Reaction of Genotypes Against Major Insect Pests of Sorghum [*sorghum bicolor* (L.)Moench]

THESIS

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by

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2017

CERTIFICATE – I

This is to certify that the thesis entitled "**Reaction of genotypes against major insect pests of Sorghum [*Sorghum bicolor* (L.) Moench]"** submitted in partial fulfilment of the requirements for the degree of ''**MASTER OF SCIENCE IN AGRICULTURE''** in the **DEPARTEMENT OF ENTOMOLOGY** of **Rajmata Vijayaraje Scindia Krishi Vishwa Vidyalaya, Gwalior** is a record of the bona-fide research work carried out by **Mr. KAKARA JATIN** under my guidance and supervision. The subject of the thesis has been approved by the student's Advisory Committee and the Director of Instruction.

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 investigations has been acknowledged by the scholar.

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CERTIFICATE – II

This is to certify that the thesis entitled **"Reaction of genotypes against major insect pests of sorghum [*Sorghum bicolor* (L.) Moench]"** submitted by **Mr. KAKARA JATIN** to the Rajmata Vijayaraje Scindia Krishi Vishwa Vidyalaya, Gwalior in partial fulfilment of the requirements for the degree of '**MASTER OF SCIENCE IN AGRICULTURE'** in the **DEPARTEMENT OF ENTOMOLOGY** has been accepted after evaluation by the External Examiner and approved by the Student's Advisory Committee after an oral examination of the same.

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ABBREVIATIONS

S.N.	Legend	Description
1	S.N.	Serial number
2	CD	Critical difference
3	cm	Centimeter
4	DAE	Days After Emergence
5	Df	Degrees of freedom
6	DAS	Days after sowing
7	*et al.*	Allied (and other)
8	g	Gram
9	ha	Hectare
10	i.e.	That is (in reference to)
11	Kg	Kilogram
12	max.	Maximum
13	min.	Minimum
14	N	Nitrogen
15	MSS	Mean Sum of Square
16	RH	Relative humidity
17	cv.	Cultivar
18	SE (m)±	Standard error of mean
19	SMW	Standard Meteorological Week
20	S.S.	Sum of Square
21	S.V.	Source of variance
22	Viz.	Wide list
23	^{0}C	Degree Celsius
24	%	Percent
25	RBD	Randomized block design
26	C.V.	Coefficient of variation
27	ANOVA	Analysis of variance
28	EMS	Error means sum of square
29	SFDH	Shoot fly dead heart
30	SBDH	Stem borer dead heart
31	SBST	Stem borer stem tunneling
32	SBLI	Stem borer leaf injury
33	Abaxial	Lower leaf surface
34	Adaxial	Upper leaf surface
35	OV	Original value
36	TV	Transformation value
37	LC	Local check

38	SC	Susceptible check
39	RH	Relative humidity
40	0C	Degree Celsius
41	*et.al.*	Allied (and other)
42	K_20 or k	Potash
43	P_20_5	Phosphorus
44	PPM	Parts per million
45	MM	Milli meter
46	Fig.	Figure
47	&	And
48	CD at P = 0.05	Probability Value

Chapter- I

INTRODUCTION

The sorghum crop [***Sorghum bicolor* (L.) Moench**] is grown in the world in over 45.81 million hectares and accounts for production of 67.83 million tons of grains with an average yield of 1492.6 kg/ha (FAO, 2016). Nearly 80% of the cultivated area lies in Asia and Africa. It is the fifth major cereal crop in the world after wheat, rice, maize and barley. In acreage, it ranks fifth and accounts for 3.5% of total cereal grain production. The term sorghum includes four groups of cultivated sorghum plants viz., grain sorghum (as food and feed), sweet stalk sorghum (as forage and for animal feed), Sudan grass (for forage and pasture) and broom corn (for making brooms).

In India, sorghum ranks third both in area and in production after rice and wheat. Sorghum is grown over an area of 6.88 million hectares with a total production of 6.45 million tones with an average productivity of 864 kg/hectare (USDA 2016). In Madhya Pradesh sorghum crop is grown mainly in Kharif season and covers an area of 272.13 Thousand hectares and production 374.97 Thousand tones with productivity of 1550 kg ha-1 respectively (Anon.2016) and cultivated mainly in Malwa, Jhabua, Nimar, Gird and Satpura plateau.

