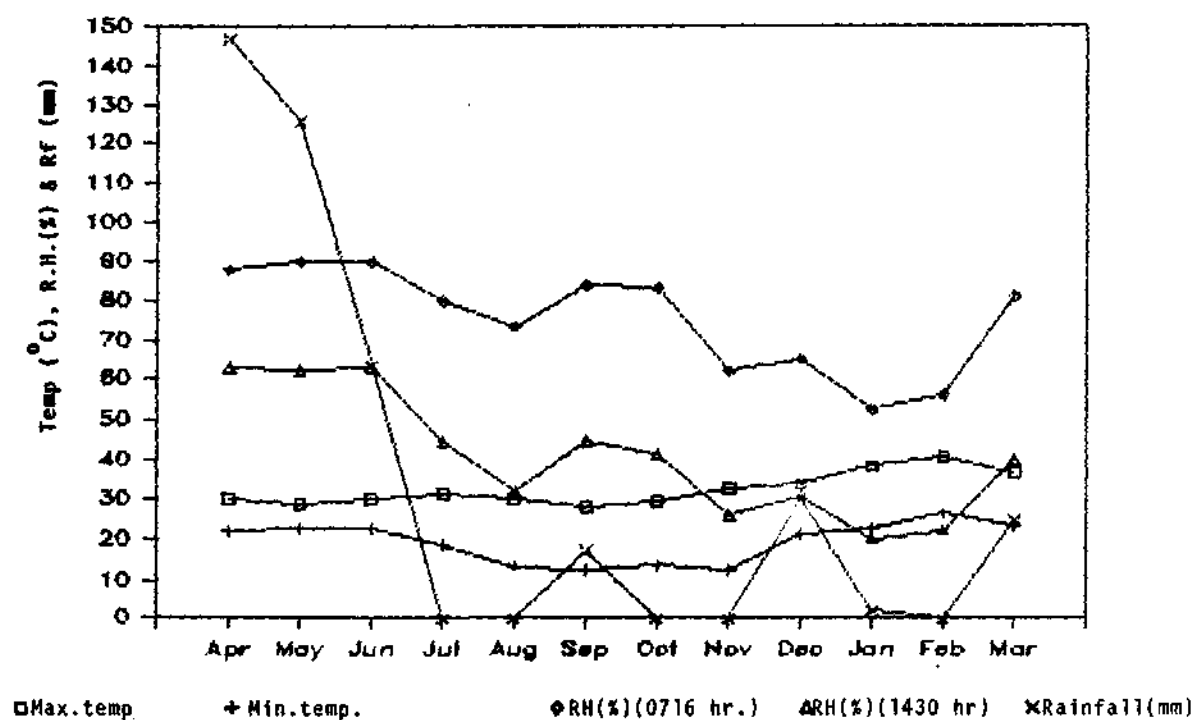


Fig.7 : PERCENT OF MIDGE INFESTED FLORETS IN RELATION TO CLIMATIC FACTORS DURING 1988-89.

Table 28 : Path Coefficient analysis : Climatological factors vs Number of head bugs

Parameters	Temperature (°C)		Relative Humidity (%)		Rain Fall (mm)	Rainy days	Correlation with Number of head bugs
	Maximum	Minimum	0716 hrs.	1416 hrs.			
Maximum temperature °C	<u>-3.0331</u>	1.1523	1.5115	-0.1017	0.0611	-0.0276	-0.440
Minimum temperature °C	-2.1488	<u>1.6265</u>	0.5875	-0.0017	-0.2015	0.3108	0.170
Morning Relative Humidity (per cent)	2.7130	-0.5655	<u>-1.6898</u>	0.1332	-0.1636	0.1750	0.600*
Evening Relative Humidity (per cent)	2.1162	-0.0194	-1.5438	<u>0.1458</u>	-0.2875	0.3257	0.740**
Rain Fall (mm)	0.2795	0.4948	-0.4172	0.0633	<u>-0.6626</u>	0.7108	0.470
Rainy days	0.1074	0.6482	-0.3791	0.0609	-0.6039	<u>0.7799</u>	0.610*

Residual effect = 0.3666
 Underlined values have direct influence, others indirect
 * Significant at 5% level
 ** Significant at 1% level

It was found that the coefficient of determination ($R_2 = 0.865$) for abiotic factors taken was able to explain the variation in the population to the extent of 86.5 out of 100.

It is observed from Table 28 that maximum temperature had the highest negative and direct effect (-3.0331) where as the highest positive and direct effect was observed in minimum temperature (1.6265) (Fig.8).

4.3 BIOECOLOGY OF SORGHUM SHOOT BUG

Studies on the habits, mating, oviposition and life history of shoot bug, *P. maidis* were carried out in the laboratory and the incidence, avoidable loss, cost-benefit ratio, and bioefficacy of certain insecticides in the field were worked out and the results are presented below.

4.3.1 Habit

The nymphs and adults were semigregarious in nature and were found occurring on leaves, leaf whorls and on the inner side of the leaf sheaths. The top shoots were more crowded with nymphs and adults than those of middle and bottom portions of the plants. The nymphal population when compared to the adults was always considerably more. The crowding of the nymphs

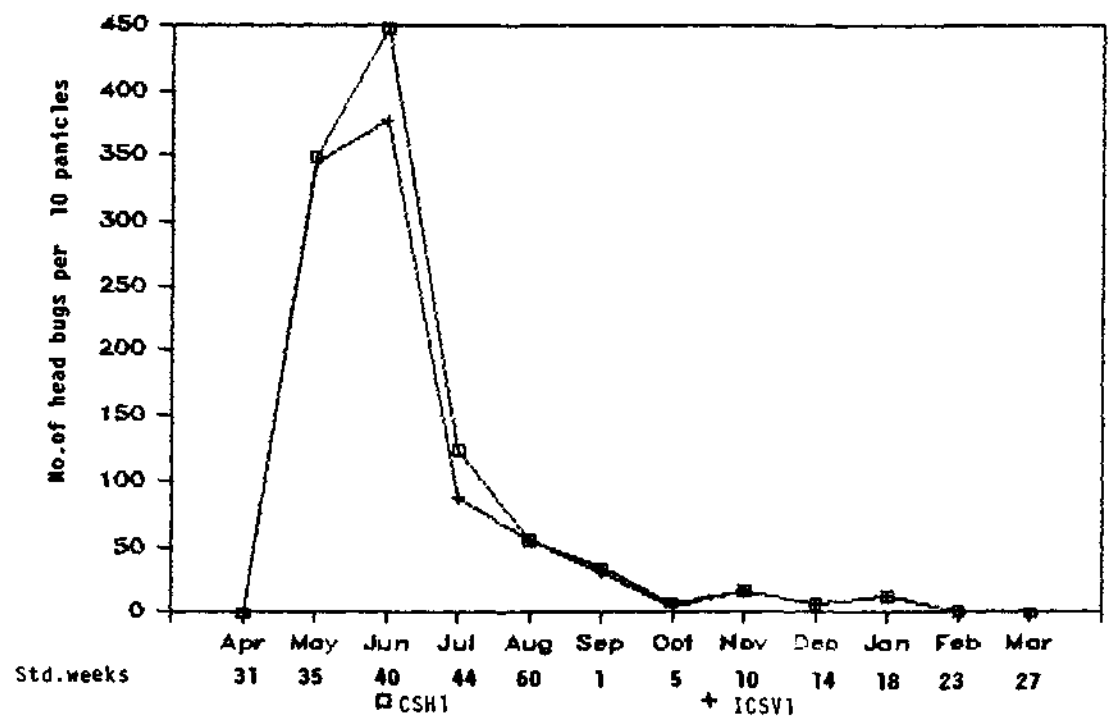
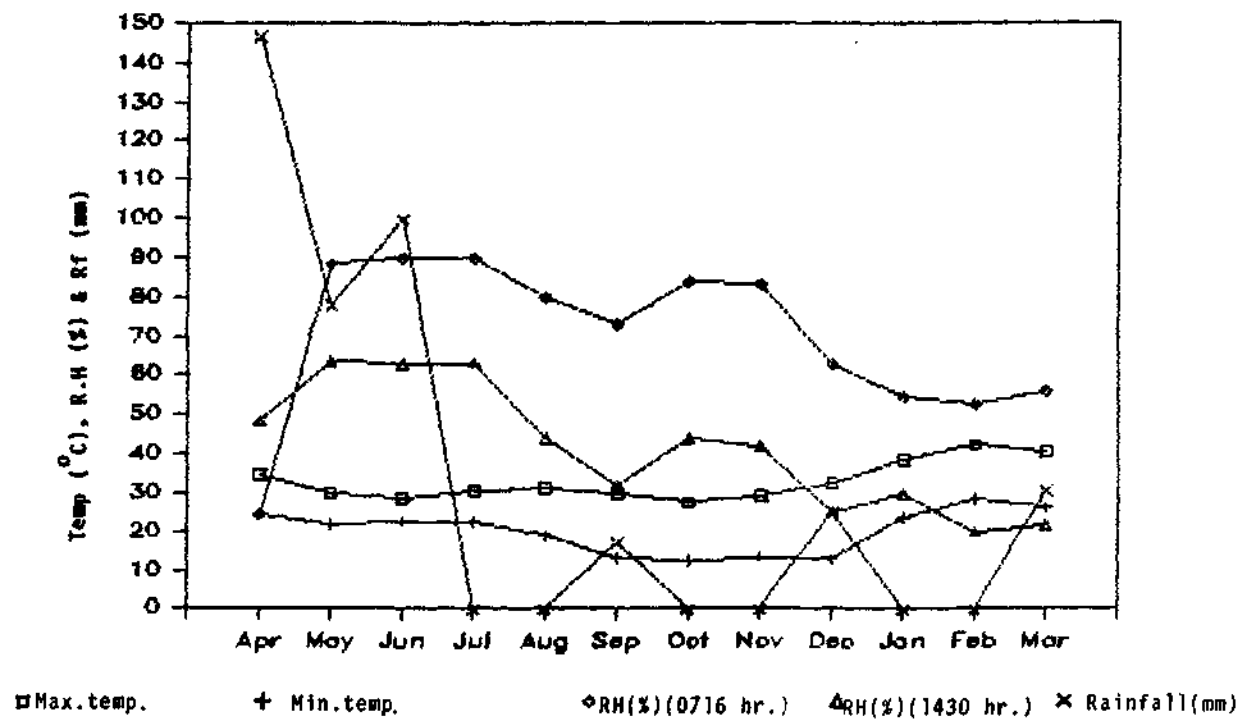


Fig.8 : SEASONAL INCIDENCE OF HEAD BUGS AT MILKY GRAIN STAGE IN RELATION TO CLIMATIC FACTORS DURING 1988-89.

and adults in the top shoots indicated their preference for the tender parts of the plants which were mostly attended by black ants (Plate 9).

Both nymphs and adults feed on the leaves and stems of plants by puncturing the tissue. During feeding, the insect was noted to excrete clear, viscous and shiny honey dew as fine drop lets.

4.3.2 Nature of injury

When in less numbers, the damage to the crop was not marked. Due to attack of large number of nymphs and adults, the attacked plants showed an unhealthy yellow appearance, combined with stunted growth. The honey dew excreted by the nymphs and adults favoured fungal growth causing sooty mold, Capnodium sp., which gave a sickly appearance to the plants. The adults were found to oviposit mostly in the midrib as a result of which the midrib turned red in colour and dried finally.

4.3.3 Life History

Biology of the sorghum shoot bug was studied on the potted plants during September to January for two generations during 1988 to 1989. During the first generation (September to November), average minimum and maximum temperatures recorded were 21.33°C and 29.64°C,



Plate No.9: Shoot bug population in sorghum leaf whorl

respectively. The relative humidity ranged from 45.16 to 79.39 percent. During the second generation (November to January) the average minimum and maximum temperatures were 17.4°C and 28.75°C , respectively. The relative humidity ranged from 33.12 to 54.62 per cent.

4.3.3.1 Mating: Mating was observed mostly in the morning hours. The duration of mating lasted for 10 to 15 minutes during September to November and 10 to 13 minutes during November to January months.

4.3.3.2 Preoviposition period and oviposition: The pre oviposition period ranged from 2 to 3 days. Mainly, the upper surface of the midrib was preferred for oviposition. The female made a slit by its ovipositor in the plant tissue inside which the eggs were deposited. Groups of one to five eggs were laid and covered from outside by a white waxy substance secreted by the female which hardened after some time. A maximum of 46 eggs were laid by a single female in five days during September to November months. The number of eggs laid were accounted from the number of nymphs hatched out.

4.3.3.3 Incubation period: The incubation period varied from 7 to 10 days with an average of 8.2 days during September to November and 7 to 9 days with an average of 8 days during November to January (Table 29).

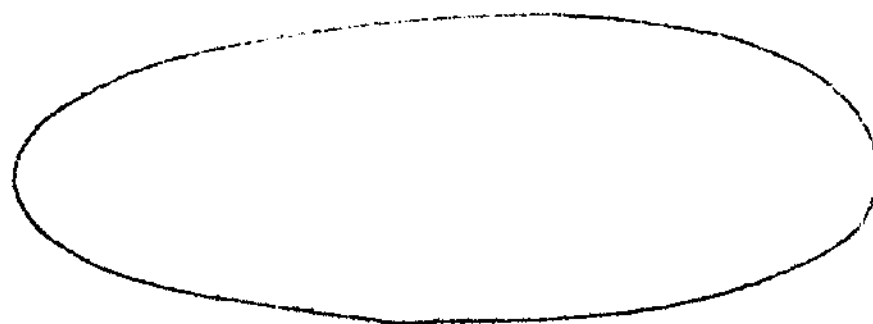
Bionomics

4.3.3.4 Egg: The egg is white, elongate, cylindrical and slightly tapering at the ends. The anterior end is narrower than the posterior. The average length and breadth were 1.23 mm and 0.33 mm, respectively during September to November and 1.24 mm and 0.29 mm, respectively during November to January (Fig.9).

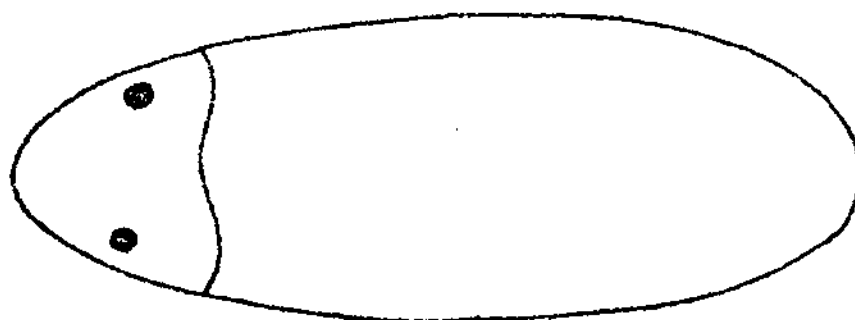
4.3.3.5 First instar nymph: The newly hatched nymph was yellowish orange in colour turning to pale yellow after it starts feeding. Eyes are oval, bright red in colour, situated at the posterior end of the head on either side distally. Hind leg longer than the other two pairs. A movable spur is present at the apex of the posterior tibia. It was active and found to possess nine visible segments (Fig.10).

The duration of first instar ranged from 3 to 4 days in both the generations. The average length and width were almost similar in both the generations (Table 29).

4.3.3.6 Second instar nymph: It was mostly similar to first instar. Development of wing pads was seen in the meso and meta thorax. Pale yellow in colour. The nymphs are active and move in all directions with equal ease (Fig.11).

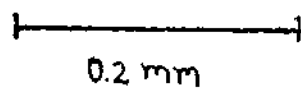


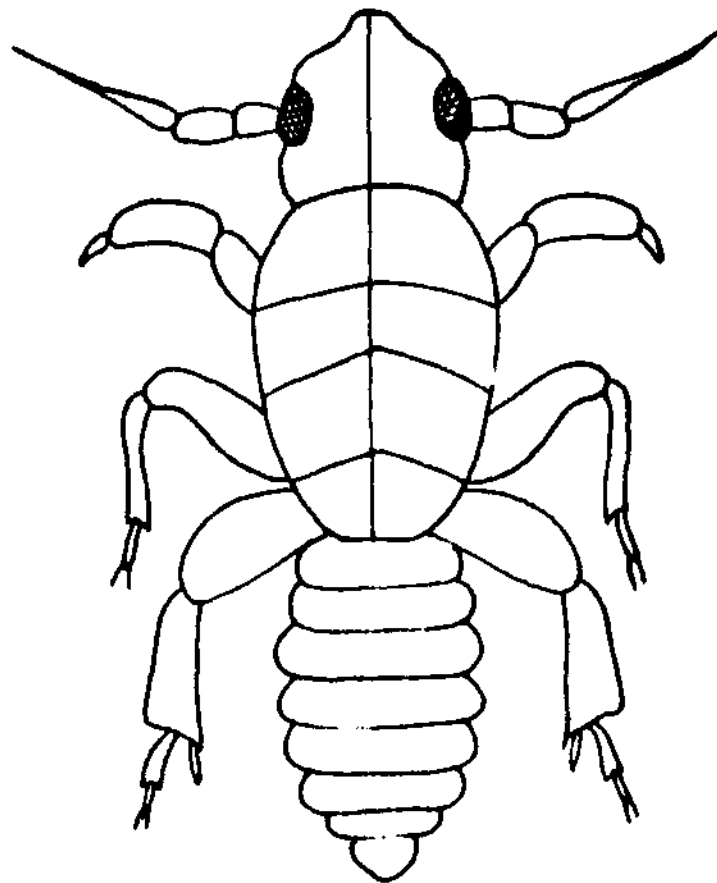
A. EGG IMMEDIATELY AFTER IT IS LAID



B. EGG BEFORE HATCHING

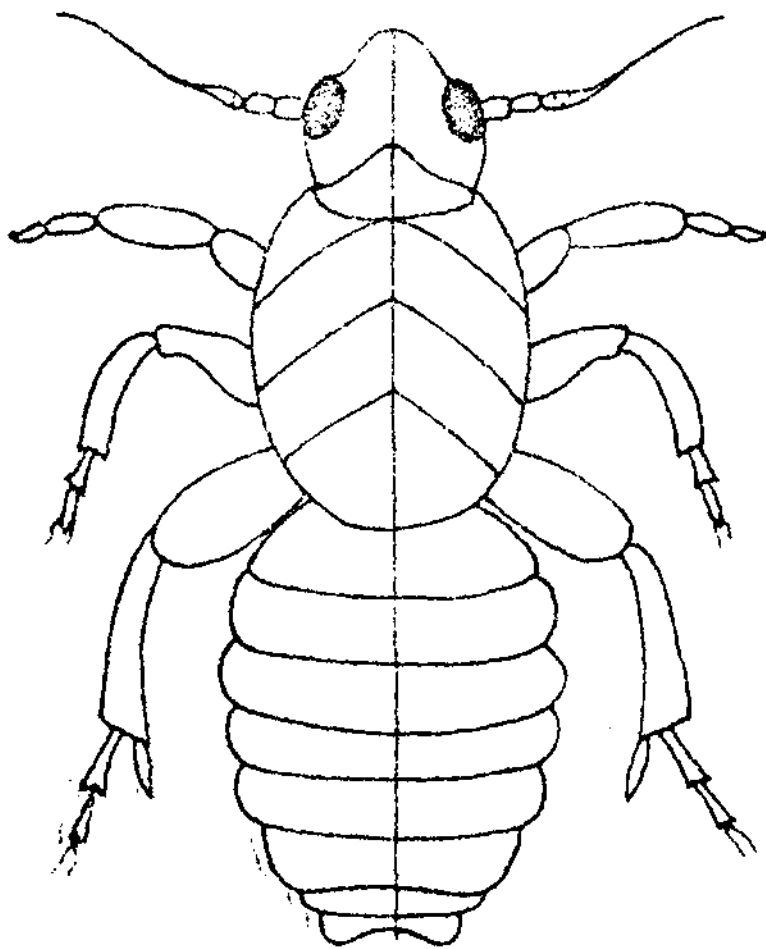
FIG.9: EGG OF P.maidis





0.2 mm

FIG.10: FIRST INSTAR NYMPH OF P.maidis



0.2 mm

FIG.11: SECOND INSTAR NYMPH OF P. maidis

The duration of second instar ranged from 3 to 4 days with an average of 3.2 days in both the generations. The length and width are 1.45 and 0.48 mm in first generation and 1.42 mm and 0.47 mm in second generation, respectively.

4.3.3.7 Third instar nymph: The third instar nymph is pale yellow in colour but darker than the second instar. Head distinct, antennal sensoria more developed and wing pads are more prominent than second instar. Abdominal terga dark coloured than the rest of the body. Very active and jumps quickly if disturbed (Fig.12).

The average duration was 2.8 days during first generation and 2.6 days during second generation. The average length and width during the first generation are 1.79 and 0.68 mm, respectively and in the second generation 1.78 and 0.67 mm, respectively (Table 29).

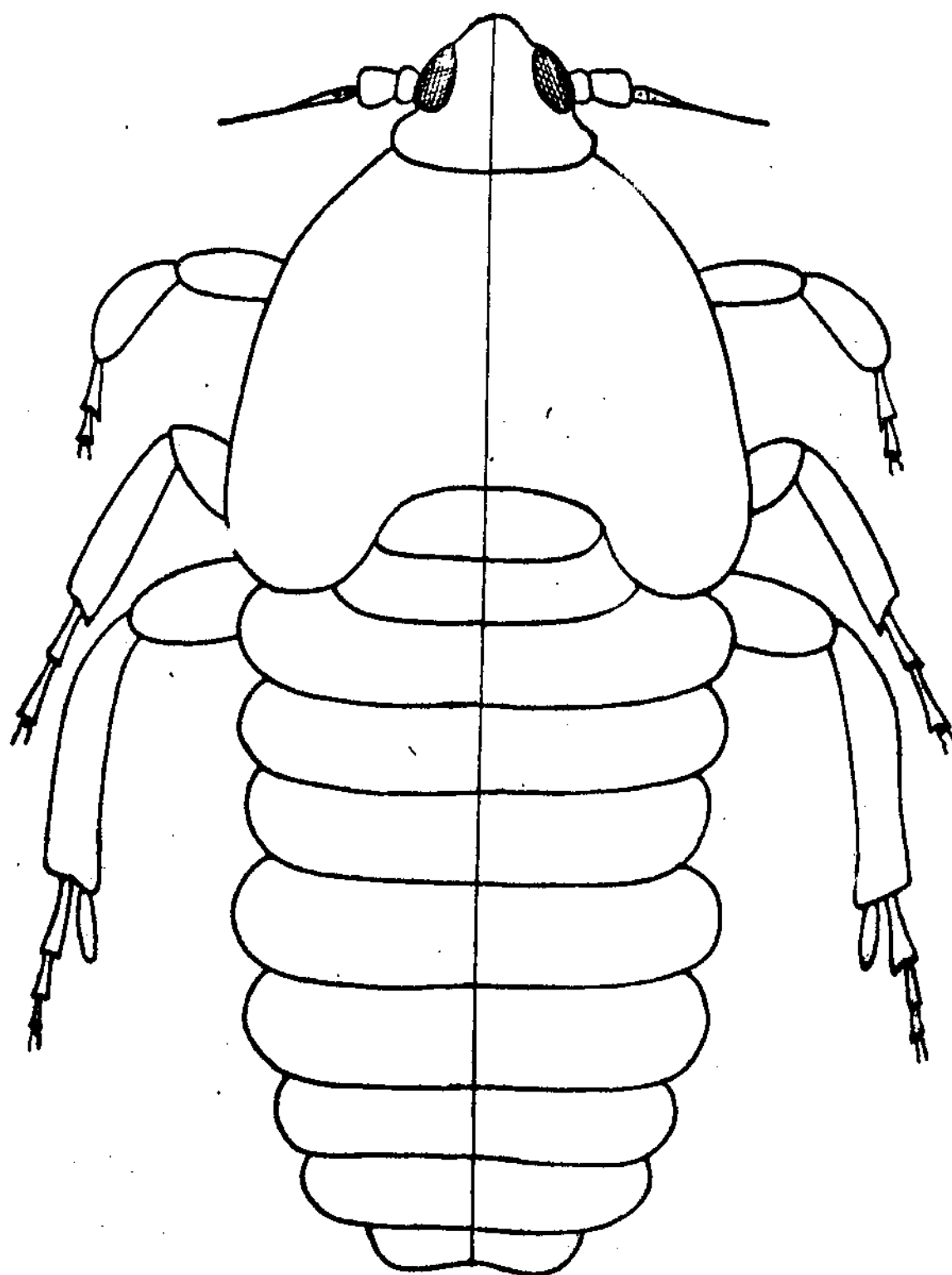
4.3.3.8 Fourth instar nymph: Prothorax broader and longer. Meso and metathorax well developed with prominent wing pads. Eyes large and prominent (Fig.13). The tenth segment of the abdomen is seen as a conical projection from the ninth segment with a posterior median cleft (Fig.14). More active than third instar.

The average duration was found to be 3.4 days in first generation and 3.6 days in second generation. The mean length and width are 2.57 and 1.07 mm and 2.55

Table 29: Duration and measurement of life stages of *P. maidis* during two generation

Stage	Duration (days)		Length (mm)		Width (mm)	
	First generation	Second generation	First generation	Second generation	First generation	Second generation
Egg	7-10 (8.2)	7-9 (8)	1.1-1.3 (1.23)	1.19-1.30 (1.24)	0.31-0.34 (0.33)	0.28-0.31 (0.29)
Nymph I instar	3-4 (3.6)	3-4 (3.8)	1.0-1.03 (1.02)	1.01-1.03 (1.01)	0.27-0.31 (0.28)	0.27-0.29 (0.28)
II instar	3-4 (3.2)	3-4 (3.2)	1.43-1.49 (1.45)	1.41-1.43 (1.42)	0.47-0.49 (0.48)	0.47-0.48 (0.47)
III instar	2-3 (2.8)	2-3 (2.6)	1.76-1.83 (1.79)	1.76-1.79 (1.78)	0.67-0.69 (0.68)	0.67-0.69 (0.67)
IV instar	3-4 (3.4)	3-4 (3.6)	2.50-2.59 (2.57)	2.50-2.68 (2.55)	1.01-1.12 (1.07)	1.02-1.11 (1.06)
V instar	3-4 (3.6)	3-4 (3.4)	3.01-3.12 (3.09)	3.01-3.17 (3.09)	1.42-1.48 (1.45)	1.42-1.47 (1.44)
Nymphal period	14-19 (16.6)	14-19 (16.6)	--	--	--	--
Brachypterous males	12-14 (12.8)	--	3.21-3.23 (3.22)	--	1.20-1.22 (1.21)	--
Brachypterous females	37-42 (39.6)	--	3.74-3.84 (3.79)	--	1.63-1.71 (1.66)	--
Macropterous males	14-16 (15.0)	10-12 (10.8)	3.16-3.20 (3.19)	3.10-3.18 (3.12)	1.13-1.18 (1.15)	1.13-1.15 (1.14)
Macropterous females	37-43 (38.2)	33-37 (35.2)	3.80-3.82 (3.81)	3.80-3.82 (3.80)	1.42-1.46 (1.44)	1.43-1.46 (1.44)
Total life cycle	21-29 (24.8)	21-28 (24.6)	--	--	--	--

Figures in parenthesis are average values



0.2 mm

FIG.12: THIRD INSTAR NYMPH OF P.maidis

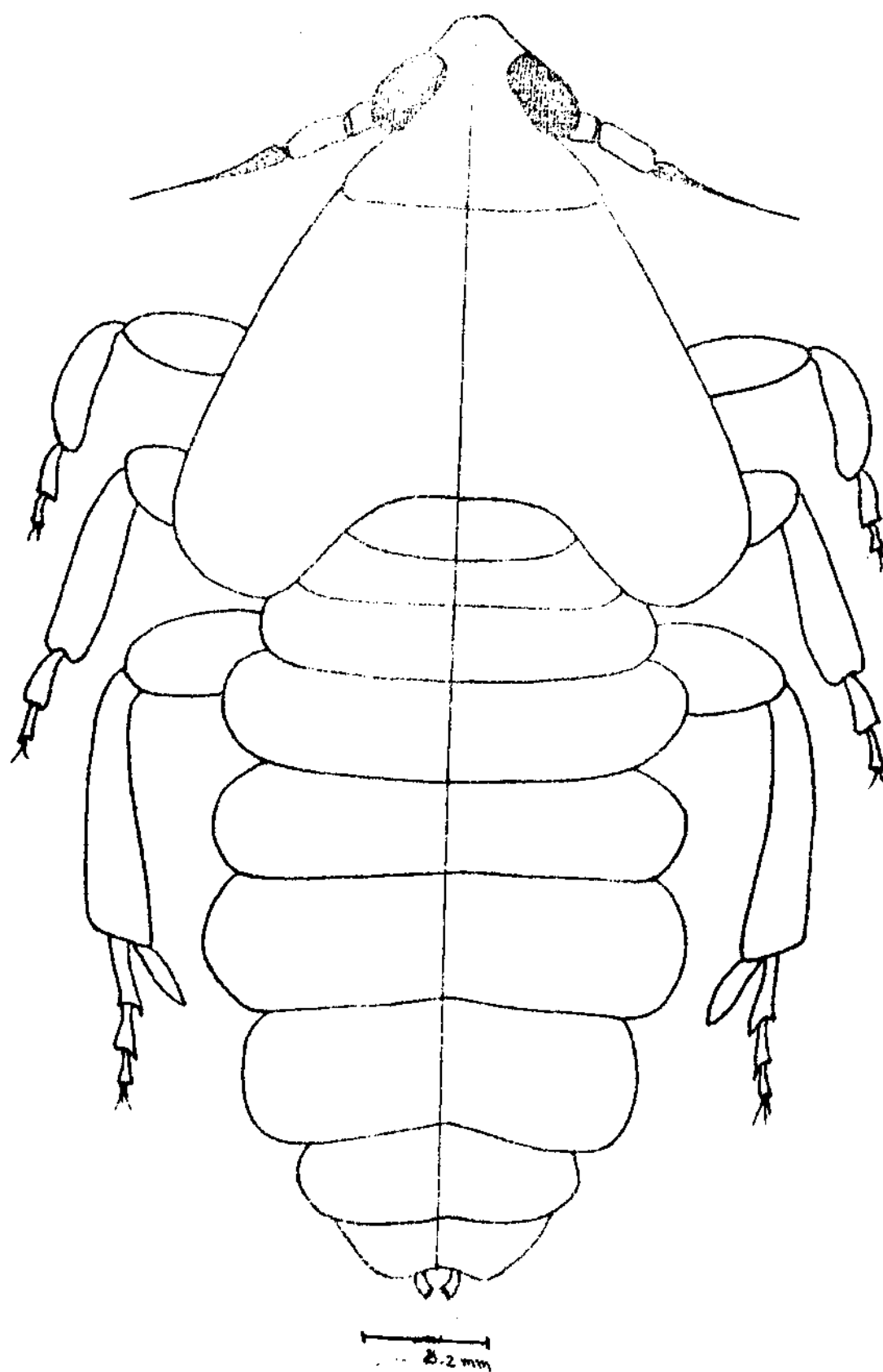


FIG.13: FOURTH INSTAR NYMPH OF P. maidis

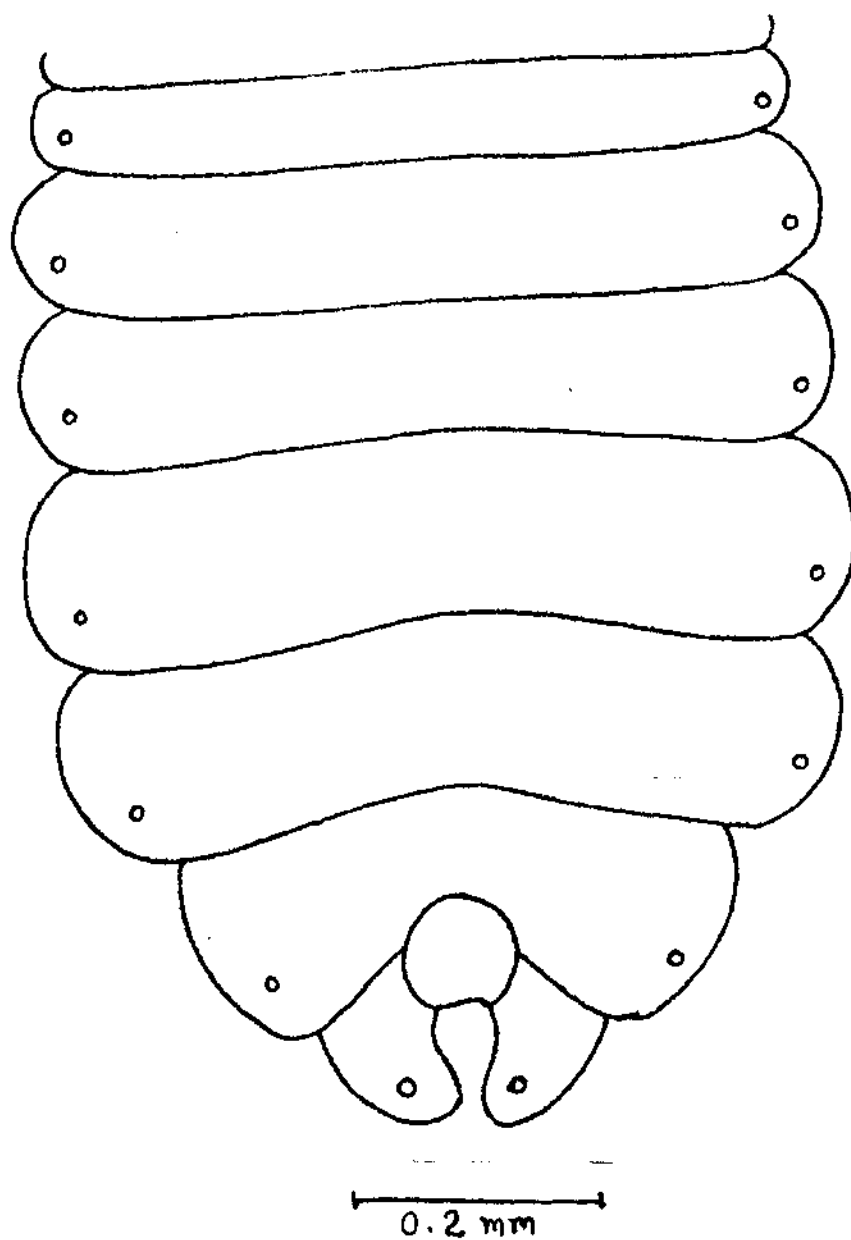


FIG.14: ABDOMEN OF FOURTH INSTAR NYMPH SHOWING THE INITIATION OF KNOB SHAPED EXTERNAL GENITALIA

and 1.06 mm during the first and second generations, respectively.

4.3.3.9 Fifth instar nymph: General colour of the body light brown, the tergal borders being dark brown. Eyes prominent. Lateral ocelli distinct. Legs well developed, stronger with prominent tibial and tarsal spurs (Fig.15). Abdomen darker than rest of the body. Developing genitalia is seen at the distal end of the abdomen (Fig.16 and 17).

The duration of the instar in the first generation was 3.6 days and in the second generation it was 3.4 days. The mean length and width are 3.09 and 1.45 mm and 3.09 and 1.44 mm in the first and second generation, respectively.

4.3.3.10 Total nymphal period: There were five nymphal instars. The total nymphal period on an average was 16.6 days in both the generations (Table 29).

4.3.3.11 Total life cycle: The life cycle of the shoot bug from egg to adult emergence was completed in a period ranging from 22 to 26 days with an average of 24.8 days during first generation and with 21 to 28 days in the second generation (Plate 10).

4.3.3.12 Adult: Macropterous and brachypterous adults are found in both the sexes. Colour yellowish brown in

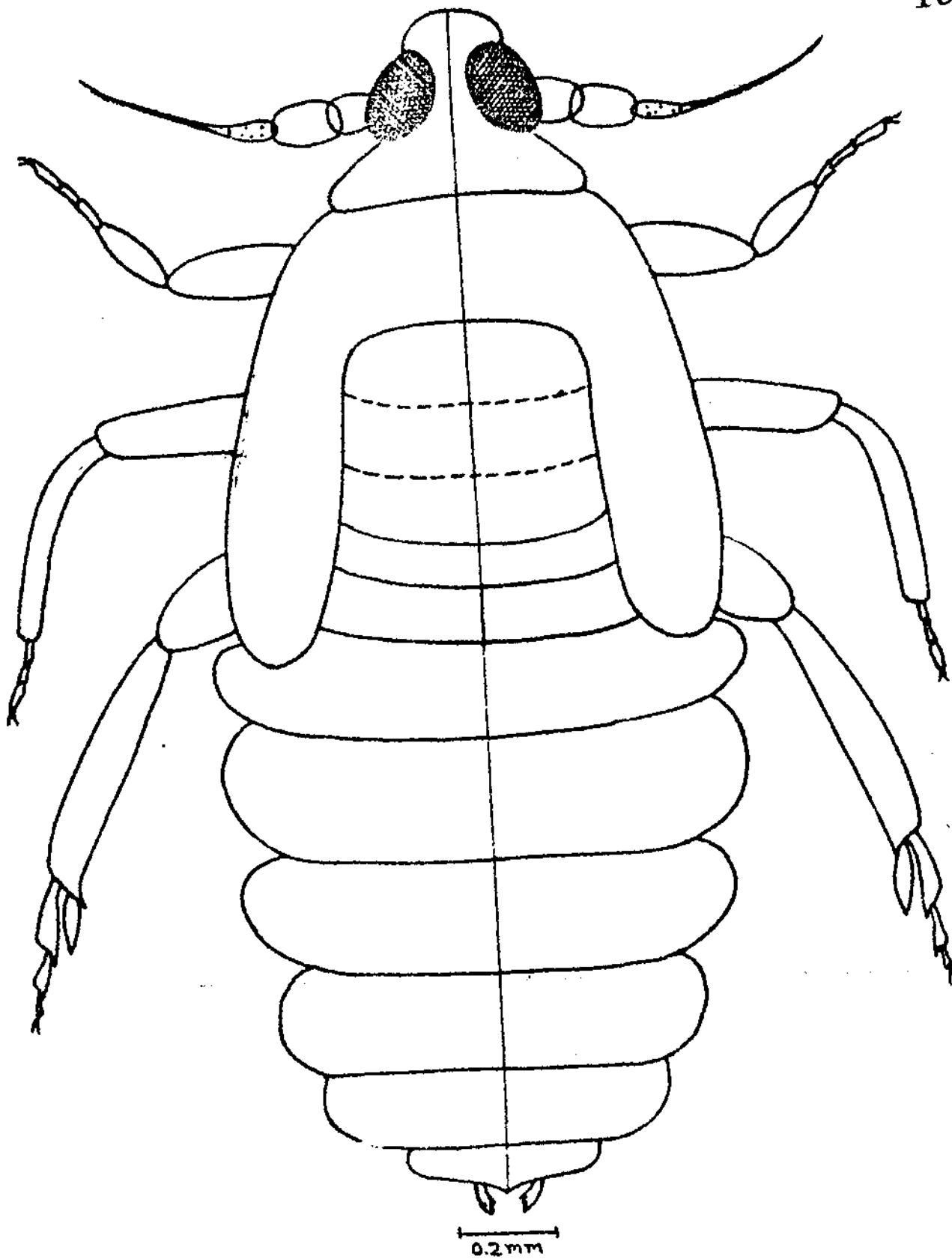


FIG.15: FIFTH INSTAR NYMPH OF P.maidis

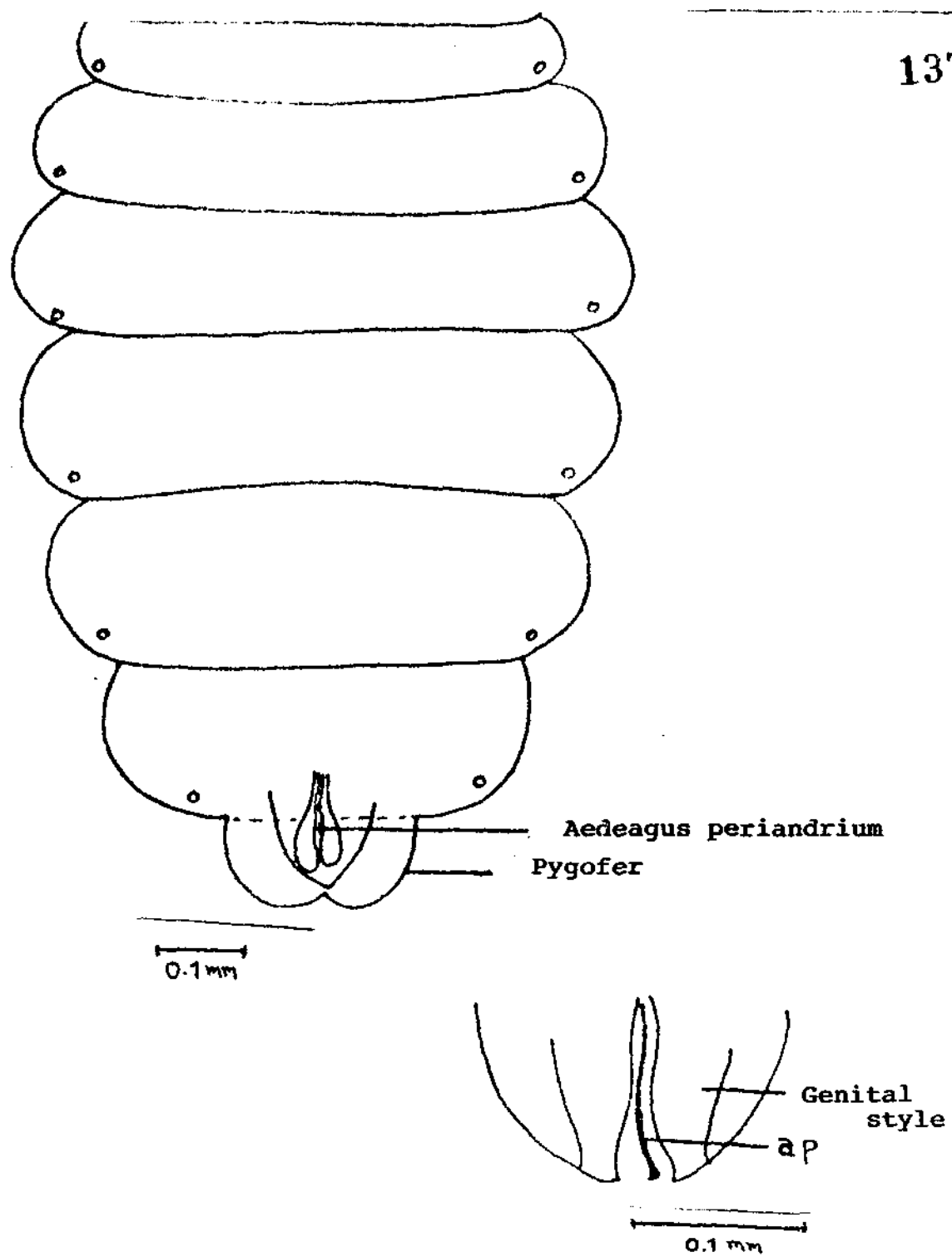


FIG.16: EXTERNAL MALE GENITALIA OF FIFTH INSTAR NYMPH
OF *P. maidis*

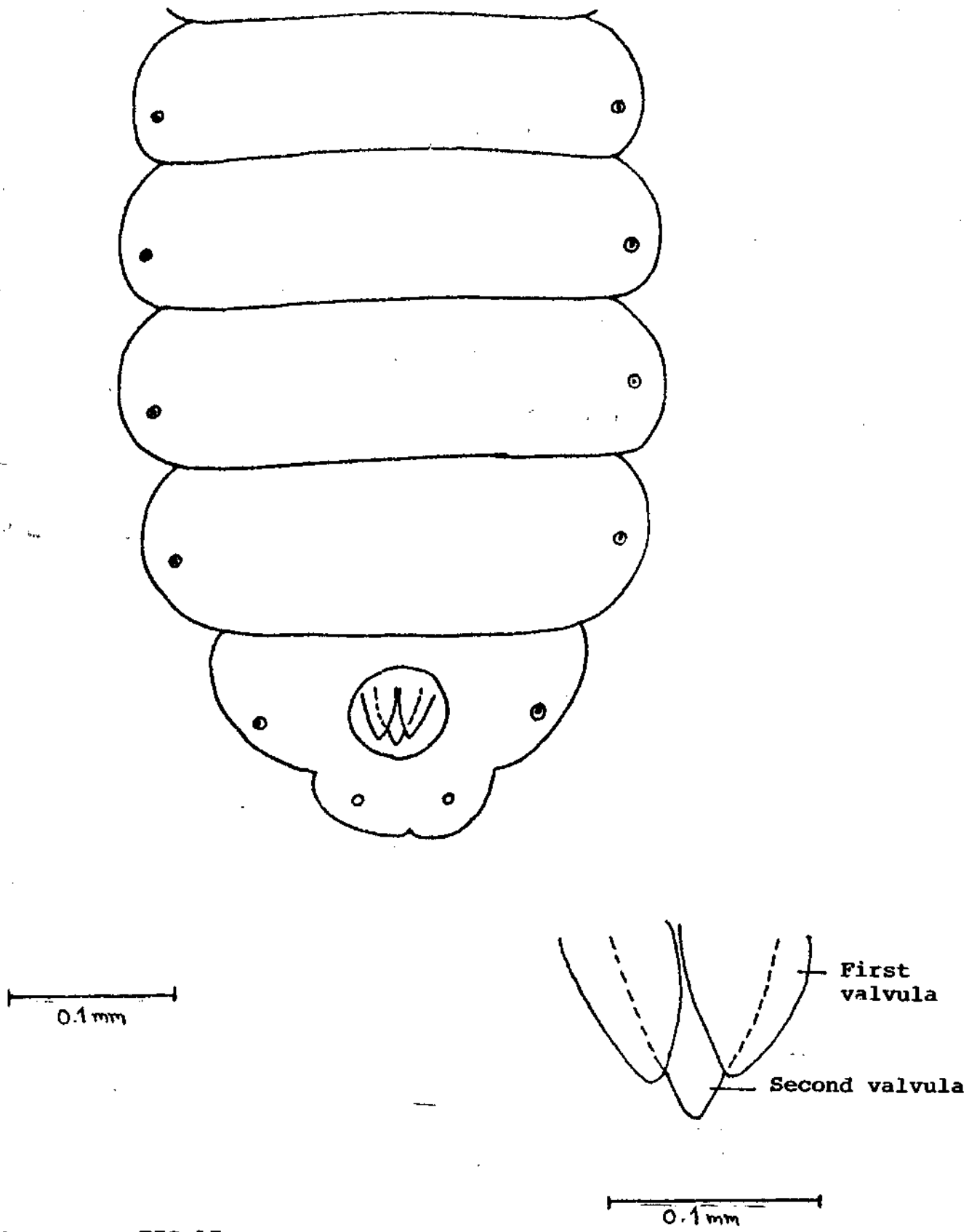


FIG.17: EXTERNAL FEMALE GENITALIA OF FIFTH INSTAR NYMPH OF P.maidis

female and dark brown in male. Wings translucent with prominent veins provided with macrotracheae. Dark shades are seen here and there in the tegmen. Wings of the brachypterous form extend only upto the sixth abdominal segment. Females nearly one and half times bigger than the males. Legs well developed with rows of short spines and hind legs with a tibial spur (Plate 11).