Sorghum is grown predominantly for human consumption. The grain is usually milled for flour and used for a variety of unleavened breads such as roti and chapatti in India, and leavened pancake-like breads. Sorghum is also an important source of animal feed and fodder. It is a principal feed ingredient for both cattle and poultry. The grain is fed as milled or steam flaked to beef and dairy cattle, and to poultry and pigs as a major energy source (Godwin, 2004). Sweet sorghum is being used in the preparation of syrup, beer, bio-fuel (ethanol). Demand for other confectionaries, jaggery and malted beverages are increasing in India (Ratnavathi et al., 2003). Sorghum is cultivated in different agro ecosystems and the grain yield is influenced by various biotic and abiotic factors. Sorghum grain yields on farmer’s fields in Asia and Africa are generally low (500-800 kg/ha) mainly due to insects, diseases, weeds and drought. Nearly 150 insect species have been reported as pests on sorghum (Reddy and Davies 1979; Jotwani et al., 1980). Shoot fly

(*Atherigona soccata* Rondani), stem borer (*Chilo partellus* Swinhoe), army worm (*Mythimna separata* (Walker)), shoot bug (*Peregrinus maidis* Ashmead), aphids (*Rhopalosiphum maidis* (Fitch.) and *Melanaphis sacchar*i Zehntner), spider mites (*Oligonychus spp*.), grasshoppers and locusts (*Heiroglyphus sp*., *Oedaleus sp., Aiolopus sp*., *Schistocerca sp*. and *Locusta sp*.), sorghum midge (*Stenodiplosis sorghicola* Coquillett), mirid bug (*Calocoris angustatus* Lethiery) and panicle-feeding caterpillars (*Helicoverpa armigera* Hubner, *Eublemma sp*., *Cryptoblabes sp., Pyroderces sp*., and *Nola sp*.) are the major pests of sorghum worldwide. Among them the shoot fly (*Atherigona soccata* Rondani), stem borer (*Chilo partellus* Swinhoe), ear head bug (*Calocoris angustatus* Leth.) and ear head worm (*Cryptoblebes gnidiella* Mab.) are the major important pests attacking sorghum at differnet stages of crop growth in gird region of Madhya-Pradesh.

Borad and Mittal (1983) have found that nearly 32.2% of the grain yield was lost due to insect damage. On the basis of all India Shoot fly has been reported to cause an average loss of 5 % (Jotwani, 1983). In India, the shoot fly has attained the status of a key pest because of the introduction of improved sorghum varieties and hybrids susceptible to this insect, continuous cropping, ratooning, and reduced genetic variability (Singh & Rana, 1986).Yield reduces of 55 to 83 % has been observed due to stem borer infestation in northern India (Jotwani et al. 1971). Losses due to panicle pests have been estimated to be over Rs. 972 million annually (Leuschner and Sharma, 1983). The major components of pest management in agro-ecosystem are cultural practices, resistant cultivars, natural enemies and pesticides. Insecticides play an important role in minimization of the insect pest population, but the farmers generally do not use plant protection measures, because of low returns. Cultural practices are most effective against certain insect species. The varietal selection is good agronomical tactice which could be used to minimize the damage caused by insect pests.

Major emphasis has been placed on developing cultivars resistant to shoot fly, stem borers, midge, shoot bug, aphid and head bugs. Considerable progress has been made in developing techniques to screen for resistance to these insects, identifying the source of resistance and transferring resistance to high-yielding sorghum cultivars (Sharma et al., 1992). Screening for resistance to insects under green house or field conditions is the most effective method of developing insect resistant cultivars.

Resistant or tolerant genotypes play a major role in reducing the pest attack. Resistant genotype is defined as "the consequence of heritable plant qualities that result in a plant being relatively less damaged than a plant without the qualities."" In practical agricultural terms, an insect-resistant genotype is one that produced yield more than a susceptible cultivar when attacked with insect pest. Insect-resistant genotypes suppress insect pest abundance or elevate the damage tolerance level of the plants. The relationship between the insect and plant affected depending upon the kind of resistance, e.g. antibiosis, antixenosis (non-preference), or tolerance.