The longevity of the adults showed that in both the forms, the females lived longer than the males. The maximum longevity for the macropterous female and male was 43 and 16 days while the brachypterous female and male lived to a maximum of 42 and 14 days, respectively during the first generation and the macropterous female and male lived for a maximum of 37 and 12 days, respectively during second generation (Table 29).

4.3.3.13 Fecundity: The number of eggs laid by a female ranged from 29 to 46 eggs with an average of 41.8 eggs during September to November and 34 to 45 eggs during November to January. Maximum number of eggs (13) were laid on third day after emergence during first generation and during fourth day (12.6) in second generation (Table 30). The fertility on an average was 86% and proportion of males to females was 4.4 to 5.6.

The growth index was 5.22 during September to November and 5.02 during November to January.

Table 30: Fecundity of *P. maidis* under laboratory conditions during two generations

Female number	First generation							Total number of eggs	Ovi- position period	Second generation							Total number of eggs	Ovi- position period
	Number of eggs laid on day									Number of eggs laid on day								
	2	3	4	5	6	7				2	3	4	5	6	7			
1	3	5	11	6	4	-		29	5	3	10	13	7	4	1	38	6	
2	-	14	13	7	3	2		39	5	4	9	11	7	3	2	36	6	
3	5	15	9	7	3	4		43	6	-	12	15	9	5	4	45	5	
4	6	13	12	8	5	-		44	5	4	11	14	6	4	-	39	5	
5	-	18	14	6	4	4		46	5	3	10	10	7	4	-	34	5	
Total	14	65	59	34	19	10		201	-	14	52	63	36	20	7	192	-	
Mean	2.8	13	11.8	6.8	3.8	2.0		40.2	5.2	2.8	10.4	12.6	7.2	4.0	1.4	38.4	5.4	

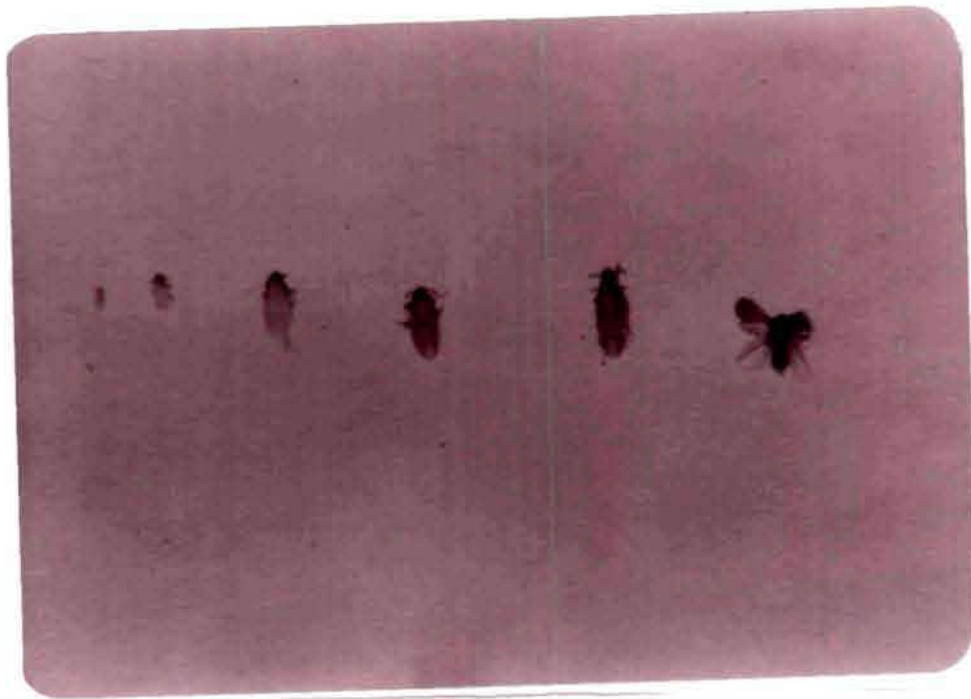


Plate No.10: Different instars of P. maidis

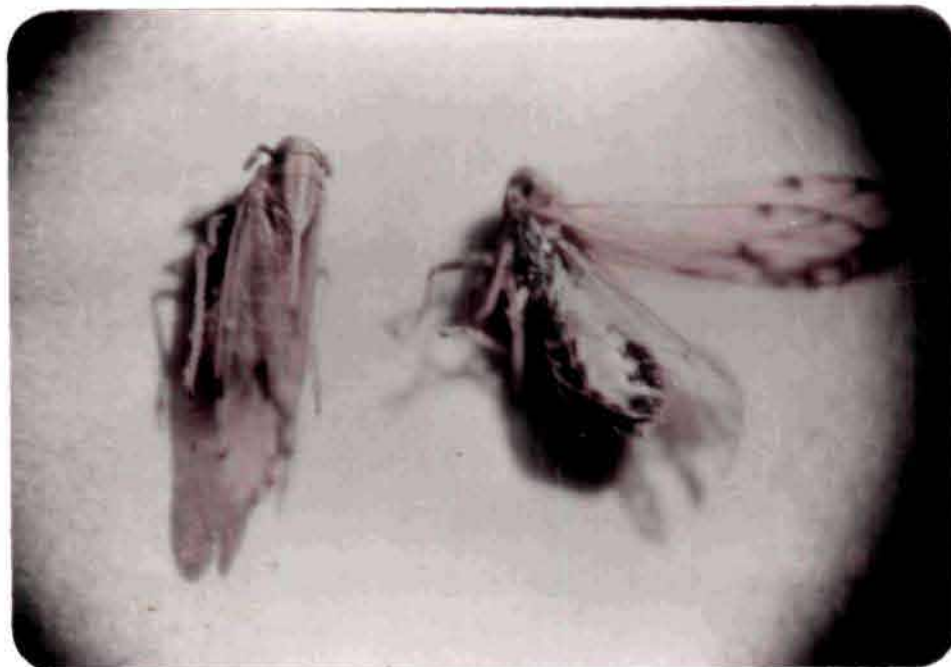


Plate No.11: Macropterous adults of P. maidis

4.3.3.14 Sex differentiation: Sex determination could be made in the fifth instar nymph by the development of external genitalia. The fifth instar male nymphs possessed parameres and aedeagus developed as linear structures initially on the ninth segment. The eighth and ninth segments of fifth instar female nymph possessed valvulae which are short and v-shaped and the tenth segment is larger than in males.

4.3.4 Duration of mating in male

The males were allowed to mate for 4 hours, 8 hours, 16 hours, 24 hours, 48 hours and 72 hours and the fecundity was noted and the data presented in Table 31.

The mean fecundity was 39.2, 36.2, 38.8, 41.8, 38.8 and 42.4 eggs in 4, 8, 16, 24, 48 and 72 hours of male mating, respectively, during September to November.

4.3.5 Ratio of males to females

The proportion of males to females was 1 : 1, 1 : 1.5, 1 : 2.0, 1.5 : 1.0 and 2 : 1 and the corresponding mean figures for fecundity were 41.8, 34.5, 41.8, 38.0 and 34.6 eggs during September to November (Table 32).

The fertile population in different male to female ratio was 86%, 88.3%, 91.65%, 95% and 98% in the

Table 31 : Fecundity of female during different mating interval (times) with male during September to November, 1988.

Duration of mating of males (hours)	Number of eggs laid during the oviposition period	
	Range	Mean
4	29 - 45	39.2 $\pm$ 9.27
8	29 - 45	36.2 $\pm$ 8.12
16	29 - 44	38.8 $\pm$ 8.53
24	29 - 47	41.8 $\pm$ 10.2
48	28 - 44	38.8 $\pm$ 8.4
72	35 - 47	42.4 $\pm$ 10.5

$\pm$ denotes standard error

Table 32 : Fecundity of P.maidis under different proportions of males to female during September to November, 1988.

Proportion of males to females	Number of eggs laid during the oviposition period	
	Range	Mean
1 : 1	29 - 47	41.8 $\pm$ 10.3
1 : 1.5	30 - 38	34.5 $\pm$ 8.12
1 : 2.0	36 - 48	41.8 $\pm$ 10.12
1.5 : 1.0	28 - 48	38.0 $\pm$ 9.37
2 : 1	30 - 40	34.6 $\pm$ 8.13

$\pm$ denotes standard error

1 : 1, 1 : 1.5, 1 : 2, 1.5 : 1.0 and 2 : 1 combinations, respectively.

4.4 LIFE FECUNDITY TABLE

The life fecundity table studies conducted in the laboratory revealed that the survival of different stages of shoot bug development on sorghum (Table 33) per individual was 0.75 at the end of nymphal period.

Adults emerged on 30th day and started ovipositing from 32 to 37th day. Since the sex ratio was approximately 1 : 1, 50 per cent of the total eggs laid were reckoned as females for the construction of the life fecundity. The survival per cent (lx) and the number of females born per female (mx) on 32, 33, 34, 35, 36 and 37th day, respectively, were 0.75 and 3.00, 0.75 and 6.5, 0.75 and 6.0, 0.75 and 4.0, 0.75 and 2.5 and 0.75 and 2.0 (Table 34 and Fig.18).

The product of female survival at different intervals (lx) and the number of females per female (mx) (i.e. $\sum lx.mx$) was 17.99.

The product of pivotal age in days (x) and the $\sum lx.mx$. (i.e., $\sum x.lx.mx$) was 613.87.

The length of immature stages was 29 days and survival of immature stages (lx) from egg to adult was 0.75. The preoviposition period ranged from 30 to 31st

Table 33: The survival of different stages of shoot bug during development on sorghum (September to November, 1988)

Number surviving						
Eggs kept	Egg period (0-10 days)	Nymphal period (days)				
		I	II	III	IV	V
		(11-14)	(15-18)	(19-21)	(22-25)	(26-29)
10	10	9	9	9	8	8
10	10	10	9	9	9	8
10	10	9	9	8	8	8
10	10	9	9	9	8	8
10	9	9	8	8	8	8
10	9	8	8	8	7	7
10	9	9	8	8	8	7
10	10	8	8	8	7	7
10	9	9	8	8	8	7
10	9	8	8	7	7	7
Total 100	95	88	84	82	78	75
Percent survival rate per individual	0.95	0.88	0.84	0.82	0.78	0.75

Table 34: Age specific fecundity of shoot bug on sorghum

Pivotal age in days (x)	Survival of females at different intervals (lx)	Age schedule for female births (mx)	lx.mx.	x.lx.mx
0-29	0.75	Immature stages		
30-31	0.75	Pre-oviposition period		
32	0.75	3	2.25	72.00
33	0.75	6.5	4.87	160.87
34	0.75	6.0	4.50	153.00
35	0.75	4.0	3.00	105.00
36	0.75	2.5	1.87	67.50
37	0.75	2.0	1.50	55.50
38	0.75	0.0	0.0	0.0
			* 17.99	= 613.87

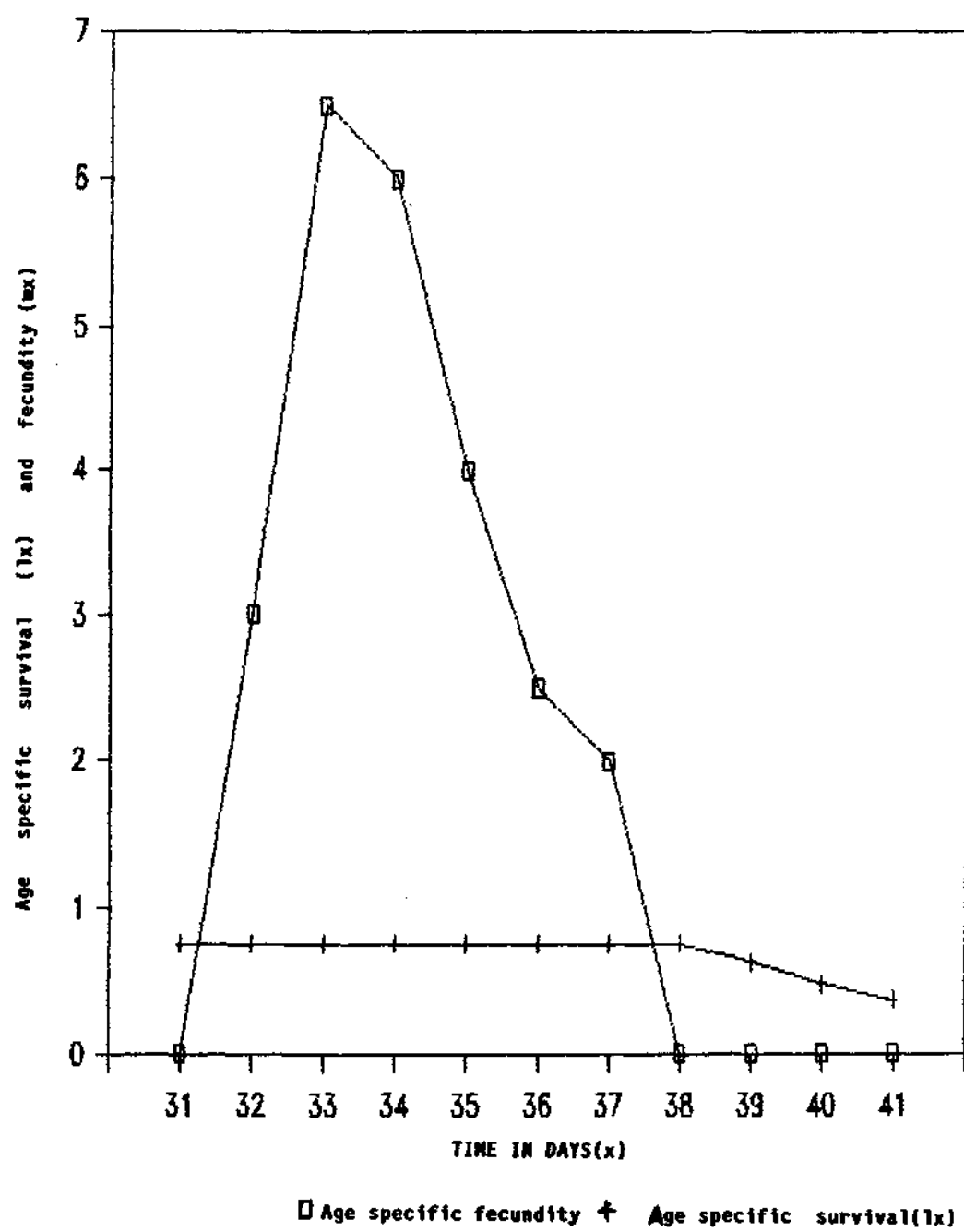


Fig.18 :AGE SPECIFIC SURVIVAL AND FECUNDITY ON SORGHUM

day of pivotal age. On the 39th day after adult emergence i.e., on the 10th day, first adult mortality occurred and continued thereafter. Adults reproduced over a period of six days commencing from third day and terminating on ninth day of emergence. The adults registered the highest mean progeny production of 4.87 per day on fourth day of emergence. The reproductive rate (R_0) indicated that the pest would be able to multiply 17.99 times on sorghum at the end of each generation.

The mean length of generation (T_c) was 34.12 days. The innate capacity for increase in number (r_m) (Fig.19) and finite rate of increase was 0.0846 and 1.088 females per day, respectively (Table 35). The population would multiply by 1.81 times every week end. It was estimated that on reaching stable age distribution, the population of shoot bug would comprise 64.98 per cent eggs, 30.82 per cent nymphs and 4.18 per cent adults (Table 36). Thus, maximum contribution was made by immature stages.

4.5 CROP LOSS ASSESSMENT DUE TO SHOOT BUG INCIDENCE

The effect of spraying methyl demeton 0.03 per cent at various stages of crop growth, namely, singly on 30, 45 and 60 DAE and twice at 30 and 45, 45 and 60

Table 35: Calculation of corrected 'rm' (Trial and error method)

Pivotal age in days (x)	1x.mx	rm=0.07*			rm=0.08*			rm=0.085*			rm=0.09*		
		$\frac{7-rmx}{e}$	$\frac{7-rmx}{e} \frac{1x.mx}{xmx}$	$\frac{7-rmx}{e}$	$\frac{7-rmx}{e}$	$\frac{7-rmx}{e} \frac{1x.mx}{xmx}$	$\frac{7-rmx}{e}$	$\frac{7-rmx}{e}$	$\frac{7-rmx}{e} \frac{1x.mx}{xmx}$	$\frac{7-rmx}{e}$	$\frac{7-rmx}{e}$	$\frac{7-rmx}{e}$	$\frac{7-rmx}{e} \frac{1x.mx}{xmx}$
32	2.25	116.74	262.66	84.77	190.74	72.24	162.54	61.55	138.50				
33	4.87	108.85	530.11	78.25	381.11	66.35	323.14	56.26	273.99				
34	4.50	101.49	456.72	72.24	325.08	60.94	274.26	51.41	231.38				
35	3.00	94.63	283.89	66.68	200.05	55.70	167.10	46.99	140.97				
36	1.87	88.23	164.99	61.55	115.11	51.41	96.15	42.94	80.31				
37	1.50	82.26	123.40	56.82	85.23	46.99	70.48	39.25	58.07				
		1821.77		1297.32		1093.67		924.02					

* Arbitrary 'rm' are 0.07, 0.08, 0.085 and 0.09

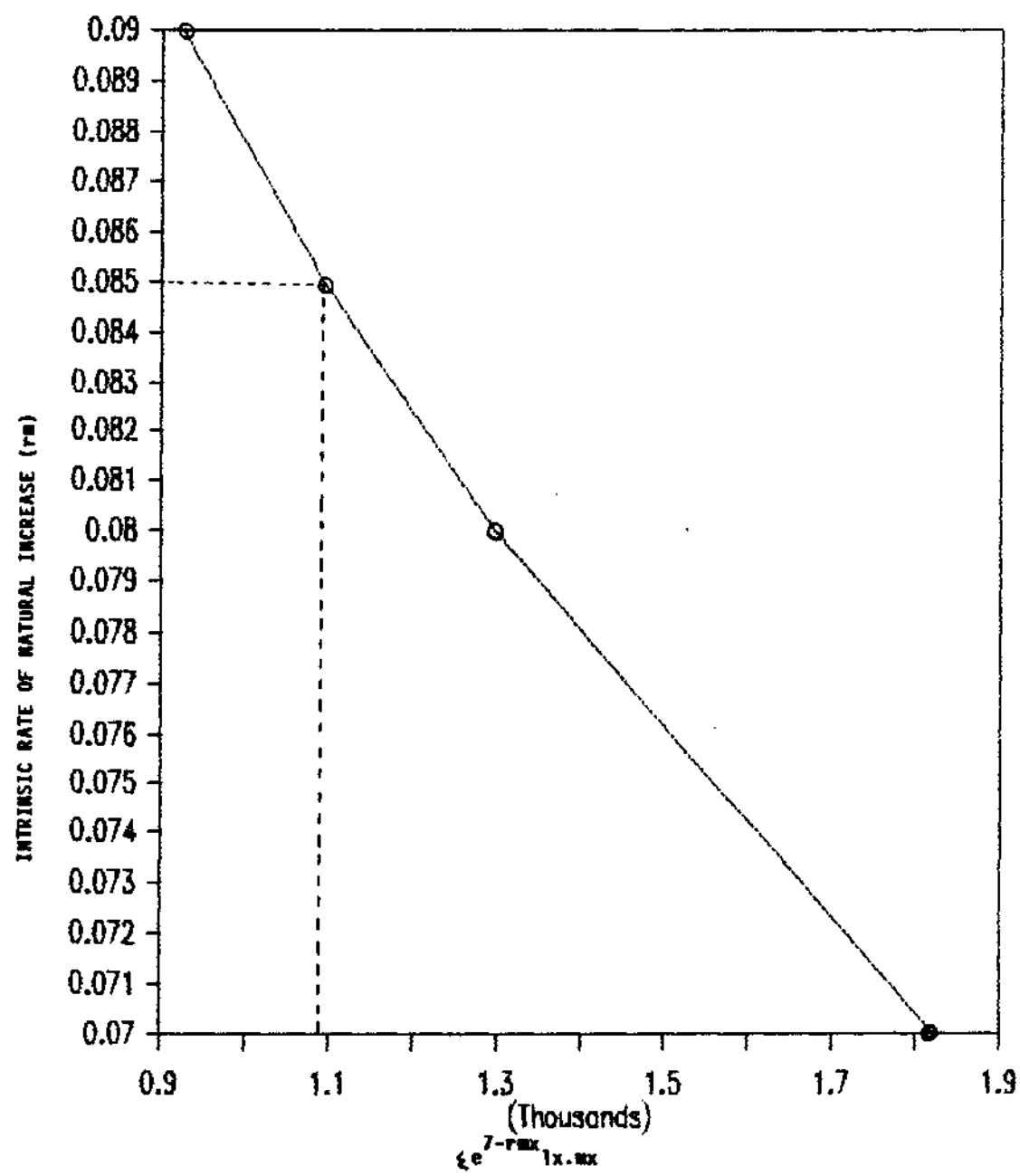


FIG.19: DETERMINATION OF THE ACCURATE INTRINSIC RATE OF INCREASE (r_m) ON SORGHUM (GRAPHICALLY)

Table 36: Stable age distribution of shoot bug on sorghum (rm=0.085)

Pivotal age in days (x)	1x	$e^{-rm(x+1)}$	$1x.e^{-rm(x+1)}$	Percentage distribution	
0	1.00	0.9185	0.9185	9.2533	64.9843 eggs
1	1.00	0.8436	0.8436	8.4988	
2	1.00	0.7749	0.7749	7.8066	
3	0.95	0.7117	0.6761	6.8113	
4	0.90	0.6537	0.5883	5.9267	
5	0.90	0.6004	0.5404	5.4442	
6	0.90	0.5515	0.4964	5.0009	
7	0.90	0.5066	0.4559	4.5929	
8	0.90	0.4653	0.4188	4.2191	
9	0.90	0.4274	0.3846	3.8746	
10	0.90	0.3925	0.3533	3.5559	11.5047 I instar nymphs
11	0.90	0.3605	0.3245	3.2691	
12	0.90	0.3312	0.2980	3.0021	
13	0.90	0.3042	0.2737	2.7573	
14	0.88	0.2794	0.2458	2.4762	8.0463 II instar nymphs
15	0.88	0.2566	0.2258	2.2748	
16	0.88	0.2357	0.2074	2.0894	
17	0.88	0.2165	0.1905	1.9191	
18	0.88	0.1988	0.1750	1.7630	4.2684 III instar nymphs
19	0.84	0.1826	0.1534	1.5454	
20	0.84	0.1677	0.1409	1.4194	
21	0.84	0.1541	0.1294	1.3036	

Contd..