Use of insect-tolerant genotype is economically, ecologically, and environmentally advantageous. Economic profits occur due to crop yields are saved from loss to insect pests and money is saved by not employing insecticides that would have been applied to susceptible varieties. Biological control methods reduce insect pests population and damage by use of natural enemies. Reduction in pest populations through host plant resistance can also enhance the effectiveness of natural enemies and reduce the need to use pesticides (Sharma, 1993). This can help to preserve the environment and avoid the risks associated with the use of pesticides. host plant resistance is not a panacea for all pest problems but it is most useful when carefully combined with other components of pest management. Host plant resistance can be used as a principal component of pest control .Therefore, in order to continue the process of selecting for resistance to insects, it is important to understand the mechanism of resistance and the factors associated with insect resistance. Keeping all these in view this study was conducted with following objectives.

1. To find out the less susceptible genotype against sorghum shootfly.(*Atherigona soccata*, Rondani)

- To find out the less susceptible genotype against sorghum stemborer.(*Chilo partellus,* swinhoe)

3. To find out the less susceptible genotypes against panicle pests. (ear head bug *Calocoris angustatus* ,Leth& ear head worm *Cryptoblabus gnidiella*, Mab)

Chapter- II
REVIEW OF LITERATURE

In This chapter the following headings The literature pertaining to the reaction of different sorghum genotypes to shoot fly, Stem borer and ear head pests and responsible for resistance and management of shoot fly, stem borer and ear head pests are presented under this chapter.

2.1. Reaction of Sorghum genotypes to insect pests infestation:

Shoot fly (*Atherigona soccata*)

Singh *et al.* (1989) tested 15 sorghum germplasm for resistance to A. soccata. IS 5359 and IS 5470 had the lowest eggs deposited on them and ultimately the lowest deadheart formation. According to Dalvi et al. (1990), oviposition intensity and preference of *A. soccata* on sorghum varieties at weekly intervals starting from 7th days after sowing steadily increased and reached to peak at 21 days in both the kharif and rabi seasons. Out of 45 varieties of sorghum screened for resistance to the pest, five varieties viz., R 24, 370 x 3660A, E 0303, M 35-1 and M 47-3 were the most tolerant; this appeared to be due to higher silica content in the seedling stage of these varieties.

Chandurwar *et al.* (1992) noticed that mid late planting (August) was the most favorable time for infestation of sorghum shoot fly

Mote and Jadhav (1993) determined the ability of the sorghum varieties IS 5490 and IS 18551 (resistant), SPV 504 (moderately resistant) and CSH 1 (susceptible) to recover from damage caused by *A. soccata*. Balikai et al. (1998) evaluated 205 sorghum genotypes for resistance to shoot fly in rabi and six were reported as resistant.

Balikai *et al*. (1999) developed sorghum lines resistant to the shoot fly. M 35-1, a popular local variety in Karnataka, India was crossed with the resistant check IS 2312 during 1989-90. An F2 population consisting of 400 plants was grown during 1990-91 and 50 promising plants were selected. Of these, 11 were retained and tested over the next 4 years; these showed a resistance level of 9.0-12.8 per cent, which was on par with IS 2312 and higher than M 35-1 (28.1%).

Rao *et al*. (2000) studied correlations between the shoot fly incidence and the plant characters. Shoot fly incidence was positively correlated with days to flowering and days to maturity. It showed a negative correlation with number of leaves per plant and plant height. The taller varieties with increased leaf number appeared desirable for minimizing shoot fly incidence.

Kumar *et al.* (2000a) screened 29 sorghum genotypes belonging to seven different groups for their relative resistance/tolerance to sorghum shoot fly, *Atherigona soccata*. Resistance was best showed upon some genotypes in the form of certain morphological characters possessed by the genotypes. Apart from these morphological characters of seedlings, antixenosis or non-preference was also due to other physiological mechanisms. Genotypes IS-18551, ICSV-700 and ICSV-705, with longer roots and shoots, narrow leaves (length greater than width), and greater droopiness of leaves, contributed significantly to conferring resistance, and these genotypes were found to be the most promising resistant lines against the shoot fly.

Sahib *et al.* (2002) tested the PSH 1, sorghum hybrid, derived from the cross between PSA 3 and PSR 23, in AICSIP trials conducted in Palem, Andhra Pradesh, India in 1994. Grain and fodder yields were higher in PSH 1 than in the popular hybrids CSH 9, PSH 1 was relatively more tolerant to stem borer, shoot fly and grain mould than CSH 9.

Narkhede *et al.* (2002) screened 1150 rabi sorghum cultivars for resistance to shoot fly (*Atherigona soccata*) in preliminary field evaluations conducted in Maharashtra, India. The cultivars selected in the preliminary selection were further screened in cages under multi-choice and no-choice conditions. In the preliminary evaluations, 125 cultivars recorded <50% dead hearts. In the advanced cage screening, 19 cultivars were identified as sources of resistance to shoot fly. Stability analysis of the 19 cultivars over 3 seasons showed that the resistance of cultivars RSV-175, RSV-176, RSV-182 and RSV-290 to shoot fly was stable across several locations.

Bhatt (2003) reported Genotypes GD 54686, GD 54681 and GD 54675 were resistant to shoot fly, whereas GD 54739, GD 54631 and SDSL 92140 were moderately resistant.

Kumar *et al.* (2003) evaluated 29 genotypes belonging to seven different groups of sorghum for their resistance to sorghum shoot fly. Ovipositional non-preference or antixenosis was expressed by the resistant controls (IS 2312 and IS 18551) and elite resistant lines (ICSV 700, ICSV 705, ICSV 708, ICSV 93088, ICSV 93089, ICSV 93091 and PB 14390-4) as these recorded less number of eggs compared to other genotypes. In contrast, the susceptible controls (CSV 1 and DJ 6514) and forage sorghum genotypes (GSSV 148, SR 350-1-16 and SSG 59-3) were the most preferred groups for shoot fly oviposition. Among the genotypes, ICSV 708 and ICSV 705 recorded the lowest number of dead hearts, while CSV 1 and DJ 6514 recorded the highest dead heart formation.

Deshpande *et al.* (2003) screened 230 sorghum genotypes against shoot fly to assess their tolerance level. The highest glossiness has been recorded in genotypes SP 15140, SP 15230 and SP 15229. The lowest dead heart percentage recorded in genotypes SP 15147, SP 15150, SP 15140 (15, 16 and 17%, respectively). Genotype SP 15224, SP 15044, SP 15110, SP 15003, and SP 15230 were tolerant to shoot fly (27.5-35.5% dead hearts).

Gite *et al.* (2003) evaluated 45 sorghum hybrids and their 10 parents (IS 18551, IS 2205, IS 1122, AKENT 1, AKENT 2, AKENT 3, HK 90012, GJ 40, SPV 1023 and ICS 70B) at Akola, Maharashtra, India, during kharif 1998 for heterobeltiosis for resistance to shoot fly (*A. soccata*) and related characters. Significant heterobeltiosis in the desired direction was recorded for deadheart percentage, number of eggs per plant, plant height, number of trichomes, chlorophyll content and grain yield per plant. AKENT 3 x IS 1122, AKENT 3 x GJ 40, ICS 70B x GJ 40, ICS 70B x HR 90012 and HR 90012 x AKENT 1 showed significant heterobeltiosis in the desired direction for low deadheart percentage. Five hybrids exhibited positive and significant heterobeltiosis in the desired direction for number of trichomes on the leaf surface (HR 90012 x SPV 1023, ICS 70B x HR 90012, ICS 70B x GJ 40, HR 90012 x GJ 40 and AKENT 3 x GJ 40). HR 90012 x AKENT 1 recorded negative and significant heterobeltiosis in the desired direction for low chlorophyll content.