Pivotal age in days (x)	1x	$e^{-rm(x+1)}$	$1x \cdot e^{-rm(x+1)}$	Percentage distribution	
22	0.84	0.1415	0.1189	1.1978	
23	0.84	0.1300	0.1092	1.1001	4.2361 IV instar nymphs
24	0.84	0.1194	0.1003	1.0104	
25	0.84	0.1097	0.0921	0.9278	
26	0.78	0.1007	0.0785	0.7908	
27	0.78	0.0925	0.0721	0.7262	2.7743 V instar nymphs
28	0.78	0.0850	0.0663	0.6679	
29	0.75	0.0780	0.0585	0.5893	
30	0.75	0.0717	0.0537	0.5409	
31	0.75	0.0628	0.0494	0.4976	4.1859 adults
32	0.75	0.0605	0.0453	0.4563	
33	0.75	0.0555	0.0416	0.4190	
34	0.75	0.0540	0.0382	0.3848	
35	0.75	0.0468	0.0351	0.3536	
36	0.75	0.0430	0.0323	0.3254	
37	0.75	0.0395	0.0296	0.2982	
38	0.75	0.0363	0.0272	0.2740	
39	0.63	0.333	0.0210	0.2115	
40	0.48	0.0306	0.0147	0.1480	
41	0.37	0.0281	0.0104	0.1047	
42	0.35	0.0258	0.0090	0.0906	
43	0.30	0.0237	0.0071	0.0715	
44	0.02	0.0218	0.0004	0.0040	
45	0.00	0.0200	0.0000	0.0000	

$\chi^2 = 9.9262$

DAE, and thrice at 30, 45 and 60 days after emergence was evaluated to assess the extent of crop loss due to shoot bug. The results of the experiment conducted during kharif 1988-89 are presented in Table 37 and Plate 12.

4.5.1 Shoot bug incidence

The incidence was recorded three times at fortnightly interval starting from 30 DAE. There was no significant difference between different treatments with respect to bug incidence. Complete protection with chemical recorded the lowest bug incidence (142.21 bugs/ten plants) followed by the treatment, spraying at 30 and 45 DAE. The highest population was recorded in control plot (440.77 bugs/ten plants).

4.5.2 Grain yield and fodder yield

The highest grain yield of 33.38 q/ha and 60.44 q/ha of fodder were recorded in complete protection treatment followed by the treatment, spraying at 45 and 60 DAE with 30.37 q/ha of grain and 55.11 q/ha of fodder. The lowest yield was recorded in untreated check (26.27 q/ha) (Table 37). The treatments, spraying at 30 DAE, 45 DAE, 60 DAE and 30 and 45 DAE were on par with each other with 28.19, 28.83, 29.23 and 29.33 q/ha of grain. Similarly the treatments, spraying at 60 DAE,



Plate No.12: General view of the experimental field

30 and 45 DAE, and 45 to 60 DAE were on par with each other.

With respect to fodder yield, the treatments, spraying at 45 DAE and 60 DAE were on par with each other. Similarly the treatments, spraying at 30 and 45 DAE and 45 and 60 DAE were on par and the remaining treatments differed significantly from one another (Table 37).

4.5.3 Correlation and regression studies

The relationship between the bug incidence and per cent loss in grain and fodder weight was computed and the results revealed that the bug incidence was minimum (142.21 bugs/ten plants) when complete protection was given, leading to maximum grain yield of 33.38 q/ha. Similarly when no protection was given the incidence was maximum (440.77 bugs per ten plants). The correlation between the extent of incidence and grain yield was found to be negative and significant ($r = -0.7123$). The regression equation worked out was, $y = 33.256 - 0.013 x$ indicating that for every one shoot bug present on ten plants, the yield decreased by 0.013 kg/ha.

Similarly, the correlation coefficient for fodder yield was negative and significant ($r = -0.7329$). The regression equation was, $y = 65.458 - 0.0623 x$

indicating that for every one bug on ten plants the yield decreased by 0.0623 kg/ha.

4.5.4 Avoidable loss

It was found that when the crop was given a protection cover with insecticide the avoidable loss was nil followed by the treatment spraying at 45 and 60 DAE. Also the highest additional yield over control was obtained in complete protection as 7.11 q/ha followed by the treatment spraying at 45 and 60 DAE with 4.10 q/ha. The minimum additional yield was obtained when the crop was protected at 30 DAE with 1.92 q/ha. The fodder yields also followed the same trend with the treatment, complete protection recording no avoidable loss followed by the treatment, spraying at 45 and 60 DAE (8.81 per cent). Likewise, the highest additional yield over control was obtained in complete protection as 28.4 q/ha followed by the treatment spraying at 45 and 60 DAE with 23.07 q/ha. The minimum additional yield was obtained when the crop was protected at 30 DAE with 6.67 q/ha (Table 37).

Minimum avoidable loss of 21.03 per cent and yield loss of 7.11 q/ha was recorded when the crop was completely exposed to pest damage. Similar figures for fodder, yield was 46.98 per cent and 28.40 q/ha, respectively. The avoidable loss was reduced to 9.01

Table 37 : Shoot bug population, grain and fodder yields, avoidable loss and cost-benefit ratio under various protection levels (Kharif).

Treatment	Number of shoot bugs per ten plants	Grain yield (q/ha)	Fodder yield (q/ha)	Available loss (%)	Cost of insecticide + application charges Rs./ha	Gross income (Rs./ha)	Net gain over control (Rs./ha)	ICBR
T1	272.44	28.19	38.71	15.54	35.95	7186.40	650.80	1:4.46
T2	300.77	28.83	45.38	13.63	33.18	7581.20	1045.60	1:7.17
T3	429.99	29.23	46.91	12.43	22.38	7722.40	1186.80	1:8.13
T4	167.11	29.33	53.08	12.13	12.17	7989.20	1453.60	1:4.98
T5	277.22	30.37	55.11	9.01	8.81	8278.40	1742.80	1:5.97
T6	142.21	33.38	60.44	0.00	0.00	9093.60	2558.00	1:5.59
T7	440.77	26.27	32.04	21.03	46.98	6535.60	-	-
C.D. at 5%	NS	1.39	2.07					

* Avoidable loss (%) =

Yield in complete protection - Yield in particular treatment

----- x 100

** Operational charges for one application @ Rs.45/ha. (Insecticide : Methy1 demeton 25 EC @ 0.03%)

*** Grain price @ Rs.200/q and fodder @ Rs.40/q.

per cent and 8.81 per cent over grain and fodder when the crop was protected at 45 and 60 DAE, respectively. The avoidable loss increased to 12.13 and 12.17 per cent for grain and fodder, respectively when the crop was protected at 30 and 45 DAE. The results indicated that spraying at 45 and 60 DAE was the best treatment in reducing the avoidable loss due to shoot bug followed by spraying at 30 and 45 DAE.

4.5.5 Cost-benefit ratio

The additional yields of grain and fodder were higher in complete protection treatment with 33.38 and 60.44 q/ha, respectively. The value of increased produce was Rs.2558.00 in complete protection followed by Rs.1742.00 in the treatment spraying at 45 and 60 DAE. The corresponding cost-benefit ratios were 1:5.59 and 1:5.97 for the two treatments, respectively. The highest cost-benefit ratio was obtained in the treatment, spraying at 60 DAE with 1:8.13 and the lowest in the treatment, spraying at 30 DAE with 1:4.46 (Table 37).

4.5.6 Rabi season

The crop loss assessment experiment was repeated in the rabi season of 1988-89 and the results are presented in Table 38.

The pre-treatment count at 30 DAE in all the treatments showed no significant difference. The mean grain yield in different treatments revealed that the highest grain yields of 34.66 q/ha and 61.42 q/ha of fodder were recorded in complete protection followed by the treatment, spraying at 45 and 60 DAE with 31.00 q/ha of grain and 55.65 q/ha of fodder. The lowest grain and fodder yields were recorded in untreated check (Table 38). The treatments, spraying at 45 DAE and 60 DAE were on par. Similarly, the treatments, spraying at 30 and 45 DAE and 45 and 60 DAE were on par with each other. With respect to fodder yield, the treatments single spraying at 45 DAE and 60 DAE were on par and the remaining treatments differed significantly from one another (Table 38).

The relationship between the bug incidence and per cent loss in grain and fodder weight was calculated and the results revealed that the correlation between the extent of incidence and grain yield was found to be negative and significant ($r = -0.4902$). The regression equation was $y = 33.115 - 0.02 x$ indicating, that for every one bug on ten plants, yield decreased by 0.02 kg/ha.

Similarly, the correlation coefficient for fodder yield was negative and significant ($r = -0.4466$). The regression equation was,

$Y = 59.02 - 0.0637 x$ indicating, that for every one bug on ten plants the yield decreased by 0.0637 kg/ha.

4.5.6.1 Avoidable loss: It was found that when the crop was completely protected by insecticidal application the avoidable loss was nil, followed by the treatment spraying twice at 45 and 60 DAE. It was also found that the highest additional yield over control was obtained in complete protection (9.43 q/ha) followed by spraying at 45 and 60 DAE (5.77 q/ha). The minimum additional yield was obtained when the crop was protected at 30 DAE (1.37 q/ha). The fodder yields also followed the same pattern with complete protection recording no avoidable loss, followed by the treatment, spraying twice at 45 and 60 DAE. The minimum additional yield was obtained when the crop was protected at 30 DAE (5.83 q/ha).

Maximum avoidable loss of 27.20 and 46.46 per cent was recorded when the crop was completely exposed to pest damage for grain and fodder, respectively. The avoidable loss was reduced to 10.55 and 9.39 per cent for grain and fodder, respectively when the crop was protected at 45 and 60 DAE which increased further to 13.67 and 12.86% for grain and fodder, respectively when the crop was protected at 30 and 45 DAE (Table 38).

Table 38 : Shoot bug population, grain and fodder yields, avoidable loss and cost-benefit ratio under various protection levels (Rabi).

Treatment	Number of shoot bugs per ten plants	Grain yield (q/ha)	Fodder yield (q/ha)	Avoidable loss (%)	Cost of insecticide + application charges Rs./ha	Gross income (Rs./ha)	Net gain over control (Rs./ha)	ICBR
T1	215.23	27.60	38.71	36.97	145.80	7068.40	707.20	1:4.85
T2	208.00	28.83	45.42	26.05	145.80	7582.80	1221.60	1:8.37
T3	220.66	29.18	46.96	23.54	145.80	7714.40	1353.20	1:9.28
T4	227.00	29.92	53.52	12.86	291.60	8124.80	1763.60	1:6.04
T5	223.00	31.00	55.65	9.39	291.60	8426.00	2064.80	1:7.08
T6	231.33	34.66	61.42	0.00	457.40	9388.80	3027.60	1:6.61
T7	215.00	25.23	32.88	46.46	-	6361.20	-	-
C.D. (P=0.05)	NS	0.65	1.74					

$$\text{* Avoidable loss (\%)} = \frac{\text{Yield in complete protection} - \text{Yield in particular treatment}}{\text{Yield in complete protection}} \times 100$$

** Operational charges for one application @ Rs.45/ha. (Insecticide : Methyl demeton 25 EC @ 0.03%)
 *** Grain price @ Rs.200/q and fodder @ Rs.40/q

4.5.6.2 Cost-benefit ratio: The quantity of increased grain and fodder yield was higher in complete protection treatment with 34.66 and 61.42 q/ha, respectively. The value of increased produce was Rs.3027.60 in complete protection followed by Rs.2064.80 in the treatment spraying at 45 and 60 DAE with an ICBR of 1 : 6.61 and 1 : 7.08, respectively. The highest cost-benefit ratio was obtained in the treatment, spraying at 60 DAE with 1 : 9.28 and the lowest in the treatment, spraying at 30 DAE with 1 : 4.85 (Table 38).

4.6 AVOIDABLE LOSS UNDER CAGE CONDITIONS

Data on crop loss estimation during 1st October and 15th October sown crops under cage conditions are presented in Table 39.

In both the experiments, the treatment with no infestation recorded the highest grain yield per plant (24.5 and 25.96 g, respectively). All the treatments studied differed significantly. In both the experiments, the correlation between incidence and grain yield was found to be negative and highly significant with $r = -0.9668$ in 1st October sown crop and $r = -0.9758$ in 15th October planted crop.

The regression equation for 1st October sown crop was $y = 28.32 - 0.5140 x$ indicating, that for every one bug present on a plant, yield decreased by

Table 39: Avoidable losses due to shoot bug infestation under caged conditions

Treatment	Experiment I (1st October, 1988)		Experiment II (15 October, 1988)	
	Grain yield (g/plant)*	Avoidable loss (%)**	Grain yield (g/plant)	Avoidable loss (%)
15 nymphs/plant T1	22.57	7.88	22.28	14.17
20 nymphs/plant T2	20.43	16.61	21.34	17.79
25 nymphs/plant T3	16.87	31.14	17.08	34.20
30 nymphs/plant T4	14.44	41.06	15.51	40.25
35 nymphs/plant T5	8.52	65.22	8.95	65.52
40 nymphs/plant T6	6.17	74.81	7.33	71.76
No infestation T7	24.50	-	25.96	-
C.D. (P=0.05)	1.36		0.895	
* Average of 3 observations				
** Avoidable loss (%) =	$\frac{\text{Yield in uninfested plants} - \text{Yield in infested plant}}{\text{Yield in uninfested plants}} \times 100$			

0.514 g. Similarly, for 15th October planted crop the regression equation was $y = 28.59 - 0.5179 x$.

The results (Table 39) indicated that 7.88% of avoidable loss was recorded when 15 nymphs were allowed to feed throughout the crop period which increased to a maximum of 74.81% when the number of nymphs released was increased to 40. Similarly, 15th October sown crop recorded an avoidable loss of 14.17% when 15 nymphs were allowed to feed throughout the crop period (Table 39).

The crop loss estimation data from cage studies, the prevailing market price of sorghum grain and fodder and the insecticide were utilised to compute the economic injury level (EIL) as described in materials and methods.

Three sprays were required to keep the crop completely free from shoot bug and the insecticide and its application cost worked out to Rs.457.40/ha. The cost of sorghum grain and fodder was taken at Rs.200.00 and 40.00/ha, respectively. The EIL worked to be 3.73 bugs per plant while ETL was estimated to be 3.0 bugs per plant.

4.7 VARIETAL SCREENING

A total number of twenty hybrids and eighteen varieties were screened in two seasons of 1988 and 89 and the results obtained are presented in Table 39.

4.7.1 Kharif

During the Kharif sown crop the observation on shoot bug incidence was recorded starting from 30 DAE and the mean for total crop period was taken for screening the genotypes.

The incidence of shoot bug per ten plants throughout the crop growth (Table 39) revealed that the varieties SPV 736, 858, 775, 756, 741, 678, 475, 462, 881, 710, 829, 827, 813, 824, CSV 10 and CSV 11 were on par with each other with regard to bug population. Similarly, the varieties, SPV 824, 669 and SPV 815 were on par with each other. The only variety which differed significantly from all other treatments was ICSV 1.

Among the hybrids, the treatments which were on par with each other were MSH 65, SPH 388, SPH 350, SPH 417, NSH 152, PSYH 3, SPH 430, SPH 384, 334 and SPH 370. Similarly the treatments SPH 370, SPH 296 and CSH 5, CSH 10, 9, 11 and CSH 1 were on par with each other. The CSH 1 in turn was on par with SPH 426 and NSH 147 at five per cent level of significance.

4.7.2 Grouping of Hybrids and varieties

The mean ($\bar{X}$) and Standard deviation (S.D.) of mean population count was utilised to group the varieties and hybrids and a preliminary classification was done and the results are presented in Table 40.

The results revealed that promising varieties were SPV 736, 858, 775, 756, 741, 678, 475, 819 and CSV 10 and hybrids are MSH 65 and SPH 388. The highly susceptible variety was ICSV 1 and the hybrids viz., CSH 5, 9, 10, 11, 1, SPH 426 and NSH 147.

4.7.3 Rabi

During the rabi season of 1988-89 the same genotypes were screened and the results are given in Table 39.

The varieties SPV 736, 858, 775, 678, 710, 741, 756, 475, 829, 462, 813, 881, 819, 815, CSV 10 and CSV 11 were found to be on par with each other. Similarly, SPV 815, 824, 827 and SPV 669 were on par with each other at five per cent level of significance. The only treatment which differed significantly from all other varieties was ICSV 1.

Among the hybrids PSYH 3, SPH 430, MSH 65, SPH 334, NSH 152, SPH 417, SPH 388 and SPH 350 were on par with each other. Similarly, SPH 350, 370, 296, CSH 5,

Table 40: Shoot bug population on different genotypes during kharif and rabi seasons, 1988-89

Genotype	Number of shoot bug/10 plants	
	kharif	rabi
SPV 462	92.91	81.66
SPV 475	86.83	80.66
SPV 669	111.08	104.33
SPV 678	85.66	61.33
SPV 710	95.07	67.55
SPV 736	70.83	44.66
SPV 756	83.08	75.55
SPV 775	74.58	57.44
SPV 813	101.49	84.88
SPV 815	111.91	90.55
SPV 819	89.58	88.55
SPV 824	108.33	95.21
SPV 829	97.49	81.55
SPV 741	83.74	69.77
SPV 827	100.16	100.66
SPV 881	93.33	85.66
SPV 858	73.16	56.22
CSV 10	85.41	80.10
CSV 11	86.91	80.77
CSH 5	146.24	143.88
SPH 296	126.08	126.99
SPH 350	93.83	112.99
SPH 370	116.66	122.88

contd..		
Genotype	Number of shoot bug/10 plants	
	kharif	rabi
SPH 384	103.74	139.88
SPH 388	87.49	108.77
SPH 417	95.41	93.33
SPH 430	101.82	76.33
SPH 334	109.83	87.66
SPH 426	192.74	183.66
MSH 65	86.08	78.77
NSH 147	196.58	207.44
NSH 152	96.08	90.99
PSYH 3	99.41	75.10
CSH 9	165.74	154.44
CSH 10	162.91	159.77
CSH 11	175.08	211.44
CSH 1	175.66	159.66
ICSV 1	185.57	172.21
CD (P=0.05)	39.62	47.54

Table 41: Classification of genotypes based on mean and standard deviation of shoot bug population during kharif, 1988

Promising genotypes ₁		Susceptible genotypes ₂		Highly susceptible genotypes ₃	
Varieties	Hybrids	Varieties	Hybrids	Varieties	Hybrids
SPV 736	MSH 65	SPV 462	SPH 350	ICSV1	CSH5
SPV 858	SPH 388	SPV 881	SPH 417		CSH10
SPV 775		SPV 711	NSH 152		CSH 9
SPV 756		SPV 829	PSYH 3		CSH 11
SPV 741		SPV 827	SPH 430		CSH 1
CSV 10		SPV 813	SPH 384		SPH 426
SPV 678		SPV 824	SPH 334		NSH 147
SPV 475		SPV 669	SPH 370		
CSV 11		SPV 815	SPH 296		
SPV 819					

1 Bug population less than mean - S.D.

2 Bug population between mean - S.D. and mean + S.D

3 Bug population more than mean + S.D

9, 1, and CSH 10 were on par while the hybrids CSH 10, SPH 426, and NSH 147 and CSH 11 were on par with each other.

4.7.4 Grouping of Hybrids and varieties

The means ($\bar{X}$) and Standard deviation (S.D.) of mean count was utilised to group the varieties and hybrids and a preliminary classification was done and the results are presented in Table 41.

The promising genotypes among varieties are SPV 736, 858, 775, 678, 710, 741, 756, 475, CSV 10 and CSV 11. Among hybrids PSYH 3, SPH 430, and MSH 65 proved to be promising.