Nineteen hybrids showed positive and significant heterobeltiosis for grain yield per plant. In general, GJ 40 x IS 18551, AKENT 3 x GJ 40, AKENT 1 x AKENT 2, HR 90012 x AKENT 3 and ICS 70B x GJ 40 appeared promising for grain yield per plant and characters associated with resistance to shoot fly. Heterotic effects exhibited by resistant x susceptible parental crosses may be useful for the development of resistant and high yielding genotypes in segregating generations.

Balikai and Biradar (2004) screened 200 sorghum germplasms for resistance against shoot fly. The result revealed that, 17 entries viz, IS 2191, IS 4481, IS 4516, IS 17596, IS18366, IS 33714, IS 37722, IS 37740, IS 33742, IS 33756, IS 33761, IS33764, IS33810, IS 33820, IS 33839, IS 33843, IS 33889, were recognized as resistance to shoot fly.

Shekharappa and Ramegowda (2005) screened 15 sorghum cultivars for their resistance to the shoot fly. The per cent of dead heart ranged from 10 to 25%, in comparison to 61% in IS 2312 (RC) and 81% in DJ 6514 (SC). The entries SPV 1537, SPV 1546, SPV 1548, SPV 1549, SPV 1587, SPV 1588, SPV 1591, SPV 1592 and CSV 14R were recorded <17% dead heart.

Berg *et al.* (2005) conducted three field trials during growing season to determine the level of resistance in sorghum varieties to shoot fly. Twenty-five varieties were evaluated in two of the seasons and 24 in the other. High shoot fly densities in the trials were achieved by planting late using fishmeal to attract flies to the field. Significant difference in resistance to shoot fly damage was observed in two of the three seasons. Varieties Pirira-1 and Pirira-2 were the most resistant across season. Although the level of resistance in sorghum varieties was low, several varieties with moderate level of resistance were also identified.

Karibasavaraja and Balikai (2006) determined the seasonal occurrence of shoot fly (*Atherigona soccata*) infesting CSH 16. The occurrence of dead heart was highest on 13th-19th August (93.4%), corresponding to the occurrence with the highest mean number of eggs of the pest per plant (3.20). The highest temperature and relative humidity were significantly negatively correlated, whereas the lowest temperature and relative humidity were significantly positively correlated with egg laid and dead heart occurrence.

Badgujar *et al.* (2006) screened 20 sorghum genotypes for their resistance against shoot fly. Genotypes MASS 9205-6/20, SPV 1535, MASS 32-1/20 and SPV 1531 showed minimum dead heart. Genotype SPV 1513 exhibited the highest resistance and yield.

Gite *et al.* (2006) Twenty sorghum hybrids along with two hybrid checks (CSH 15R and CSH 19R) were evaluated for shoot fly resistance and grain yield. Hybrids AKSH 182R, AKSH 187R, AKSH 194R, AKSH 195R had more resistance to shoot fly and have high grain yield.

Balikai and Biradar (2007) evaluated twenty sorghum lines along with a resistant check (IS 2313) and a susceptible check (DJ 6514) for their resistance to shoot fly. The lines 104A, 104B, RR 9817, RR 9818, RS 585 and RS 653 were found to be resistant to the shoot fly.

Shekharappa and Ramegowda (2007) evaluated 11 sorghum genotypes (SPV 1155, SPV 1215, CSV 8 R, SPV 1359, SPV 1360, CSV 14 R, SPV 1380, M 35-1, Swathi, IS 2312 and DJ 6514) for resistance to *Atherigona soccata*. Among all shoot fly dead heart per cent was minimum for SPV 1360 (9.28%), followed by IS 2312 (12.1%), and maximum for the susceptible control DJ 6514 (89.80%).

Aghav *et al.* (2007) reported the impact of sowing time from 36th to 44th meteorological week. Maximum dead heart on 14 DAE was recorded during 36th meteorological week (45%). Maximum dead heart on 28 DAE was recorded during 36th meteorological week (78.8%).

Ogola and Kamau (2008) studied impact of time of planting with seed sown in September and October and found that impact of *Atherigona soccata* was reduced and sorghum grain yield was increased through the adjustment of management practices such as genotype selection, time of sowing, fertilizer and insecticide application etc.

Al-Karboli and Al-Nakhli (2008) found that there were no significant differences among the 3 sorghum cultivars (lunched, Rabih and Kaifer) in terms of shoot fly.