The variety ICSV 1 and hybrids SPH 384, 426, CSH 5, 9, 1, 10, CSH 11 and NSH 147 proved to be highly susceptible to shoot bug attack in the rabi season.

4.8 EFFICACY OF DIFFERENT INSECTICIDES IN THE CONTROL OF SORGHUM SHOOT BUG

Four insecticides, dimethoate, methyl-S-demeton, endosulfan and methamidophos were evaluated under field conditions during kharif of 1988-89 against the shoot bug.

The efficacy of the treatments was assessed, based on the surviving shoot bug population. The mean

Table 42: Classification of genotypes based on mean and standard deviation of shoot bug population during rabi, 1988-89

Promising genotypes ¹		Susceptible genotypes ²		Highly susceptible genotypes ³	
Varieties	Hybrids	Varieties	Hybrids	Varieties	Hybrids
SPV 736	PSYH 3	SPV 829	SPH 334	ICSV1	SPH 384
SPV 858	SPH 430	SPV 462	NSH 152		CSH 5
SPV 775	MSH 65	SPV 813	SPH 417		CSH 9
SPV 678		SPV 881	SPH 388		CSH 1
SPV 710		SPV 819	SPH 370		CSH 10
SPV 741		SPV 815	SPH 350		SPH 426
SPV 756		SPV 824	SPH 296		NSH 147
CSV 10		SPV 827			CSH 11
SPV 475		SPV 669			
CSV 11					

1 Bug population less than mean - S.D.

2 Bug pupulation between mean - S.D. and mean + S.D

3 Bug population more than mean + S.D

per cent reduction of the population at 24 hours, 48 hours and 7 days after spraying in the three sprays taken at 30, 45 and 60 DAE was calculated taking into account, the pre and post treatmental counts in the treatment in relation to pre and post treatmental counts in the control plot.

4.8.1 30 days after emergence

The pre-treatment counts were taken 24 hours prior to application of insecticides in all the plots on ten plants selected at random. The mean number of shoot bugs were highest in the treatment, methamidophos 0.05% (402.66 bugs per ten plants) and the lowest bug incidence was recorded in dimethoate 0.05% treatment (395.33 bugs per ten plants). However, all the treatment means were on par with each other at five per cent level of significance (Table 43).

4.8.1.1 24 hours after application: A perusal of the data (Table 43) reveals that among the treatments, methamidophos (0.1%) was the most effective treatment by recording 93.82 mean per cent reduction of shoot bug population, while endosulfan (0.05%) was the least effective with a mean per cent reduction of 77.98. The other treatments that followed methamidophos (0.1%) were methyl demeton (0.05%) and dimethoate (0.05%) which recorded 92.75 and 91.89 mean per cent reduction of bug

population, respectively and were on par with each other. However, methyl demeton (0.05%) and dimethoate (0.05%) were in turn on par with methyl demeton (0.03%) which recorded 91.51 mean per cent reduction of the bug population. Methamidophos (0.05%) and dimethoate (0.03%) with 92.75 and 86.74 mean per cent reduction of the bug population, respectively came next in the order of efficacy and were on par with each other. The treatments endosulfan 0.07% and 0.05% recorded 81.41 and 77.98 mean per cent reduction, respectively and found to be non-significant. The control plot recorded no reduction in the population, and all the treatments were found significantly superior to control in bringing down the shoot bug population.

4.8.1.2 48 hours after application: The data recorded at 48 hours after application was presented in Table 43. It could be seen that methyl demeton (0.05%) was the most effective treatment over the rest with the highest mean per cent reduction of 98.90 in the shoot bug population among the treatments, followed by methyl demeton (0.03%), methamidophos (0.1%) and dimethoate (0.05%) with a mean per cent reduction of 98.33, 98.33 and 97.70, respectively and were on par with methyl demeton (0.05%). The treatments that followed in the order of efficacy were methamidophos (0.05%) with 96.64, dimethoate (0.03%) with 96.21 and endosulfan (0.07%)

with 95.03 mean per cent reduction of bug population and were on par with each other. Endosulfan (0.05%) with 89.84 mean per cent reduction of the shoot bug population was found least effective among the treatments. However, all the treatments were significantly superior to control (15.04%) in bringing down the bug population.

4.8.1.3 Seven days after spraying: Observations made on the reduction in population of shoot bug seven days after insecticidal application indicated that the treatment, methamidophos (0.1%) was the most effective treatment with 98.77 mean per cent reduction followed by methyl demeton (0.05%) and endosulfan (0.07%) with 98.05 and 97.11 mean per cent reduction, respectively and were on par with each other. The treatments, methyl demeton (0.03%), dimethoate (0.05%) and methamidophos (0.05%) were next in the order of efficacy with 96.51, 96.37, and 95.86 mean per cent reduction, respectively and were on par with each other including the treatment, endosulfan (0.07%). Endosulfan (0.05%) with 94.57 mean per cent reduction was on par with methamidophos (0.05%), dimethoate (0.05%) and methyl demeton (0.03%). However, all the treatments were significantly superior to control (18.81%) in bringing down the shoot bug population.

4.8.2 45 days after emergence

Prior to spraying of insecticides at 45 DAE the shoot bug incidence was recorded. The highest number of bugs were recorded in the treatment, untreated check (331.33 bugs per ten plants) and the lowest population was recorded in the treatment dimethoate (0.05%). The treatments, dimethoate (0.03%) and endosulfan (0.05%) were on par with each other in recording bug population. However, endosulfan (0.05%) was on par with all other treatments (Table 43).

4.8.2.1 24 hours after application: The mean per cent reduction in the treatments at 24 hours after spraying were presented in Table 43. The data indicates that the methyl demeton (0.05%) was the most effective treatment with 95.32 mean per cent reduction. The next best treatments were methamidophos (0.1%), dimethoate (0.05%), methyl demeton (0.03%), dimethoate (0.03%) and methamidophos (0.05%) which recorded 88.63, 87.34, 86.64, 83.46 and 83.04 mean per cent reduction, respectively and were on par with each other and also with methyl demeton (0.05%). The treatments that followed in the order of decreasing efficacy were endosulfan (0.07%) and (0.05%) with mean per cent reduction of 76.72 and 62.49, respectively and were on par with each other. However, endosulfan (0.07%) was on par with methamidophos (0.05%), dimethoate (0.03%), methyl

demeton (0.03%), dimethoate (0.05%) and methamidophos (0.1%) at five per cent level of significance. All the treatments were significantly superior to control (16.11% reduction) in bringing down the bug population at 24 hours after spraying.

4.8.2.2 48 hours after spraying: The data with regard to the reduction of shoot bug population at 48 hours after spraying was presented in Table 43. The data indicated that methyl demeton (0.05%) was the most effective among the treatments with 95.50 mean per cent reduction but was on par with methamidophos (0.1%), dimethoate (0.05%), methyl demeton (0.03%) and dimethoate (0.03%) which recorded 95.32, 93.45, 93.47 and 92.03 mean per cent reduction, respectively. The treatments that followed in the order of efficacy were methamidophos (0.05%) and endosulfan (0.07%) with 89.47 and 85.56 mean per cent reduction and were on par with each other. Among the treatments, endosulfan (0.05%) was the least effective with 83.61 mean per cent reduction but was on par with endosulfan (0.07%).

4.8.2.3 Seven days after application: Observations made on the reduction in population of shoot bug seven days after insecticidal application indicated (Table 43) that the treatments methyl demeton (0.05%), methamidophos (0.1%) methamidophos (0.05%), endosulfan (0.07%), methyl demeton (0.03%), dimethoate 0.05% and

0.03% were on par with each other by recording 95.32, 95.10, 94.54, 93.17, 91.96, 91.70, and 90.94 mean per cent reduction, respectively. The treatment endosulfan (0.05%) was the least effective with 89.35 mean per cent reduction. However, the treatment was on par with dimethoate (0.03%), dimethoate (0.05%), methyl demeton (0.03%), endosulfan (0.05%) and methamidophos (0.05%). However, all the treatments were significantly superior to untreated control.

4.8.3 60 days after emergence

The pre-treatment count was taken prior to 24 hours of insecticide spraying. The treatments, methyl demeton (0.03%), methamidophos (0.05%), endosulfan (0.07%), methyl demeton (0.05%), dimethoate (0.03%), dimethoate (0.05%) and methamidophos (0.1%) were on par with each other in having similar incidence. The treatment, untreated check recorded highest number of shoot bugs and was superior to all other treatments.

4.8.3.1 24 hours after application: A perusal of the data (Table 43) reveals that the highest reduction of bug population was in the treatment, methamidophos (0.1%) followed by methyl demeton (0.05%) and methamidophos (0.05%) with 95.14, 92.45 and 92.67 mean per cent reduction, respectively and were on par with each other. Next in the order of decreasing efficacy

were methyl demeton (0.03%), dimethoate (0.05%) and dimethoate (0.03%) which were on par with each other with a mean reduction of 88.13, 87.11 and 83.78, respectively. The least effective treatment was the endosulfan (0.07%) with a mean per cent reduction of 72.94 bugs. However, all the insecticide treated plots were superior to untreated check in reducing shoot bug population.

4.8.3.2 48 hours after application: The data recorded at 48 hours after application was presented in Table 43. It could be observed that methamidophos (0.1%) was the most effective treatment with a mean per cent reduction of 97.34 bugs. The next best treatments were methyl demeton (0.03%), methyl demeton (0.05%), dimethoate 0.05% and 0.03% which recorded 97.27, 96.04, 95.58 and 95.49 mean per cent reduction, respectively and were on par with each other. The treatment, methamidophos (0.05%) recorded a mean per cent reduction of 94.13 and was on par with dimethoate 0.03%, 0.05%, and methyl demeton (0.05%). The treatments that followed in the order of efficacy were endosulfan (0.03%) with 92.72 and endosulfan (0.05%) with 91.94 mean per cent reduction, respectively and were on par with each other including the treatment, methamidophos (0.05%).

4.8.3.3 Seven days after application: Observations made on the reduction in population of shoot bug seven

Table 43 : Efficacy of different insecticides for the control of shoot bug during Anaraj...

Shoot bug population per ten plants													
Treatment	First Spray (30 DAE)				Second Spray (45 DAE)				Third Spray (60 DAE)				
	24 hours before spray	24 hours after spray	48 hours after spray	7 days after spray	24 hours before spray	24 hours after spray	48 hours after spray	7 days after spray	24 hours before spray	24 hours after spray	48 hours after spray	7 days after spray	7 days after spray
T1 Dimethoate 0.03% 401.33	55	12.66	23.66	104.00	17.33	8.00	8.00	8.00	62.33	11.00	2.66	3.66	3.66
	(68.61)*	(78.76)	(74.32)	(65.96)*	(73.57)	(73.57)	(73.57)	(73.57)	(66.19)*	(77.61)	(73.26)	(73.26)	(73.26)
T2 Methyl demeton 0.03%	397.00	34.66	5.66	86.33	11.00	5.33	5.33	5.66	69.66	9.00	1.66	4.00	4.00
	(86.74)**	(96.21)	(92.71)	(83.46)**	(92.03)	(92.03)	(92.03)	(92.03)	(83.78)**	(95.49)	(91.72)	(91.72)	(91.72)
T3 Endosulfan 0.05% 395.33	89.66	33.66	17.33	92.00	31.00	14.00	14.00	8.00	66.66	13.33	5.00	4.00	4.00
	(73.05)	(82.51)	(79.22)	(68.53)	(75.11)	(73.46)	(73.46)	(73.46)	(69.82)	(80.37)	(74.11)	(74.11)	(74.11)
T4 Methamidophos 0.05%	402.66	47.66	11.33	85.66	13.73	8.66	8.66	4.00	68.00	5.66	3.66	3.33	3.33
	(77.98)	(89.84)	(94.57)	(62.49)	(83.61)	(89.35)	(89.35)	(89.35)	(81.84)	(91.94)	(92.26)	(92.26)	(92.26)
T5 Methyl demeton 0.05%	401.00	30.00	3.66	86.00	7.00	3.66	3.66	3.33	66.00	5.33	2.33	2.00	2.00
	(74.32)	(83.98)	(81.87)	(72.24)	(77.75)	(77.48)	(77.48)	(77.48)	(74.00)	(78.46)	(79.00)	(79.00)	(79.00)
T6 Endosulfan 0.07% 398.00	76.33	16.66	9.33	80.00	17.00	11.00	11.00	4.66	44.66	13.33	3.00	2.33	2.33
	(64.45)	(77.08)	(80.19)	(61.14)	(67.62)	(74.77)	(74.77)	(74.77)	(58.60)	(74.32)	(75.23)	(75.23)	(75.23)
T7 Dimethoate 0.05% 395.33	33.00	7.66	11.66	80.00	9.33	5.00	5.00	5.66	56.66	8.00	2.33	3.00	3.00
	(73.36)	(81.28)	(78.91)	(69.12)	(75.11)	(73.26)	(73.26)	(73.26)	(68.95)	(77.75)	(75.00)	(75.00)	(75.00)
T8 Methamidophos 0.1%	401.66	25.33	4.00	80.66	8.33	3.66	3.66	3.33	55.33	3.00	1.33	1.66	1.66
	(75.58)	(82.51)	(83.45)	(70.27)	(77.48)	(77.21)	(77.21)	(77.21)	(77.08)	(80.54)	(78.46)	(78.46)	(78.46)
T9 Untreated control	400.00	412.33	340.00	331.33	305.00	314.33	283.33	283.33	279.33	310.66	260.33	215.33	215.33
	(22.79)	(25.70)	(22.22)	(16.11)	(12.92)	(22.22)	(22.22)	(22.22)	(15.12)	(28.59)	(28.59)	(28.59)	(28.59)
	(15.04)	(18.81)	(14.32)	(7.72)	(5.07)	(14.32)	(14.32)	(14.32)	(6.84)	(22.99)	(22.99)	(22.99)	(22.99)
C.D. (P = 0.05)	NS	2.46	4.20	3.30	17.38	9.91	4.53	5.77	16.83	3.92	4.00	7.53	7.53

* Figures in parentheses indicate the mean per cent reduction values in arcsin percentage transformation.

** Figures in brackets indicate the original mean per cent reduction values.

days after insecticidal application against shoot bug indicated (Table 43) that the highest mean per cent reduction was in methamidophos (0.1%) followed by methyl demeton (0.05%), endosulfan (0.07%), dimethoate (0.05%), methamidophos (0.05%), methyl demeton (0.03%), endosulfan (0.05%) and dimethoate (0.03%) with 96.08, 95.76, 93.58, 93.34, 92.67, 92.56, 92.26 and 91.72 mean per cent reduction, respectively and were on par with each other.

4.8.4 Efficacy of different insecticides in increasing the yield

Studies on the yield data (Table 44) revealed that the highest grain yield was obtained in the treatment, methyl demeton (0.05%) with 36.24 q/ha which was significantly superior to other treatments. The next best treatments which were on par were endosulfan (0.07%), methyl demeton (0.03%), methamidophos (0.1%), methamidophos (0.05%), dimethoate (0.05%) and endosulfan (0.05%) with 35.25, 35.25, 35.11, 34.91, 34.81 and 34.31 q/ha, respectively. The treatment dimethoate (0.03%) recorded lowest grain yield of 34.22 q/ha but was on par with endosulfan (0.05%), dimethoate (0.05%), methamidophos 0.05% and 0.1%. However, all the insecticidal treatments were found superior to untreated check (24.88 q/ha) in increasing the grain yield by controlling the shoot bug population.

Regarding the fodder yield (Table 44), highest yield was obtained in the treatment, methyl demeton (0.05%) followed by endosulfan (0.07%), dimethoate (0.05%), methamidophos (0.1%) and methyl demeton (0.3%) with 61.67, 61.67, 61.53, 60.78 and 60.54 q/ha, respectively and were on par with each other. The next best treatment in increasing the fodder yield were dimethoate (0.03%), endosulfan (0.05%) and methamidophos (0.05%) with 60.24, 59.55 and 59.50 q/ha, respectively and were on par with each other. However, these treatments were also on par with methyl demeton (0.03%) and methamidophos (0.1%).

4.8.5 Cost Benefit ratio

The economics of different insecticidal treatments based on the prevailing market prices of the chemical and operational expenses have been worked out and presented in Table 44. Since methamidophos was not registered for trade in India, the economics of this treatment could not be worked out.

From the Table 44, it was clear that the maximum net income per hectare was due to the treatment, methyl demeton (0.05%) followed by endosulfan (0.07%), methyl demeton (0.03%) with Rs.3548.00, Rs.3350.00 and Rs.3304.80, respectively. The corresponding cost benefit ratios were 1:5.55, 1:5.55 and 1:7.55,

Table 44: Shoot bug population, grain and fodder yields and cost-benefit ratio in various treatments in kharif 1988

Treatment	Mean shoot bug popula- tion/ten plants	Mean yield (q/ha)	Cost of insecti- cide + applica- tion cost (Rs/ha)	Gross income (Rs/ha)	Net income (Rs/ha)	ICBR
T1 Dimethoate 0.03%	401.33	34.22	60.24	300.60	9253.60	3086.80 1:10.26
T2 Methyl dimeton 0.03%	397.00	35.25	60.54	437.40	9471.60	3304.80 1:7.55
T3 Endosulfan 0.05%	395.33	34.31	59.55	469.23	9244.00	3077.20 1:6.55
T4 Methamidophos 0.05%	402.66	34.91	59.50	-	9362.00	3195.20 -
T5 Methyl demeton 0.05%	401.00	36.24	61.67	639.00	9714.00	3548.00 1:5.55
T6 Endosulfan 0.07%	398.00	35.25	61.67	603.00	9516.80	3250.00 1:5.55
T7 Dimethoate 0.05%	395.33	34.81	61.53	411.00	9423.20	3256.40 1:7.92
T8 Methamidophos 0.1%	401.66	35.11	60.78	-	9453.20	3287.40 -
T9 Untreated check	400.00	24.88	29.77	--	6166.20	- -
C.D. (P=0.05)	NS	0.954	1.40			
Operational charges @ Rs.135/ha for 3 sprays Cost of grain @ Rs.200/q and fodder @ Rs.40/q						

respectively. The net income due to various chemicals varied from Rs.3548.00 to Rs.3077.20 with cost benefit ratio ranging from 1:10.26 to 1:5.55. The highest cost-benefit ratio was in the treatment dimethoate (0.03%), with 1:10.26 followed by dimethoate (0.05%) with 1:7.92 and with a net income of Rs.3086.80 and Rs.3256.40, respectively.

During the rabi of 1988-89 the same insecticides at two concentrations were tested to know their efficacy against shoot bug and the data on the reduction of population in different treatments was collected at 24 hours, 48 hours and seven days after spraying of insecticides.

4.8.6 30 days after emergence

The pre-treatment counts on ten plants, 24 hours prior to application of insecticides, indicated that the treatments were on par with each other. The number of shoot bugs ranged from 174.33 to 111.33 bugs per ten plants (Table 45).

4.8.6.1 24 hours after application: All the insecticidal treatments were found to be statistically superior to untreated control (Table 45). A perusal of the data reveals that highest mean per cent reduction was obtained in the treatment, methamidophos 0.1% (92.24%) followed by methyl demeton 0.05% (88.17%) and

methyl demeton 0.03% (87.18%), respectively which were on par with each other. Next in the order of efficacy were endosulfan 0.07% (86.08%) and dimethoate 0.03% (85.92%) which were on par with each other. In turn, these treatments were on par with methyl demeton 0.03%, dimethoate 0.05% and methamidophos 0.05%. The lowest mean per cent reduction was in the treatment endosulfan 0.05% (76.28%).

4.8.6.2 48 hours after application: It is evident from the data (Table 45) that the most effective treatment was methyl demeton 0.05%, (96.68%) followed by methamidophos 0.1% (96.64%), dimethoate 0.05% (93.65%), endosulfan 0.07% (93.16%), methamidophos 0.05% (92.25%) and dimethoate 0.03% (91.51%) which were on par with each other. The treatments of next best effectiveness were methyl demeton 0.03% (90.07%) and endosulfan 0.05% (85.89%) and were on par with each other. However, these treatments were on par with dimethoate 0.03%, methamidophos 0.05%, endosulfan 0.07%, and dimethoate 0.05%.

4.8.6.3 Seven days after application: The observation of the data revealed that all the insecticidal treatments were superior to untreated check and were on par with each other. The highest mean per cent reduction was in the treatment, methamidophos 0.1%

(94.45%) and the lowest was in endosulfan 0.05% (90.61%).

4.8.7 49 days after emergence

The pre-treatment counts indicated that all the treatments, methamidophos (0.1%), methyl demeton (0.05% and 0.03%), dimethoate (0.03 and 0.05%) and endosulfan (0.05 and 0.07%) were on par with each other. However, the treatment, methamidophos (0.05%) recorded lowest bug population but was on par with endosulfan (0.05 and 0.07%), dimethoate (0.03 and 0.05%) and methyl demeton (0.03 and 0.05%). The untreated check recorded the highest number of shoot bugs and was superior to all other treatments (Table 45).

4.8.7.1 24 hours after application: All the insecticidal treatments proved to be superior to untreated check in reducing the population of shoot bug (Table 45). The best treatment, methamidophos 0.1% recorded 91.36 mean per cent reduction and was on par with methyl demeton 0.05% (90.00%), methyl demeton 0.03% (89.93%), dimethoate 0.05% (89.41%) and dimethoate 0.03% (87.37%). The next best treatments in the order of efficacy were endosulfan 0.07% (81.75%), methamidophos 0.05% (77.45%) and endosulfan 0.05% (76.35%) which were on par with each other. Endosulfan 0.07% in turn was on par with

Table 45: Efficacy of different insecticides for the control of shoot bug during Rabi, 1988-89

Treatment	Shoot bug population per ten plants									
	First Spray (30 DAE)					Second Spray (49 DAE)				
	24 hours before spray	24 hours after spray	48 hours after spray	7 days after spray	24 hours before spray	24 hours after spray	48 hours after spray	7 days after spray	7 days after spray	
T1 Dimethoate 0.03%	163.33	23.66 (67.94)*	14.33 (73.05)	11.00 (73.57)	49.00	5.33 (69.12)*	2.66 (74.55)	3.33 (63.44)		
		(85.92)**	(91.51)	(92.04)		(87.37)**	(92.92)	(80.04)		
T2 Methyl demeton 0.03%	139.66	18.66 (68.95)	14.33 (71.56)	10.33 (72.95)	50.00	4.33 (71.47)	2.66 (74.55)	3.33 (64.16)		
		(87.18)	(90.07)	(91.49)		(89.93)	(92.92)	(81.07)		
T3 Endosulfan 0.05%	111.33	27.66 (60.80)	16.66 (67.86)	9.00 (72.15)	47.33	9.66 (60.87)	4.66 (68.95)	5.00 (56.91)		
		(76.28)	(85.89)	(90.61)		(76.35)	(87.16)	(70.28)		
T4 Methamidophos 0.05%	135.66	15.66 (70.09)	10.66 (73.78)	8.33 (79.46)	37.66	7.33 (61.62)	3.33 (70.18)	1.66 (70.09)		
		(88.49)	(92.25)	(91.98)		(77.45)	(88.59)	(88.44)		
T5 Methyl demeton 0.05%	174.33	13.66 (73.46)	5.66 (79.37)	9.00 (75.46)	50.00	4.33 (71.56)	1.66 (78.03)	1.33 (74.77)		
		(91.94)	(96.68)	(93.71)		(90.00)	(95.72)	(93.17)		
T6 Endosulfan 0.07%	171.00	23.66 (68.03)	11.66 (74.77)	8.66 (75.58)	46.33	6.66 (64.47)	4.00 (69.30)	1.33 (72.95)		
		(86.08)	(93.16)	(93.83)		(81.75)	(87.57)	(91.42)		
T7 Dimethoate 0.05%	124.00	15.33 (69.82)	8.33 (75.35)	9.33 (72.64)	47.33	4.33 (71.00)	1.66 (77.34)	1.66 (72.05)		
		(88.17)	(93.65)	(91.15)		(89.41)	(95.26)	(90.56)		
T8 Methamidophos 0.1%	145.00	11.00 (73.78)	5.00 (79.36)	6.66 (76.31)	53.66	4.00 (72.84)	2.33 (76.06)	1.00 (76.95)		
		(92.24)	(96.64)	(94.45)		(91.36)	(94.26)	(94.93)		
T9 Untreated control	111.66	117.33	118.66	129.66	160.00	138.00	122.33	63.00		
						(21.64)	(28.86)	(51.47)		
						(13.63)	(23.34)	(61.29)		
C.D. (P = 0.05)	NS	5.41	7.68	5.27	13.22	7.19	6.28	10.58		

* Figures in parentheses indicate the mean per cent reduction values in arcsin $\sqrt{\text{percentage}}$ transformation.

dimethoate 0.03 and 0.05% and methyl demeton 0.03% and 0.05%.

4.8.7.2 48 hours after application: A perusal of the data (Table 45) indicates that the treatments, methyl demeton (0.05%), dimethoate (0.05%), methamidophos (0.1%), dimethoate (0.03%) and methyl demeton (0.03%) were on par by recording mean per cent reduction of 95.72, 95.26, 94.26, 92.92 and 92.92, respectively. The next best treatments in the order of efficacy were methamidophos (0.05%), endosulfan (0.07%) and endosulfan (0.05%) with 88.59, 87.57 and 87.16 mean per cent reduction, respectively and were on par with each other. However, these three treatments, in turn were on par with methyl demeton (0.03%) and dimethoate (0.03%). In control also there was 23.34 mean per cent reduction, but all the treatments were superior to untreated control.

4.8.7.3 Seven days after spraying: After seven days of insecticidal application (Table 45), it was clear that the best treatment was methamidophos (0.1%) followed by methyl demeton (0.05%), endosulfan (0.07%), dimethoate (0.05%) and methamidophos (0.05%) with 94.93, 93.17, 91.42, 90.56 and 88.44 mean per cent reduction, respectively and were on par with each other. Even in untreated check, there was a mean reduction of 61.29

per cent and was on par with the treatment endosulfan 0.05%.

4.8.8 Efficacy of insecticides in increasing the yield

Studies on the yield data from Table 46 indicated that the highest grain yield was recorded in methamidophos 0.1% (36.39 q/ha) followed by methyl demeton 0.05% (36.19 q/ha), endosulfan 0.07% (35.70 q/ha), dimethoate 0.05% (35.35 q/ha) and methyl demeton 0.03% (35.35 q/ha) which were on par with each other. The next best treatments in increasing the grain yield were endosulfan 0.05% (34.91 q/ha), methamidophos 0.05% (34.76 q/ha) and dimethoate 0.03% (34.71 q/ha) and were on par with each other. However, these treatments in turn were on par with methyl demeton 0.03%, dimethoate 0.05% and endosulfan 0.07%. The lowest grain yield was obtained in untreated control (28.09 q/ha).

Regarding the fodder yield all the insecticidal treatments were on par and the highest fodder yield was in the treatment, dimethoate 0.05% (62.91 q/ha) and the lowest was from endosulfan 0.05% (60.59 q/ha). The control recorded a yield of 35.85 q/ha and found to be inferior to all other insecticidal treatments.

Table 46: Shoot bug population, grain and fodder yields and cost-benefit ratio in various treatments in rabi, 1988-89

Treatment	Mean shoot bug popula- tion/ten plants	Mean yield (q/ha)	Cost of insecti- cide + applica- tion cost (Rs/ha)	Gross income (Rs/ha)	Net income (Rs/ha)	ICBR
T1 Dimethoate 0.03%	163.33	34.71	62.51	200.40	2390.40	1:11.92
T2 Methyl dimeton 0.03%	139.66	35.35	61.62	291.60	2482.80	1:8.51
T3 Endosulfan 0.05%	111.33	34.91	60.59	312.82	2353.600	1:7.52
T4 Methamidophos 0.05%	135.66	34.76	60.78	-	2331.20	-
T5 Methyl demeton 0.05%	174.33	36.19	62.81	426.00	2698.40	1:6.33
T6 Endosulfan 0.07%	171.00	35.70	61.38	402.00	2543.20	1:9.24
T7 Dimethoate 0.05%	124.00	35.35	62.91	274.00	2534.40	1:6.18
T8 Methamidophos 0.1%	145.00	36.39	62.41	-	2722.40	-
T9 Untreated check	111.66	28.09	35.85	-	-	-
C.D. (P=0.05)	NS	1.06	4.14			

Cost of grain @ Rs.200/q and Fodder @ Rs.40/q
Operational charges @ Rs.90 for two sprays

4.8.9 Cost Benefit Ratio

The cost-benefit ratio of different insecticidal treatments revealed (Table 46) that the maximum net income per hectare was due to the treatment, methyl demeton (0.05%) followed by endosulfan (0.07%) and dimethoate (0.05%) with Rs.2698.40, 2543.20 and 2534.40, respectively. The corresponding cost-benefit ratios were 1:6.33, 1:9.24 and 1:6.18, respectively. The net income due to various chemicals ranged from Rs.2698.40 to Rs.2353.60 with cost-benefit ratio ranging from 1:11.92 to 1:6.18. The highest cost-benefit ratio was in the treatment dimethoate (0.03%) with 1:11.92 followed by endosulfan (0.07%) with 1:7.24 and with a net income of Rs.2390.40 and Rs.2543.20, respectively.

...

DISCUSSION

CHAPTER V

DISCUSSION

Although, there is a wealth of documented work on various aspects of sorghum pests, there remains many lacunae, particularly, in the areas of seasonal incidence, bioecology, crop loss assessment and management of the shoot bug which would go a long way in managing this pest effectively.

In any plant protection programme, the information on seasonal occurrence of major pests and influence of abiotic factors is helpful in planning timely control measures. Detailed biology and life table studies have been made to fill the gaps in the existing knowledge on the above aspects so as to utilise the same to exploit the weak links if any in the chain of insect's biology based on which a pragmatic integrated pest management programme could be evolved. Investigations have also been carried out to formulate an effective and economical chemical control strategy for shoot bug.

The results on the above aspects have been discussed in detail in the light of available literature collected and presented in the following text.

5.1 SEASONAL INCIDENCE AND RELATION WITH ENVIRONMENT FACTORS

5.1.1 The shoot fly

A perusal of the data on oviposition and deadhearts indicates, that maximum incidence was observed in July to December plantings (ranging from 84.69 to 97.11 per cent deadhearts), the highest being in November planting. There was no incidence during April planting.

It was evident that the crop planted between July to December had suffered heavily due to pest incidence than crops sown in April to June and January to March which had lower per cent of deadhearts. In all the plantings, both the genotypes had similar level of infestation with regard to oviposition and damage. The first treatment (carbofuran soil application) recorded less number of deadhearts in all the plantings (ranging from 0.0 to 9.66 per cent) even in the face of high levels of incidence, indicating its efficiency in controlling the pest effectively.

Studies on the interaction between pest abundance and abiotic components of the environment viz., temperature, relative humidity and rainfall indicated a significant and negative correlation between oviposition and deadhearts and maximum

temperature. A significant and positive relationship was observed between deadhearts and morning relative humidity. But the multiple linear regression analysis revealed that none of the abiotic factors individually were significant but there was interaction among different factors.

However, the impact of the maximum temperature and the number of rainy days seemed to be more marked as demonstrated with the help of path coefficient analysis. When maximum temperature prevailed between March to June, the pest abundance was limited, ranging between 13.8 to 6.4 per cent of deadhearts. With the onset of monsoon and subsequent fall in maximum temperature, the pest build up started gradually and its activity continued unabated with little fluctuations till December. However, there was a steep decline of incidence in January planting (from 96.8 per cent in December to 11.3 per cent in January) which might be due to low temperatures and lower relative humidity prevailed during that period.

The earlier studies at Dharwad (Thimmiah et al., 1973) revealed that crops sown during late June to October were severely attacked. Similar results were observed by Rao deo et al. (1972) in Maharashtra. At Hyderabad, the pest incidence was high during post rainy season and very few plants escaped attack

according to Davies and Seshu Reddy (1981). The present studies are largely in confirmity with the above workers. Contrary to this, Jotwani et al. (1970) reported peak incidence during March-April in Delhi. This may be attributed to changes in cropping pattern and lower temperature prevailing in that region during those months.

Earlier studies conducted by Naitam and Sukhani (1985), revealed negative and significant relationship with maximum temperature and no significant relationship could be established with minimum temperature by Gahukar (1987), who also observed interaction between rainfall, temperature and relative humidity. The results obtained in the present study are in agreement with the above workers.

According to Usman (1968), a mean maximum temperature of 30 to 33°C, minimum temperature of 21°C and 80 to 90 per cent relative humidity during the first four weeks from sowing are the most favourable conditions for the activity of shootfly. Similar view was expressed by Doharey et al. (1977) who reported that a temperature of 30°C and 90% RH are very ideal for its emergence.

The results obtained have conclusively shown that optimal maximum temperature of 27 to 33°C, minimum

temperature of 11 to 22°C, morning RH of 70 to 92 per cent and evening RH of 30 to 68 per cent as obtained in these investigations seemed to have highly favoured the pest and suitably adjusting the time of sowing should help in controlling this pest in kharif to an appreciable extent.

5.1.2 The stem borer

Information on the seasonal occurrence of a pest with reference to the time of sowing and the favourable stage of crop growth suitable for breeding as well as feeding will give a definite clue as to the period of peak occurrence as well as its low level of activity. This knowledge can be utilised to suggest suitable time of sowing with reference to normal cropping period or to make acceptable modifications in the cropping system and also to time the various approaches for the control to have an ecologically sound method to check the pest.

Seasonal occurrence of stem borer was studied by taking up monthly sowings in normal cropping period.

The leaf feeding injury was more in June, July, November and February months and low in August (1.54) followed by September and May months. The two genotypes were on par with respect to leaf damage in all the plantings. The extent of deadheart formation

was nearly proportionate to the intensity of leaf feeding. The crop sown in the month of June, January and October registered the highest infestation and lower per cent of deadhearts were observed in September, March, August, February, November and April sowings.

It is evident from these studies, that the crop during June, July, November and February suffered heavily due to higher leaf feeding and deadheart formation. Hence, it may be advantageous to delay the sowing upto August in the stem borer endemic areas avoiding the peak period of activity of the pest and protecting the crop from shoot fly and other early season pest which are favoured by delayed sowing.

The correlation studies failed to bring out any significant factor contributing to pest build up or decline. However, the multiple regression has revealed that evening relative humidity was significant and negatively contributing to leaf feeding. It was observed that coefficient of determination ($R^2 = 0.652$) was able to explain the variation in the leaf damage to the extent of 65.2 out of 100. An one per cent increase in evening relative humidity will decrease the leaf feeding damage by 0.94%. The path coefficient analysis also supported the findings that evening relative humidity had a negative and direct effect both

for leaf feeding and deadheart formation. Further, maximum temperature and number of rainy days had direct and negative influence while rainfall, minimum temperature and relative humidity had positive and direct influence on leaf feeding and deadheart formation.

Earlier studies at Rajasthan (Sharma, 1964) revealed that the pest was active from June to November and early planted crop was severely damaged in summer.

Mahadevan and Chelliah (1986) reported negative correlation with minimum temperature and evening relative humidity while positive correlation was observed with maximum temperature and rainfall. The results obtained in the present study are in conformity with that of above workers.

Contrary to the present findings it was reported by Singh (1964), who found that plants were infested to the extent of 100 per cent during October, after which the population decreased with a period of diapause.

The mean stemborer population was highest in June sowing (21.87 per cent) followed by February planting at boot leaf stage. Lowest mean population was observed in August planting. The population at harvesting was the highest in April (22.44 per cent)

followed by January and March plantings. It can be inferred from these findings that during March to August, the population was high and the crop in those months suffered heavily due to pest attack and the pest activity declined in October to December months.

The population had a significant and positive correlation with minimum temperature and the path coefficient analysis revealed that maximum temperature and rainfall had strong positive and direct effect along with morning relative humidity. These results are in close confirmity with Singh et al. (1985), who reported that adult emergence was dependent on rainfall.

Thus, the results clearly showed that the leaf feeding was negatively influenced by evening relative humidity, whereas the minimum temperature positively influenced larvel diapause. However, the correlation between number of rainy days and population at harvesting, proved to be nonsignificant and positive. But the path coefficient analysis has revealed that the rainy days had a strong negative and direct effect, indicating that the diapausing larvae start pupating with the first summer showers and will emerge subsequently, there by giving rise to low larval counts.

In November and February to April plantings the genotype, CSH 1, had more deadhearts and pest population than the variety ICSV 1. This seemed to support the assumption that CSH 1 was more preferred to ICSV 1 because of its darker green foliage, thicker and more dwarf and succulent stem which might have favoured the pest for feeding. The carbofuran whorl application treatment proved to be significantly superior in reducing the population over other treatments which were on par with each other.

5.1.3 The shoot bug

The shoot bug incidence was found to be high in June to October plantings and with no activity during other plantings, the incidence being the highest in August planting (151.28 bugs ten plants⁻¹), while the lowest incidence was noticed in October planting (17.05 bugs ten plants⁻¹).

In the bioecology of an insect, the various weather factors prevalent in the ecosystem of the insect, play an important role in determining the population survival as well as population build^{up}. Weather factors not only influence the concerned insect but also the host plant, natural enemies, etc., which have a say in the development of insect population. Correlating the weather factors prevalent during the

period of observation or during definite periods prior to the time of observation individually or collectively, gives an indication on the influence of these factors on the pest population. Such data gathered over a long period helps to develop a meaningful forecasting system and appropriate measures to suppress the pest. Keeping these goals in view studies on incidence of shoot bug in relation to weather factors had been initiated and the results are discussed below.

Studies on the interaction between pest incidence and abiotic components have indicated a highly positive and significant correlation between the bug incidence and relative humidity, rainfall and number of rainy days. It was observed that coefficient of determination ($R^2 = 0.8740$) was found to be significant. It shows that climatic factors have collectively influenced the population fluctuation to the extent of 87.40 per cent. It may be noted that most of the partial regression coefficients were found to be non-significant, though the coefficient of determination tended to reach significant level. This may be due to close inter relationship among environmental factors which acted more in concert than individually. This merits further intensive probe by reducing the time interval for recording the data. However, the path coefficient analysis brought out distinctly, that

there was positive and direct influence of evening relative humidity on the incidence followed by rain fall and number of rainy days.

These results are in agreement with the observation of Prabhakar^{Y_a} et al. (1981) who reported that bugs were more in rainy season. They also confirm the findings of Agarwal et al. (1981) who reported the occurrence from mid July to end of December, with a population peak in September. Similarly, Rawat and Saxena (1967) reported a population peak in August to October at sehare. However, the present findings donot agree with the work of Sharma (1985) who found that the shoot bug was a serious pest during rabi crop and dry periods.

Thus, the results have conclusively shown that the amount of rainfall and number of rainy days which influence the relative humidity were the most important abiotic components of environment on the incidence of shoot bug. Maximum temperature range of 28.5 to 31.2°C, minimum temperature range of 13.1 to 22.8°C and more rainy days were found to be optimal for the pest, as the highest incidence was recorded at that range. Decrease in rainfall and number of rainy days had a delitorius effect on shoot bug incidence.

5.1.4 The sorghum midge

A perusal of the data on midge population reveals that the midge incidence was absent during June, December, April and May months. Maximum population was noticed between July to September months and the minimum during February and March months. Similar observations were also made with regard to midge damage, the highest being in May planting (97.52%) which bloomed in July followed by August, September, January and October bloomed crops.

A maximum temperature of 28.71 to 30.06°C, minimum temperature of 21.8 to 23.01°C, morning RH of 88.28 to 90.33% and evening RH range of 62.28 to 65.66% appeared to be optimum which favoured the pest, as the highest adult population was recorded at that range.

The correlation between morning and evening relative humidities, rainfall, number of rainy days and adult population was positively significant. However, the multiple regression analysis revealed that among the abiotic factors, only number of rainy days was found to be significant and all other abiotic factors included in the study did not exert significant influence individually but together were able to explain the variation in the population to the extent of 87.8 out of 100. The path coefficient analysis also

revealed that there was direct and positive effect of number of rainy days on incidence. Thus, number of rainy days which inturn influence the relative humidity, exerted profound influence on the adult population. The partial regression coefficient, amount of rainfall was significant and negatively influencing the midge damage. The path coefficient analysis also reaffirmed the same fact indicating that the amount of precipitation had the highest negative and direct effect (-2.1340) on damage followed by morning RH (-2.0477). However, the evening RH was found to have high positive and direct effect (2.1328).

Earlier studies conducted by Roth and Pitre (1975) revealed the sorghum bloomed during August and September were damaged extensively by midge. Similar results were obtained by Summers et al. (1976) who reported severe infestation of midge in the plantings made after 22nd June. Gowda and Thontadarya (1977) also reported a peak incidence during August and September with lowest activity in January and they also opined that moisture was the most important climatic factor in terminating diapause of midge maggot. Fisher and Teetes (1982) proved that higher RH was conducive for emergence of adults immediately before and after heavy rainfall under field conditions. Similarly, Mote and Ghule (1986) recorded positive and highly

significant correlation with rainfall. The present findings were in agreement with the above workers. On the contrary, Taley et al. (1971) noticed maximum incidence during December and January at Nagpur. In the present study, no midges were observed during December and less incidence was noticed in January. This might be due to climatic variation in the two regions. The minimum temperature was very low during the nadir of pest activity. The low temperature might have brought down the activity of midges as shown by path coefficient analysis. Even though the correlation coefficient was positive for rain fall, its effect was negative and the positive 'r' value was contributed indirectly through the number of rainy days as evidenced from Table-26. Similar pattern was observed with midge damage. The present study also brought the effectiveness of endosulfan spray at flowering stage to control midge damage effectively.

Thus, from these studies it was conclusively shown that minimum and maximum temperature, morning RH and intensity of rainfall had deleterious effect on midge infestation.

5.1.5 The head bug

The mean number of head bugs at milky stage were maximum in June followed by May and July to September plantings. However, there was no activity in

March-April plantings and had less infestation in February planting (Table 12).

It was evident that those crops which flowered during August to December suffered heavily due to higher population than crops coming to flowering in May to July which had no incidence or had low population of head bugs.

In general, morning and evening relative humidities and number of rainy days had a significant and positive influence while maximum temperature, exerted a negative effect. The path coefficient analysis also revealed highest negative and direct effect (-3.031) with maximum temperature. The number of rainy days also had a significant and positive correlation ($r = 0.610$) and had a direct and positive effect (0.7799) on head bug incidence.

These results agree with the work of Hiremath and Thontadarya (1984) who reported the presence of head bug throughout the year with peak activity during August to October and January, and they also observed a positive relationship with RH and negative relationship with maximum temperature at milky stage. However, Natarajan et al. (1989) recorded highest incidence during April, June and December with low population during August and November. The present findings donot

agree with the above reports. This variation in incidence may be due to changes in cropping pattern and different set of weather condition, obtained in the region. The damage by the head bug also followed the same trend as that of population.

However, the studies by Balasubramanian and Balasubramanian (1979) at Coimbatore and Bhavanisagar revealed higher population of the bug during summer than rainy season. Further, they found no correlation between bug population and maximum temperature, sunshine hours, morning and evening relative humidity and rain fall. They have reported negative correlation with the number of rainy days which do not agree with the present findings. In the present study head bug was absent during summer which does not receive any rainy days. Hence, the conclusions of Balasubramanian and Balasubramanian (1979) seemed to be unlikely to hold true. Maximum bug incidence was normally observed during the rainy season, and the crop planted during the late rainy season or post-rainy season was comparatively less damaged. However, the weather data showed that there were 13 and 12 rainy days during the summer season at Coimbatore and Bhavanisagar, respectively within a short period of 33 days. This situation was very close to the rainy season conditions obtained in most parts of the sorghum growing belt.

The fourth treatment (endosulfan spray at milky stage) controlled the head bugs effectively and significantly lower number of bugs were found in the T₄ treatment compared to other three treatments.

Thus, it can be concluded that a maximum temperature of 28.7°C to 31.4°C, minimum temperature of 18.9 to 22.8°C, morning RH of 80.0 to 89.9 per cent and evening RH of 44.2 to 63.7 per cent favours the pest incidence to a great deal as evidenced from the field population.

5.1.6 The oriental armyworm

The incidence of armyworm was noticed during August to October months with peak incidence during September which was in agreement with the observation of Ram Singh et al. (1987) who reported severe incidence during September. The present study also agreed with the findings of ICRISAT (1985) whose report revealed severe incidence during September.

5.2 BIONOMICS OF SHOOT BUG

A review of available literature shows that only preliminary studies were carried out with regard to biology of sorghum shoot bug. The developmental period of different stages for different generations has not been studied in detail. With reference to life

table studies also, very little has been reported. Detailed investigations on the above aspects was carried out and the findings are discussed below.

The biology of the insect was studied for two generations coinciding with insect activity in the field. The difference between the two generations was not much with regard to nymphal development and fecundity.