Satish *et al.* (2009) reported QTLs for resistance to sorghum shoot fly. They discovered 29 QTLs by multiple QTL mapping. IS18551 contributed resistant alleles for most of the QTLs, and the related QTLs were co-localized, indicating they may be tightly linked genes. Interestingly, the insect resistant QTLs are located in synthetic maize genomic regions, showing conservation of insect resistance loci between maize and sorghum.

Khandare and Patil (2010) reported that resistant checks IS 18551 and IS 2205 had significantly lowest number of eggs per plant and were closely followed by AKSV 37 and AKSV 30. The resistant checks also exhibited lowest average percentage of dead heart.

Noowisai *et al.* (2010) screened five sorghum varieties (Cowley, Rio, Wray, BT 281 and Keller) and it was shown that in the dry season, the least damage of shoot fly was observed on Cowley, Wray, BT 281 and Keller varieties with 0.67 and 1.54% of plants with dead heart at 4 and 5 weeks after emergence, respectively. In the early rainy season, the least shoot fly dead heart of 0.03, 0.90 and 2.36% were recorded on Cowley, Wray and Keller varieties at 4, 5 and 6 weeks after emergence, respectively.

Chamarthi *et al.* (2011a) susceptibility to shoot fly was associated with high amounts of soluble sugars, fats, leaf surface wetness and seedling vigor; whereas, leaf glossiness, plumose and leaf sheath pigmentation, Trichome density and high tannin, Mg and Zn showed resistance to shoot fly.

Chamarthi *et al.* (2011b) reported that the sorghum genotypes IS 1054, IS 1057, IS 2146, IS 4664, IS 2312, IS 2205, SFCR 125, SFCR 151, ICSV 700, and IS 18551 exhibited antixenosis for oviposition and suffered less dead heart due to sorghum shoot fly, *Atherigona soccata*.

Vyas *et al.* (2014) conducted field experiments for screening of breeder's material for shoot fly and stem borer. Data revealed that in IVHT grain, entries SPH 1654, SPV 462, CSV 15, SPV 2013 and SPH 1615 recorded minimum shoot fly damage, whereas SPV 1616, SPV 1907, CSV 15, CSV 17, SPV 1870, SPV 12016, SPH 1615 and SPH 1596 recorded minimum stem borer dead hearts (2.46 and 2.92%) and minimum leaf injury by entry SPH 1648, SPV 1870 and SPH 1615, whereas SPH 1634 (108 g/plant) SPV 2016 and SPV 2018 recorded significantly maximum grain yield in terms of g/plant (80 g both). In case of local check resistance trial entries SPV 1616, PKV 809 and CSV 17 recorded minimum shoot fly, stem borer and leaf injury.

2.2 sorghum stem borer (*Chillo partellus*):

Sarailoo (1986) noted leaf feeding injury of 0.3 and 3.5 rating; stem length tunnelling 0.00 to 0.58 per cent and 1.12 to 7.11 per cent , peduncle length tunneling 0.51 to 5.6 and 0.66 to 5.05 per cent in early and late sown crop respectively.

Verma *et al.,* (1988) reported 27.73 to 57.25 per cent and 25.53to 61.40 per cent peduncle tunneling and 19.62 to 25.42 per cent and 16.52 to 29.52 per cent grain yield losses in variety CS-3541 and hybrid CSH-5 respectively.

Kishore (1991) tested 17 cultivars of sorghum for resistance to the *Chilo partellus*, and reported only P921, P930, P933, P934 and P936 free from stem tunneling. There was no dead-heart formation in these varieties. The percentage of tunneling and dead-heart in susceptible varieties averaged 22.3-28.2 and 28.6-37.4% and the leaf injury grade 5.6 – 7.0.

Singh *et al.* (1991) screened 40 sorghum genotypes for their resistance to *Chilo partellus* and found that IS 2123 and IS 5469 had the lowest dead heart, leaf injury and stem tunneling damage.