The results indicated that the pre-oviposition period varied from 2 to 3 days. The eggs were generally laid on the abaxial surface of the midrib of leaves. The average incubation period was found to be 8.2 days. The description of various stages and the duration of insect made are in agreement with Chelliah and Basheer (1965). However, the total life cycle, from egg to adult emergence ranged between 22 to 26 days which deviated from the observations made by the above authors, who reported the life cycle to be 18 to 31 days. However, the average life cycle period of 24.8 days was in accordance with the above authors.

Macropterous and brachypterous adults were found in both sexes. In female the colour was yellowish brown while it was dark brown in males. The females were nearly one and half times bigger than the males. The longevity of th adults showed that females

lived longer than the males. The average adult longevity was 43 and 16 days for macropterous male and female and 42 and 14 days for brachypterous male and female, respectively. This is in agreement with the work of Rawat and Saxena (1967). The average male to female ratio in shoot bug was found to be 1:1.27 in the current investigations. Preponderance of female was recorded in both the seasons. The highest growth index with reference to faster nymphal development was observed during September to November, which indicated that the environmental factors prevalent during that period was highly conducive to the build up of the pest.

The fecundity of the insect in relation to different durations of mating and different sex ratios was studied. The results revealed that the fecundity did not vary much inspite of repeated matings and with different durations of matings or with different sex ratios. Further, it is interesting to note that the population during the second generation did not possess any brachypterous forms which was amply supported by parallel observations made in the field. It is therefore clear from the present studies that the population had migrated to some other areas which might account for substantial decrease in the numbers after November. This affords a clue to find out its off-

season shelter and particularly the carry over mechanism after November which may help in effectively containing the pest building up in subsequent generations.

5.3 LIFE TABLE STUDIES

The survival value at the end of nymphal instars was 75 per cent. The net reproductive rate was 17.99 on sorghum. In general, the contribution of female towards the progeny was maximum on the fourth day of oviposition. The mean length of generation was 34.12 days. The innate capacity of a species for increase in numbers is governed by a number of components viz., the length of development of immature stages the adult life table and the age specific fecundity. Higher ' r_m ' value indicates higher multiplication rate. The results showed that the pest would be able to multiply 17.99 times on sorghum at the end of each generation and that on reaching stable age distribution, the population of the bug in its various stages viz., egg, nymph and adult contributed at the rate of 64.98, 30.82 and 4.18 per cent, respectively. Thus, it is clear from life-fecundity tables that the maximum contribution towards stable age distribution was made by the immature stages. The present studies seem to be the earliest on record as no information on this aspect is available in the literature.

5.4 CROP LOSS ASSESSMENT DUE TO SHOOT BUG

According to Pradhan (1964), in the absence of correct estimates of loss due to insect pests, various guesstimates have been made by scientists and administrators but none of them is backed by adequate data collected on a sufficiently large scale either in respect of time or space.

In India, research on this aspect of crop loss estimation is still in its infant stage and the information of scientific and practical value available so far leaves much to be desired.

Assessment of crop losses due to insect pests is a prerequisite for any planned programme of crop protection for getting economically higher returns. In India intensive cropping and planting of high yielding susceptible varieties have contributed to considerably higher losses due to insect pest attack. The efforts made to assess the losses due to the pests of major crops in the country are meagre and on the other hand the existence of few insects on a crop or few damaged plants in a field has resulted in unnecessarily spending on protection in addition to polluting the ecosystem. A great deal of careful field experimentation is necessary before a tangible relationship between the insect attack and the crop loss can be

established. The present work is an effort in that direction.

With a view to evolve an effective, economical and judicious spray schedule, spraying of methyl demeton 0.03% was given in all the treatments as per the schedule.

The incidence was lowest with 142.21 bugs per ten plants in the complete protection treatment and highest with 440.77 bugs per ten plants in unprotected plot. The treatment, complete protection recorded less number of bugs per ten plants and gave the highest grain yield of 33.38 q ha⁻¹. The treatment, spraying at 45 and 60 DAE yielded 30.37 q ha⁻¹ which was on par with the treatments, protection twice at 30 and 45 DAE and 60 DAE. The lowest yield was recorded in unprotected plot. With respect to fodder yield, the treatments, protection at 45 DAE and 60 DAE were on par. Similarly the treatments, protection at 30 and 45 DAE and 45 and 60 DAE were on par with each other.

The effectiveness of methyl-demeton 0.02% for the control of shoot bug and in increase in the grain yield over control was reported by Gandhele et al. (1986). In the present studies, also it was found that protecting the crop twice at 45 and 60 DAE was superior than protecting the crop at 30 and 45 DAE and other

single spray treatments. It was also observed that spraying methyl demeton 0.03% at any stage of the crop viz., 30, 45 and 60 DAE was better than the untreated control. No published reports were available on the crop loss studies in relation to shoot bug damage.

The relationship between the bug incidence and the grain yield was found to be negative and significant ($r = -0.7123$). It showed that, as the bug incidence increased the grain yield decreased. Similarly, negative significant correlation was observed with fodder yield ($r = -0.7329$) thereby indicating decrease in the fodder yield with increased incidence.

The complete protection (three sprays at an interval of 15 days starting from 30 days after emergence) brought down the bug incidence and increased grain and fodder yields. But the other treatments viz., single spray protection at 30, 45, 60 and twice at 30 and 45 DAE were on par with each other in respect of grain yield. From the data it appears that no significant difference was observed among the treatments of spraying at 30, 45, 60 and twice at 30 and 45 DAE. When the maximum protection was given, the damage due to shoot bug was not completely checked. Though, it recorded the highest grain and fodder yields

it would be advisable to adopt most economic spray schedule in terms of number of sprays.

Regarding the avoidable loss due to the pest, maximum additional yield of 7.11 q/ha was obtained in complete protection treatment compared to control, followed by spraying at 45 and 60 DAE (4.10 q/ha). The fodder yields also followed the same trend.

Completely protected plot recorded maximum yield and the avoidable loss was zero. So, it was taken as a standard for comparing the yields in other plots. When the crop was sprayed twice at 45 and 60 DAE, the avoidable loss in grain yield was minimum (9.01 per cent) and the avoidable loss was 12.13 per cent when the crop was protected at 30 and 45 DAE. In the untreated control the avoidable loss was 21.03 per cent. Protection at 60 DAE resulted in an avoidable loss of 12.43 per cent.

From the economic point of view, though complete protection recorded maximum yield increase of 7.11 q/ha and could get a net profit of Rs.2558.00/ha, the cost benefit ratio was low (1:5.59). The cost benefit ratio was highest in spraying at 60 DAE with 1:8.13 and the net profit obtained was Rs. 1186.80/ha, followed by spraying at 45 DAE with 1:7.17 and the net profit was Rs.1045.60/ha. From the point of cost-

benefit ratio, application of single spray with methyl demeton 0.03% at 60 DAE was superior to protection at 45 and 60 DAE or complete protection. However, when avoidable loss alone was considered spraying both at 45 and 60 DAE was the best treatment.

Thus, it is evident from the above data that the most critical stage of the crop vulnerable to the pest is 45 to 60 DAE as the crop suffered maximum yield losses when no protection was given to the crop during those periods. Further, the data on cost benefit ratio revealed that the crop sprayed at 60th day gave the highest ICBR as compared to two sprays given at 45 and 60 DAE underscoring the absolute need for protecting the crop at 60 DAE.

The present findings are in confirmity with Khan and Rao (1956) who observed that when the flag leaf was infested, it adhered to the ear and interfered with grain development. Similarly, Chelliah and Basheer (1965) and Agarwal et al (1981) reported that shoot bug causes death of top leaves when attacked at latter stages of crop growth thereby leading to failure of emergence of the earhead due to death of top leaves

Similar, results obtained in the rabi season, further, confirmed that the shoot bug damage can be

effectively minimised by affording timely protection at 60 DAE of the crop. In view of the fluctuating price pattern of the produce it is not desirable to solely depend on cost-benefit ratio and therefore assessment of avoidable loss in concert with ICBR would give a more reliable picture of the efficacy of the sprayings. Viewed from this point, in the present studies, protection twice at 45 and 60 DAE was found to be both effective and economical.

5.4.1 Crop loss under cage conditions

In view of the fact that the conditions in nature do not permit the regulation of insect population per plant or unit area and avoiding influence of other biotic factors a greenhouse experiment was conducted on potted plants on which known number of first instar nymphs were released to assess the yield loss.

The results indicated that the avoidable loss of 7.88 per cent can be eliminated by controlling 15 bugs/plant. Similarly in the second experiment, 14.17 per cent of loss can be avoided by removing 15 bugs/plant.

The economic injury level of a pest population is the most reliable index for economic management of the pest, but it is influenced by a number of

variables. They include yield potential of the variety, market value of the commodity and cost of pest control. The EIL concept is highly flexible varying from place to place depending upon the varietal, edaphic and climatic factors. According to Stehr (1975), EIL may be affected by complex interactions between the severity of pest infestation and local climate, season vigour and variety and age of crop when attacked.

Therefore the crop loss assessment under caged conditions was conducted to determine the yield reduction due to shoot bug which was used to calculate the EIL.

Hence, the present finding on EIL i.e., 3.73 shoot bugs/plant though not universally applicable serves as a broad guideline for initiating management practices in the semi-arid-tropical zone in particular and other areas in general.

These studies on loss estimation, assessment of avoidable loss both under field and cage conditions, and calculation of economic injury level of shoot bug seem to be the earliest as no information on this aspect is found in the available literature.

5.5 VARIETAL SCREENING

In any integrated pest management programme, resistant varieties play a predominant role in

minimising the application of pesticides and thereby environmental pollution. Particularly in semi-arid-tropics resistant varieties prove handy since the sorghum crop was mostly raised by small and marginal farmers with minimum economic resources, who cannot afford for plant protection. Hence, the present study was undertaken to screen 20 hybrids and 18 varieties against shoot bug for two seasons.

In the screening trials the number of shoot bugs on different sorghum genotypes was taken as criterion for identifying the promising genotypes. The results indicated that among varieties SPV 736, SPV 858, SPV 756, SPV 775, SPV 741, SPV 678, SPV 819 and CSV 10 and among hybrids MSH 65 and SPH 388 proved to be promising against shoot bug in kharif season and the same genotypes were also found to be promising in rabi season except the variety SPV 710 and hybrid SPH 388. In addition the genotypes CSV 11, PSYH 3 and SPH 430 proved to be suitable for rabi season only, recording less number of shoot bugs. This might be attributed to variation in season and nutrient status which warrant further detailed studies. The variety ICSV 1, proved to be highly susceptible in both the seasons.

Agarwal et al. (1981) screened 127 sorghum genotypes and found that resistant varieties had leaves that were very tightly wrapped round the stem, while

susceptible varieties had more loosely attached leaves. In the present study, the bugs were found mostly in the central shoot and to a lesser extent on the leaves and stem at the bottom.

Thus the genotypes which proved to be tolerant to shoot bug in both kharif and rabi seasons, may be utilised for replacing the existing susceptible cultivars in the bug prone areas and can be used as donors in the resistant breeding programmes.

5.6 CHEMICAL CONTROL OF SHOOT BUG

The sucking pest, P. maidis poses a major threat in realising the potential maximum yield, besides transmitting viral diseases. In spite of adopting all necessary agricultural practices it could not be contained. Control of insect pests, to a larger degree, depends on the judicious and proper use of insecticides. Identification of a suitable insecticide and its application at the appropriate time will be useful to achieve pest suppression with higher cost benefit ratio resulting in greater net returns. Various insecticides were tested by a few workers and among them were methyl demeton, dimethoate and endosulfan etc. In the present investigation, methamidophos, a new insecticide, belonging to organo phosphate (O, s-dimethyl phosphoranothioate) group

which is primarily systemic in action, was evaluated in comparison with other insecticides for its efficacy against shoot bug.

The evaluation of insecticidal treatments in kharif against shoot bugs at 30 DAE revealed that methamidophos 0.1% was on par with methyl demeton 0.05% and dimethoate 0.05% during 24 and 48 hours after spraying. However, endosulfan 0.07% which was not as effective initially, picked up after seven days of spraying and was on par with methamidophos 0.1% and methyl demeton 0.05%.

In the second spray at 45 DAE the results followed the same trend with methyl demeton 0.05% and methamidophos 0.1% proving to be on par with each other at one, two and seven days after spraying. In the treatment spraying at 45 days also, endosulfan 0.07% once again a late starter was on par with the above treatments only after seven days of spraying.

In the third spray at 60 DAE a similar trend was noticed. From the results it is clear that the shoot bug was effectively controlled by the higher concentrations of the insecticides tested in all the three sprays. The three systemic insecticides proved to be effective even from the time of application. However, endosulfan 0.07% which was less effective to

start with joined the other three proving as equally effective. This might be due to sucking type of feeding behaviour of shoot bug; receiving, translocated or adsorbed residues of the systemic insecticide which might have possibly lead to a better control through systemic insecticides initially.

Moreover, shoot bugs were found to infest the crop from seedling to earhead stage and the feeding was continued throughout the period. However, 60 day old crop was the most crucial stage of the crop for causing maximum damage. The attack at the bootleaf stage will prevent the earhead emergence from bootleaf and thus complete loss in grain will occur. Hence, the insect control must be directed at this most crucial stage in order to check the pest effectively.

The already available recommendation on insecticidal control of this pest lost sight of an important aspect i.e., correct time of application. In the earlier experiments Rathore et al. (1970) proved the efficacy of endosulfan 0.03% while Gandhale et al. (1986) suggested sprays of methyl demeton 0.02% and dimethoate 0.03%. The findings in the present study with regard to the above insecticides are in confirmity with that of above workers.

The yield data showed that the insecticidal treatments were found very effective against shoot bugs and recorded higher yields as compared to untreated check. Similar increase in yields with methyl demeton and dimethoate was reported by Gandhale et al. (1986). However, the control of shoot bugs and resultant yield increase have focussed the potential of methamidophos, a new insecticide, as an effective, alternate insecticide.

5.6.1 Cost benefit ratio

Among the insecticides tested for the control of shoot bugs in kharif, the highest net income was realised by the application of methyl demeton 0.05 per cent (Rs. 3548.00). But the cost benefit ratio was the highest for dimethoate 0.03 per cent (1:10.26) followed by dimethoate 0.05 per cent (1:7.92) and methyl demeton 0.03 per cent (1:7.55). The low cost benefit ratio with the latter chemical (methyl demeton) inspite of its high net return per hectare, was due to the high cost of the chemical. In methyl demeton treated plots, eventhough the per cent reduction in incidence increased with increase in concentration, the cost benefit ratio was not in the same order. Hence, these results indicate that the treatment responsible for higher mortality of shoot bugs and increased yields with consequent net returns per hectare, did not give

high cost benefit ratio. Under such circumstances, it is advisable to adopt a treatment which gives maximum net returns per hectare rather than being guided by cost benefit ratios. The relative advantage due to application of methamidophos could not be determined as the chemical was not commercially released and therefore its cost is not known.

During rabi of 1988-89 the same insecticides at similar concentration were tested against the shoot bug. But only two sprays were given at 30 and 49 DAE. The third spray could not be given as there was no sufficient incidence. However, results are consistent with those obtained during kharif, the only exception being that all the treatments were on par at seven days after spraying and were significantly superior to untreated check. The second spray given at 49 DAE also revealed the same pattern as that of first spray. However, during seven days after spray there was a general decline in the shoot bug population and then the untreated check was on par with endosulfan treatment indicating that endosulfan 0.05% treatment seemed to have failed to protect the crop. This may be due to change in weather conditions which might have depressed the bug population in the control plots.

With regard to grain yield also the rabi season results were found to be similar to that of

kharif season with methamidophos 0.1%, methyl demeton 0.05%, endosulfan 0.07%, and dimethoate 0.05% recording 36.39, 36.19, 35.70 and 35.35 q ha⁻¹, respectively. With respect to fodder yield all the insecticidal treatments were found to be on par with each other.

The highest net income was due to the treatment methyl demeton 0.05% (Rs. 2698.40), as observed in kharif while the highest cost benefit ratio was found to be with dimethoate 0.03% (1:11.92).

CONCLUSIONS

The following conclusions are drawn from the investigations carried out on the population dynamics and influence of abiotic factors on population build up of major pests of sorghum, and bioecology, crop loss assessment and management of shoot bug.

1. The peak period of occurrence of shoot fly was from July to December and the lowest incidence was recorded from April to June and January to March.
2. The findings on the impact of climatic factors on deadheart formation due to shoot fly revealed that maximum temperature had a significant and negative correlation, while morning relative humidity exerted a significant and positive influence.

3. The peak period of occurrence of stem borer as reflected by leaf feeding injury and deadhearts, was in June, July, November and February and the minimum incidence was during August, September and May months.
4. The negative influence of evening relative humidity was remarkable on the leaf injury by stem borer larvae and maximum temperature and number of rainy days had a significant and negative influence on the incidence i.e., the higher the temperature and the number of rainy days, the lesser it was favourable for the pest attack.
5. The stem borer population counts were higher during August and April at bootleaf stage and during August, May and July almost synchronising with harvesting while low counts were recorded during October at bootleaf stage and during November and December again at harvesting.
6. There was a positive influence of minimum temperature on stem borer larval counts' and increase in temperature and rainfall had an adverse influence on the larval population but favoured the pupal formation.

7. The shoot bug was found active in the crops planted between June and October and absent during other plantings.
8. The shoot bug incidence was spurred by the intensity of rainfall and number of rainy days which inturn influenced the relative humidity favouring the pest.
9. The peak period of occurrence of midge was during July to September months and minimum activity was observed during February and March months.
10. The midge activity was positively influenced by the number of rainy days where as amount of rainfall and temperature had a negative effect on midge damage.
11. The crops which flowered during August to December suffered heavily due to higher population of head bugs than those which flowered in other months.
12. The head bug population was positively influenced by relative humidity and number of rainy days whereas maximum temperature had a deleterious effect.

13. The peak period of occurrence of armyworm was during September and October months and there was no activity during other months.
14. Studies on various stages in the life period of shoot bug and their duration in two generations and description besides life fecundity tables revealed that the preoviposition period varied from 2 to 3 days and the total life cycle lasted for 22 to 26 days. The fecundity was found to be 46 eggs on an average per adult female.
15. Studies on assesement of crop losses due to shoot bug under field conditions have clearly revealed that the vulnerable stage of the crop for causing maximum damage was 60 DAE and the avoidable loss was minimum when the crop was protected twice at 45 and 60 DAE.
16. The EIL worked out for shoot bug from the data obtained from greenhouse studies conducted on ICSV 1, variety was found to be 3.73 bugs plant⁻¹.
17. The varietal screening studies indicated that among the genotypes, SPV 736, SPV 858, SPV 756, SPV 775, SPV 741, SPV 678, SPV 475, SPV 819, CSV 10, MSH 65 and SPH 388 proved to be promising against shoot bug both in kharif and rabi seasons except the entries, SPV 710 and SPH 388.

18. The chemicals viz., dimethoate, methyl demeton, endosulfan and methamidophos which were tested for the control of shoot bug proved to be equally effective at higher concentrations. However, the cost benefit ratio was found to be in favour of dimethoate 0.03%.

FUTURE LINE OF WORK

Based on the present investigation, the following guidelines are given for future research.

1. For correlation of pest incidence with different abiotic components the data needs to be collected at more frequent intervals over a long period so that the same can be utilised for construction of a prediction model.
2. The study must also include biotic components along with abiotic factors for having a better insight into the population fluctuation.
3. The life fecundity tables must be constructed based on field population studies for shoot bug.
4. The reasons for absence of brachypterous forms of shoot bug after November such as off season shelters, if any, leading to a better understanding of its carryover mechanism may be investigated.

5. As the EIL concept is flexible and location oriented it must be worked out extensively for different cultivars to determine the exact need for control intervention.
6. The genotypes which were identified as resistant to the bug may be further subjected to a critical biophysical and biochemical analysis to find out the factors associated with the mechanism of resistance.
7. Varietal screening for shoot bug must be done separately for kharif and rabi seasons, with more number of accessions.

...

SUMMARY

CHAPTER VI

SUMMARY

Studies on the population dynamics of major pests of sorghum, influence of abiotic factors on population build up of major pests of sorghum, bionomics of shoot bug, crop loss assessment due to shoot bug and management of shoot bug were carried out at the Bayer Agricultural Research Institute and Trial Farm, Medchal (Medak district of Andhra Pradesh) during 1988-89 and the results are summarised below.

Studies were conducted on two sorghum genotypes, CSH - 1 and ICSV 1 which are susceptible to major pests of sorghum. The population dynamics studies were carried out by staggering the planting at monthly intervals in a split plot design.

The results of the study showed, that population build up of insects was considerably influenced by the different weather parameters.

The shoot fly oviposition and damage was found to be in its peak from July to December and low activity was observed between January to June months. The incidence was absent during April planting. Maximum temperature proved to be decisive adverse factor while relative humidity had a significant and positive relationship with oviposition and damage.

Throughout the study both the genotypes had exhibited a similar reaction to the pest in all the plantings.

The per cent of plants with leaf feeding damage by stem borer was more in June, July, November and February while it was observed to be low in August followed by September and May months. The extent of deadheart formation was proportionate to the intensity of leaf feeding. The crop planted in the month of June, January and October received the highest infestation and lower per cent of deadhearts were observed in February to April, August, September and November sowings. Evening relative humidity was found to be significant and negatively contributing to leaf feeding along with maximum temperature and number of rainy days, which also registered a negative and direct influence.

The stem borer population was highest in August (21.87%) followed by April at boot leaf stage. Lowest counts were recorded in October. The population at harvesting stage was highest in August followed by May and July months. The lowest counts were recorded in November and December months. The population had a significant and positive correlation with minimum temperature and the path coefficient analysis clearly revealed that maximum temperature and rainfall exerted a strong positive and direct effect on incidence along

with morning relative humidity. In certain plantings viz., February to April and November the hybrid, CSH - 1 had more per cent of deadhearts and immature population than the straight variety, ICSV 1.

The shoot bug was active in June to October planted crop with highest incidence during August planting and lowest incidence was noticed in October planting. The shoot bug incidence was absent in between November to May plantings. The amount of rainfall and number of rainy days which influenced the relative humidity were found to be the Principal abiotic components associated with incidence of shoot bug in a particular eco-system.

The midge population was absent during June, December, April and May where as the highest population was noticed in between July to September months and diminished activity during February and March. Similar observations were made with regard to midge damage. For the midge activity, number of rainy days was found to be significant and positively influencing its incidence, where as rainfall was found to be a negative factor for midge damage. From the experimental results it was proved that minimum and maximum temperatures, morning RH and rainfall had deleterious effect on midge infestation.