Sharma *et al.* (1993) selected 55 advanced breeding lines these were less susceptible to stem borer under natural infestation at Hisar (Haryana) with artificial infestation during 1992-1993 in rainy and post rainy season. They found that six lines (PBBOS 14844-1, 15837-1, 15837-1, 15837-3-h, 15837-2 and 159359) suffer less than 30 per cent dead hearts.

Bhadviya (1995) screened 13 sorghum varieties against stem borer, and found that leaf injury ranged from 1.63 to 4.98 per cent; dead heart ranged from 34.26 to 63.59 per cent, stem tunneling length ranged from 2.00 to 35.50 per cent and peduncle tunneling length ranged from 5.20 to 35.00 per cent.

Patel *et al.* (1996) carried out field experiments in Delhi and Haryana, India, during the kharif season of 1988 to screen 20 diverse sorghum genotypes for resistance to *Chilo partellus*. On the basis of dead hearts, leaf injury, stem tunneling, peduncle tunneling and exit holes, IS 18584, IS 18577 and IS 2205 were the most resistant and may be used for breeding new cultivars susceptible to the pest and improving the resistance of existing high-yielding susceptible cultivars.

Singh and Batra (1997) conducted field experiments for screening 10 sorghum genotypes for ovipositional preference of spotted stem borer (SBS; *Chilo partellus*) under natural and artificial conditions during 1993-94. There were significant differences in the numbers of eggs laid in the sorghum genotypes, both under natural (1.9-13.6 egg masses per 10 plants) and cage (2.9 to 18.0 egg masses) conditions. The total numbers of egg masses were significantly higher on the susceptible than on the SBS-resistant genotypes and forage varieties. Lowest numbers of egg masses were recorded on IS 2205 (1.9 egg masses), HC 440 (2.2 egg masses) and HC 308 (2.8 egg masses) under natural conditions. Similar trends were observed under cage conditions. All grain sorghum varieties were preferred for oviposition and were at par with susceptible control, CSH 1.

Ghunguskar *et al.* (1999) evaluated 26 sorghum (Sorghum bicolor) hybrids for tolerance to stem borer (Chilo partellus) at Yavatmal and reported Hybrid 9739 and variety CSV 14+ had the lowest rates of infestation.

Singh and Shankar (2000) evaluate sorghum genotypes for the incidence of stem borer and shoot fly. MASV 33/93, ICSV 700 and PB 15438 were found to be consistently superior. The genotype MASV 33/93 had good agronomic attributes including grain yield.

Chaturvedi (2000) reported varieties IMS 9B, ICSV-705, ISSV-951 and CSV-15 to be less susceptible against stem borer on the basis of plant infestation, number of holes, larval/pupal population and stem and peduncle tunneling caused by stem borer.

Yadav (2000) screened 12 sorghum varieties against stem borer and reported varieties SPV-1022, SPV-1323, SPR-1 and SPR-1086 to be less susceptible and registered high yield, whereas, varieties CSH-9 and ISSV-951 reported to be highly susceptible.

Kishore *et al.* (2002) identified new sources of resistance against shoot fly, stem borer and sugarcane leafhopper. Eleven lines showed resistance against shoot fly, thirteen lines against stem borer and five lines resistance against *Pyrilla*. Two entries namely, SPV 1518 and SPV 1572 were identified as multiple resistances to both shoot fly and stem borer.

Verma and Singh (2003) evaluated 40 sorghum genotypes for resistance to *Chilo partellus*. The dead heart incidence ranges from 16 to 70%. Among hybrids, VSSG 121 and NFSH 10659 recorded the minimum dead heart (30%), and stem tunneled (15 & 11%). VSSG 121 (53%) had the lowest leaf damage. Resistant controls IS 5469 and IS 2205 showed the lowest dead heart, leaf damage (47% & 49%) and stem tunneled (3-4%). However, susceptible controls CSH 1 and ICSV 1 highest dead heart (>65%), leaf damage (92-96%) and stem tunnel (48% & 45%).

Garg and Singh (2003) observed that out of 10 sorghum genotypes for resistance to stem borer, CSV 13, CSV 15, SPV 1022, SPV 1231, SPV 1281, SPV 1283, SPV 1284, SPV 1293, CSH 5 and a local cultivar. CSV 15 produced grains significantly superior over the other genotypes and local cultivar was also the most resistant to *Chilo partellus*, exhibiting 72.60% infestation.