In respect of head bug, the crops which flowered during August to December suffered heavily due to higher population than crops coming to flowering in May to July which recorded either sparse or negligible population of head bug. The damage pattern also followed the same trend as that of the intensity of population. In general, relative humidity and number of rainy days had a significant and positive influence while maximum temperature, got a negative and direct effect.

The incidence of armyworm was observed only in September and October months with peak activity during September.

In the chemical control trial against the pest complex, the treatments viz., carbofuran soil application (T1), carbofuran whorl application (T2), endosulfan spray at flowering stage (T3) and endosulfan spray at milky stage (T4) to control shoot fly, stem borer, midge and head bug, respectively proved to be very effective in checking them which was clearly revealed by the fact that when particular treatment was excluded from the analysis, all the other three treatments were found to be on par with few exceptions. Even the main treatment differences for different pests was in general not much except with stem borer, where more incidence was observed on the hybrid, CSH 1.

The biology studies conducted under laboratory condition revealed that the eggs of shoot bug were observed to be elongate, cylindrical and slightly tapering at both ends. They were laid in groups of one to five on the abaxial surface of the leaf on midrib and covered with a waxy coating. The fecundity ranged from 29 to 46 eggs during September to November and it was 34 to 45 eggs during November to January while the growth index was 5.22 and 5.02 during the corresponding generations, respectively. The incubation period was 8.2 and 8 days during September to November and November to January, respectively. The nymphal stage consisted of five instars. The mean total nymphal period was 16.6 days in both the generation and the average time taken for total life period was found to be 24.8 days in September to November and 24.6 days in November to January. The longevity of male and female shoot bug was found to be 16 and 43 days, respectively, in macropterous forms while in brachypterous forms it was 14 and 42 days, respectively, during the first generation. During the second generation the longevity of macropterous male and female was 12 and 37 days, respectively.

The life fecundity table studies conducted under controlled conditions revealed that the shoot bug would multiply 17.99 times on sorghum at the end of the generation with a mean generation length of 34.12 days.

The innate capacity for increase in numbers and finite rate of increase was 0.0846 and 1.088 female/day, respectively. The stable-age-distribution revealed that the population would comprise 64.98% eggs, 30.82% nymphs and 4.18% adults.

The studies on crop loss assessment was to evolve a judicious spray schedule which brings out the maximum protection and it was observed that protecting the crop twice at 45 and 60 DAE was the most effective treatment in recording higher yields coming as a close second to complete protection treatment. Further, it was observed that the avoidable loss was minimum when the crop was protected twice^{at} 45 and 60 DAE. However, the cost-benefit ratio was observed to be more when single spray was given at 60 DAE which proved to be the best treatment from the economic point of view. Thus, that 60 day old crop was found to be the most vulnerable stage and protection of the crop at that critical stage should be invariably provided for obtaining maximum yields. The economic injury level of infestation due to shoot bug was estimated to be 3.73 bugs per plant.

Host plant resistance to shoot bug was studied in 38 genotypes. These genotypes were grouped into three distinct classes based on the mean and standard deviation of the field population. MSH 65 and SPH 388 among hybrids and SPV 736, SPV 858, 756, 775, 741, 678,

475, 819 and CSV 10 among varieties proved to be promising during the kharif season where as ICSV 1, CSH 1, CSH 5, CSH 9 and CSH 10 proved to be highly susceptible. When these genotypes (38) were further tested in rabi season based on the population throughout the crop period, the same genotypes which were proved to be promising in kharif, also proved to be promising in rabi except the variety, SPV 710 and hybrid, SPH 388. In addition CSV11, PSYH3 and SPH430 proved to be promising, only in rabi season. Popular cultivars like CSH1, CSH5, CSH 9, CSH10 and ICSV1 fell under highly susceptible group in both the seasons.

Studies on chemical control of the shoot bug were undertaken in the field adopting randomised block design layout. The observation on efficacy of the insecticides against the pest had been recorded as reduction in bug population. Methyl-s-demeton, methamidophos, dimethoate and endosulfan at higher concentration were found to be superior than their lower concentrations. Although the value of additional yields obtained was higher in the higher concentration of insecticides, the lower concentration of 0.03% dimethoate gave greater net returns and recorded the highest cost-benefit ratio in both the seasons.

...

LITERATURE CITED

LITERATURE CITED

- Abdin A M Z E 1981 Review of sorghum shoot bug research in the Sudan. Insect Science and its application 2 : 55-58.
- Adesiyun A A 1981 Seasonal abundance of shoot flies infesting sorghum and their natural enemies in Samaru, Nigeria. Insect Science and its application 2 : 49-53.
- Agarwal R K , Verma R S and Bharaj G S 1981 Screening of sorghum lines for resistance against shoot bug. JNKVV Research Journal 12 : 116.
- Akola P K V 1973 Sorghum midge and its control. Pamphlet 23, Department of Extension, Punjabrao Krishi Vidyapeeth, Akola, pp.1-3.
- Atwal A S and Bains S S 1974 Exercises in population studies. Applied Animal Ecology, Kalyani Publishers Ludhiana pp.128-138.
- Ayyar T V R 1950 Insects attacking millets. Hand book of economic entomology for South India. pp. 161-181.
- Balasubramanian G and Balasubramanian M 1979 Influence of weather factors on the population of sorghum ear head bug. Madras Agricultural Journal 66 : 830-832.
- Balasubramanian G, Sivaprakasam K, Kulandaivelu R and Robin Son J G 1979 Impact of sorghum ear heads on the incidence of earhead bug, caterpillar, webber and mould. Indian Journal of Agricultural Research 13 : 106-108.
- Balraj Singh, Battu G S, Dhaliwal J S and Atwal A S 1975 Population Studies on the maize borer in the Punjab. I-mode of hibernation and survival of overwintering larvae. Indian Journal of Entomology 37 : 132-136.

*Barral J M, Peterlin O, Stacul M V D E and Arias M G
1974 Ecological aspects of the sorghum midge in
the Central region of Chaco. Bulletin of Argentina
Estacion Experimental Regional Agropecuaria INTA
65: 34.

Baxendale F P and Teetes G L 1983 Thermal requirements
for emergence of over wintered sorghum midge.
Environmental Entomology 12 : 1078-1082.

Bernays E A, Chapman R F and Woodhead S 1983 Behaviour
of newly hatched larvae of Chilo partellus Swinhoe
associated with their establishment in the host-
plant, sorghum. Bulletin of Entomological Research
73 : 75-83.

Birch L C 1948 The intrinsic rate of natural increase
in insect population. Journal of Animal Ecology 17
: 15-26.

*Busoli A C, Gallo D, Lara F M and Sicci S O 1979
Influence of the planting time of sorghum on the
incidence of midge and Diatraea saccharalis Fabr.
Anais da Sociedade Entomologica do Brasil 8 : 103-
113.

Chatterjee S N and Ram R D 1970 A technique for
staining and counting leaf hopper eggs laid in leaf
tissues. Science and Culture 36 : 597-598.

Chelliah S and Basheer M 1965 Biological Studies of
Peregrinus maidis Ashmead on sorghum. Indian
Journal of Entomology 27 : 467-470.

Chundurwar R D 1978 Population density of immature
stages of C. partellus in sorghum stubbles. Madras
Agriculture Journal 65 : 553-554.

Chundurwar R D, Chavan V M and Tekale R R 1976
Studies on the seasonal incidence of sorghum midge
infesting sorghum cultivars. Sorghum Newsletter
19:51.

- Chundurwar R D, Kalyankar S P, Karanjkar R R and Mir Ashfaq Ali 1984a Effect of weather parameters on incidence of sorghum shoot fly at parbhani. Sorghum Newsletter 27 : 83.
- Chundurwar R D, Karanjkar R R, Kalyankar S P and Mir Ashfaq Ali 1984b Sorghum midge density relation to environmental factors. Sorghum Newsletter 27 : 84.
- Davies J C and Seshu Reddy K V 1981 Observations on oviposition of A. soccata ICRISAT Sorghum Entomology Progress Report 4:8
- Delobel A G L 1983 Influence of temperature and host plant condition on pre-imaginal development and survival in the sorghum shoot bug. Insect Science and its application 4 : 327-335.✓
- Delobel A G L and Lubega M C 1984 Rainfall as a mortality factor in the sorghum shoot fly. Zeitschrift fur Angewandte Entomologie 97 : 510-516.
- Deshpande V P, Thontadarya T S and Kulkarni K A 1982 Studies on the incidence of diapause of sorghum stem borer at Dharwad. Sorghum Newsletter 25 : 71.
- Dhaliwal G S and Sandhu G S 1981 Effect of the dates of sowing and seed rates on the infestation of sorghum shoot fly and the yield of sorghum fodder. Journal of Research (PAU) 18 : 157-162.
- Doharey K L, Srivastava B G, Jotwani M G and Dang K 1977 Effect of temperature and humidity on the development of Atherigona soccata. Indian Journal of Entomology 39 : 211-215.
- Dubey R C and Yadav T S 1980 Sorghum shoot fly incidence in relation to temperature and humidity. Indian Journal of Entomology 42 : 273-274.
- F A O (Food and Agriculture Organisation) 1986 F A O Production Year book, 1985 Vol.39, FAO, Rome, Italy.

- Firke P V and Kadam M V 1978 Studies on the seasonal incidence of the Jowar Stem borer, C. zonellus Journal of Maharashtra Agricultural Universities 3 : 141-142.
- Firke P V and Kadam M V 1979 Effect of sowing dates and seed rates on the incidence of A. soccata and grain yield of some sorghum varieties. Journal of Maharashtra Agricultural Universities 4 : 69-74.
- Fisher R W and Teetes G L 1982 Effect of moisture on sorghum midge emergence. Environmental Entomology 11 : 946-948.
- Fleming R and Retnakaran A 1985 Evaluating Single treatment data using Abbott's formula with reference to insecticides. Journal of economic entomology 78 : 1179-1181.
- Fletcher T B and Ghosh C C 1920 Borers in sugarcane, Rice etc. Rept. Proc. 3rd Entomology Meeting, Pusa, 1919, 1 : 45-50.
- Gahukar R T 1987 Population dynamics of sorghum shoot fly in Senegal. Environmental Entomology 16 : 910-916.
- Gandhale D N, Patil A S, Awate B G, Jadhav D B and Naik L M 1986 Evaluation of insecticides for the control of aphids and delphacids on Jowar. Pesticides 20 : 17-18.
- Gandhale D N, Salunkhe G N and Naik L M 1982 Relationship of sowing time and seed rate on shoot fly incidence in Sorghum. Indian Journal of Plant Protection, 10 : 67-69.
- Garg D O and Taley Y M 1978 Note on trends in population fluctuation of midge and Tetrastichus Sp., its parasite on sorghum during 1975-76. Indian Journal of Agricultural Sciences 48 : 51-53.

Gomez K A and Gomez A A 1984 Statistical procedures for Agricultural Research. A Wiley-Inter Science Publication. John Wiley and Sons, New York p.680.

Gowda B L V and Thontadarya T S 1977 Seasonal incidence of sorghum midge and its natural enemies. Mysore Journal of Agricultural Sciences 11 : 550-554.

Hardas M G, Supare N R and Chopde P R 1972 Studies in the seasonal incidence of sorghum midge infesting sorghum hybrids. Sorghum Newsletter 15 : 88-89.

Hiremath I G and Thontadarya T S 1984 Seasonal incidence of the sorghum earhead bug, Calocoris sp. Insect Science and its application, 5 : 469-474.

*Howe R W 1953 Studies on the beetles of the family ptinidae VIII. The intrinsic rate of increase of some ptinid beetles. Ann. Appl. Biol. 40 : 121-134.

*Hussaini M A 1929 Annual report of the Entomologist to Government of Punjab, Lyallapur for the year 1928-29. Department of Agriculture, Punjab, 1928-29 Part II : 137-170.

Hussaini S H and Rao P V 1967 Flowering behaviour of the parents in CSH-1 and CSH-2 Jonna hybrids under differential sowings. Sorghum Newsletter 10:33-34.

International Crops Research Institute for Semi-arid Tropics, Annual Report for 1984. Patancheru, Andhra Pradesh.

International Crops Research Institute for Semi-arid Tropics, Annual Report for 1985. Patancheru, Andhra Pradesh.

*Jabhar Khan M A 1984 Insecticidal effects of indigenous plant extracts on some delphacid rice pests in Pakistan. Annals Entomologici Fennici 50 : 95-96.

Jotwani M G, Marwaha K K, Srivastava K M and Young W R
1970 Seasonal incidence of shoot fly in Jowar
hybrids at Delhi. Indian Journal of Entomology 32
: 7-15.

Jotwani M G, Sukhani T R, Kishore P and Srivastava K P
1976 Effect of date of sowing on the incidence and
damage by sorghum midge, Cecidologia indica. Indian
Journal of Entomology 11 : 69-76.

Khan M Q and Rao A S 1956 The influence of the
black ant, Camponotus compressus F. on the
incidence of two homopterous crop pests. Indian
Journal of Entomology 18 : 199-200.

Krishnamurthy Rao B H, Subbaratnam G V and Murthy K S R
1983 Losses due to insect pests in Andhra Pradesh,
India. Indian Journal of Entomology (Special Issue)
pp.2-15. eds. B H Krishnamurthy Rao and K S R K
Murthy.

Kulkarni K A 1985 Screening Sorghums for midge
resistance. Proceedings of the International
Sorghum Entomology, Workshop, 15-21 July, 1984,
Texas A&M University, College Station, TX, USA,
pp.265-274.

*Lara F M, Gallo D, Busoli A C and Marchiori D L 1975
Diapause and population fluctuation in sorghum midge
in crops of sorghum sown on different dates.
Cientifica 3 : 168-173.

Mahadevan N R and Chelliah S 1986 Influence of season
and weather factors on the occurrence of the sorghum
stem borer, Chilo partellus Swinhoe in Tamilnadu.
Tropical pest Management 32 : 212-214.

Mogal B H, Mali A R, Rajput S G and Pawar K L 1980
Seasonal fluctuations in sorghum midge diapause.
Journal of Maharashtra Agricultural Universities 5 :
91-92.

Moray P E, Kazi S K and Ballal A S 1983 Influence of weather factors on the outbreak of armyworms. Journal of Maharashtra Agricultural Universities 8 : 128-131.

*Mote U N 1986 Seasonal incidence of sorghum stem borer. Current Research Reporter, Mahatma Phule Agricultural University 2 : 85-87.

Mote U N and Ghule B D 1986 Relationship of sorghum midge incidence with climatic factors and parasites. Sorghum Newsletter 29 : 71.

*Mote U N and Kadam J R 1986 Population dynamics and incidence of sorghum shoot fly in relation to climatic factors. Current Research Reporter, Mahatma Phule Agricultural University 2 : 81-84.

Murthy T K, Shirole S M and Bapat D R 1977 Studies on seasonal incidence of sorghum shoot fly. Sorghum Newsletter 20 : 54.

Nadagouda V B, Shastry K N R and Kulkarni K A 1974 Incidence of shoot fly adults affect on yield of rabi sorghum. Current Research 3 : 32-34.

Nageswara Rao G 1983 Statistics for Agricultural Science. Oxford and IBH Publishing Company, New Delhi pp.376.

Naitam N R and Sukhani T R 1985 Ovipositional behaviour of sorghum shoot fly under different soil, plant and weather parameters. Indian Journal of Entomology 47 : 195-200.

*Namba R and Higa S Y 1971 Host plant studies of the corn plant hopper, Peregrinus in Hawaii. Proceedings of the Hawaiian Entomological Society 21 : 105-108.

Natarajan N, Sundara Babu P C and Chelliah S 1989 Seasonal occurrence of sorghum earhead bug, Calocoris angustatus Lethierry (Hemiptera : Miridae) in Southern India, Tropical Pest Management 35 : 70-77.

Ogunlana M O and Pedigo I P 1974 Economic injury levels of potato leaf hopper on soybeans in Iowa. Journal of Economic Entomology 67 : 29-32.

Ogwaro K 1979 Seasonal activity of the sorghum shoot fly. Entomologia Experimentalis et Applicata 26 : 74-79.

*Otanés and Kargavilla 1940 Insect and other pests of corn. Philippines Journal of Agriculture 11 : 403-430.

Ponnaiya W X B 1951 Studies in the genus sorghum II The cause of resistance in sorghum to the insect pest, Atherigona indica Malloch. Journal of Madras University 21 : 203-217.

Prabhakar B, Rao P K and Rao B H K M 1981 Note on hemipterous species complex on sorghum at Hyderabad. Indian Journal of Agricultural Science 51 : 818-819.

Pradhan S 1964 Assessment of losses caused by insect pests of crops and estimation of insect populations. In Entomology in India Ed. N C Pant, Entomological Society of India, New Delhi. pp.17-58.

Prem Kishore, Rana B S and Agarwal K N 1985 Selection for the shoot fly resistance in high yielding varieties of sorghum. Journal of Entomological Research 9 : 188-194.

Ram S, Handa D P and Gupta M P 1976 Effects of planting dates of fodder sorghum on the incidence of shoot fly. Indian Journal of Entomology 38 : 290-293.

Ram Singh, Mrig K K and Chaudary J P 1987 Incidence and survival of Mythimna species on cereal crops in Hissar. Indian Journal of Agricultural Sciences 57 : 59-60.

Ranga Rao V, Ramamohan Rao M S, Hosmani S A and Ramachandram M 1973 Effect of sowing dates on the incidence of shoot fly and varietal performance of rabi Jowar in Mysore. Indian Journal of Agronomy 18 : 314-322.

Rao deo A K, Tikar D T and Chundurwar R D 1972 Records of natural parasites of sorghum shoot fly, Atherigona varia soccata Rondani. Current Science 41 : 430-431.

Rathore V S, Raghuwanshi R K, Sood N K and Kaushik U K 1970 Control of sorghum pests. PANS 16 : 358-360.

Rawat R R 1967 An estimation of population of Chilo zonellus Swinhoe in sorghum stubbles at Sehore (Madhya Pradesh). Indian Journal of Entomology 29 : 220-221.

Rawat R R and Saxena D K 1967 Studies on the bionomics of P. maidis J N K V V Research Journal 1 : 64-67.

*Ritchie A H 1926 Report of Department of Agriculture Tanganyika Terr. Dar-es-salaam pp.33-36.

Roth J R and Pitre H N 1973 Sorghum midge population dynamics and control. Sorghum Newsletter 16 : 117-118.

Roth J P and Pitre H N 1975 Seasonal incidence and host plant relationship of the sorghum midge in Mississippi. Annals of the Entomological Society of America 68 : 654-658.

Samarjit Rai and Jotwani M G 1979 Control of sorghum shoot fly by early sowing. Indian Journal of Entomology 41 : 300-302.

Sarup P, Jotwani M G and Pradhan S 1960 Chemical control of sorghum shoot bug. Indian Journal of Entomology 23 : 257-261.✓

Seshu Reddy K V 1982 Pest management in sorghum II pp.237-246 in sorghum in the Eighties : Proceedings of the International symposium on sorghum, 2-7 November 1981. ICRISAT Center, Patancheru, Andhra Pradesh, India.

Seshu Reddy K V and Davies J C 1979 Pests of sorghum and pearl millet and their parasites and predators recorded at ICRISAT centre upto August 1979. Cereal Entomology Progress Report 2, Patancheru, India.

Sharma H C 1985 Strategies for pest control in sorghum in India. Tropical pest Management 31 : 167-185.

Sharma R C 1964 Observations on some insect pests of Jowar at Ajmer (Rajasthan). Bulletin of Entomology 5 : 28-30.

Shivpuje P R, Bapat D R, Kulkarni A N and Phadnvis A N 1976 Seasonal incidence of shoot fly. Sorghum Newsletter 19 : 51-52.

Singh U C, Misra U S, Dhamdhare S V and Dwivedi U S 1985 Carry over of the sorghum stalk borer, Chilo partellus in off-season in different crops. Journal of Entomological Research 9 : 170-173.

Singh V S 1964 Studies on the incidence and infestation of Jowar stem borer. Agricultural Research 4 : 160.

Stehr F W 1975 Parasitoids and predators in pest management. In introduction to insect pest management Ed. Robert L. Metcalf and William Luckmann. Pub. John Wiley and Sons, New York, pp.147-188.

Stone J D and Pedigo I P 1972 Development of economic injury level of the green clover worm on soybean in India. Journal of Economic Entomology 65:197-201.

*Summers C G, Coviello R L, Pendery W E and Bushing R W
1976 Effect of sorghum midge on grain production in
the San Joaquin Valley relative to date of planting
and plant spacing. *Hilgardia* 44 : 127-140.

*Swaine G and Wyatt C R 1954 Observations on the
sorghum shoot fly. *East African Agricultural
Journal of Nairobi* 20 : 45-48.

Taley Y M, Deore B P and Thakare K R 1971 Bionomics of
sorghum midge, Contarinia sorghicola Coq. *Indian
Journal of Entomology* 33 : 202-208.

Taley Y M and Thakare K R 1980 Note on the population
dynamics in carry over of Chilo partellus. *Indian
Journal of Agricultural Sciences* 50 : 635-637.

Thimmaiah G, Desai K S M, Panchabhavi K S M and
Malipatil M B 1972 A note on the effect of late
sowing on the incidence of sorghum earhead bug in
North Mysore region. *Sorghum Newsletter* 15 : 54.

Thimmaiah G, Panchabhavi K S and Kulkarni K A 1973
Seasonal incidence of sorghum shoot fly and midge.
sorghum Newsletter 16 : 69-70.

Thontadarya T S, Awaknavar J S and Rao K J 1979
Diapause in the sorghum midge and its parasite,
Tetrastichus sp. and the role of moisture in its
termination. *Current Research* 8 : 60-62.

Trehan K N and Butani D K 1949 Notes on life history,
bionomics, and control of Chilo zonellus in Bombay
province. *Indian Journal of Entomology* 11 : 47-59.

Usman S 1968 Preliminary Studies on the incidence of
shoot fly on hybrid Jowar under differential
sowings. *Mysore Journal of Agricultural Sciences*
2 : 44-48.

*Van Hamburg H 1979 The grain sorghum stalk borer
seasonal changes in adult populations in grain
sorghum in the Transvaal. Journal of the
Entomological Society of Southern Africa 42 : 1-9.

Venugopal M S and Mani M 1978 Influence of weather
factors on the activity of sorghum shoot fly.
Sorghum Newsletter 21 : 68.

* Original not seen

...