Kumar *et al*. (2006) studied the antibiosis mechanism of resistance of 20 sorghum genotypes. Sorghum genotypes IS 1044, IS 2123, IS 1054, IS 18573, and ICSV 714 showed antibiosis to *Chilo partellus*.

Marulasittesha *et al.* (2007) tested 20 sweet sorghum and three grain sorghum genotypes for resistance to the damage caused by the sorghum stem borer under infested field conditions in the Dharwad region of northern Karnataka, India. Five different types of damage were taken into account: leaf scraping, dead heart, pinhole, peduncle and stem tunneling damage. Genotype SSV-7073 was found to be the most resistant with respect to all types of damage studied. In addition, the genotypes Nandyal, SSV-53, SSV-6928, HES-4 and IS-2312 showed little peduncle and stem tunneling damage.

Prasad *et al.* (2011) evaluated 47 sweet sorghum genotypes for resistance to stem borer and found 11 genotypes (viz., E 27, IS 18162, IS 18164, E 38, ICSV 700, ICSV 93046, NSSV 6, GGUB 50, IS 5353, KARS 95 and RSSV 9) resistant to stem borer.

Subbarayudu *et al.* (2011a) evaluated 27 genotypes of sorghum for resistance to shoot fly, stem borer and shoot bug. Seven genotypes viz., SR 770-2,

SR 970-2, SR 833, GFS 261, ICSV 745, IS 2312 and IS 2205 were found resistant while 14 genotypes viz., SR 1247-1, SR 2126, ICSV 705, SPV 839, CSV 15, SR 2135, RS 29, CSH 5, GSSV 251, NSS 103, SR 1115-1, CSH 6, CSH 9 and SPV 462 were moderately resistant. Four genotypes viz., SR 770-2, SR 970-2, SR 833 and GFS 261 showed high levels of multiple resistance to shoot fly, stem borer and shoot bug.

Subbarayudu *et al.* (2011b) evaluated 35 entries resistance for shoot fly and stem borer. Among all eighteen entries were resistant and fifteen entries were moderately resistant.

Padmaja *et al.* (2012) evaluated evidence of genetic transmission of antibiosis and antixenosis resistance of sorghum to the stem borer. The breeding lines 27B x PB 15881-3 and 463B x PB 15881-3 showed antixenosis and antibiosis to *Chilo partellus*. The levels of antixenosis and antibiosis of both breeding lines were similar to their resistant parents. Results indicated that transmission of characteristics responsible for resistance to the progeny from the resistant parent occurred.

2.3 Earhead pests(bug, *Calocoris angustatus* Leth. and worm, *Cryptoblabes gnidiella* Mab.)

Mote and Kadam (1984) evaluated 30 genotypes for damage caused by *Calocoris angustatus* and found that SPV 472, Swarna, SPH 196, CSH 1, CSH 6 and CSH 9 were moderately resistant.

Hiremath (1986) found that S-GIRL, MR 1 and CSV 5 showed resistance, whereas D 340, SB 901, BH 1-4-1, SB 32B SB 2612 was highly susceptible to *Calocoris angustatus*.

Gagre (1990) recorded incidence of ear head bug on sweet sorghum variety, which ranged from 5.99 to 34.49 per cob and grain damage ranged from 2.33 per cent (SPV 96) to 9.08percent (HES 3). He further found the grain weight loss ranged from 0.95 g (MTRS 920) to 2.30 g (SSV 12611) per 100 g.

Sekhar (1997) studied the seasonal incidence and population fluctuation of sorghum ear head bug by planting two cultivars (CSH 1 and ICSV 1) at monthly intervals and found the pest incidence was high in crop sown in May-August.

Choudhary and Garg (2004) studied the incidence of sorghum ear head bug (*Calocoris angustatus*) on sorghum and reported that the percentage of ear head infestation range was from 93 to 99%. The percentage of population ranged from 31.3 to 49.7 per cob.

Patel (2010) reported the lowest number of bug per plant in IS-2205 (9.22) and it was at par with CSH-16 (10.55), SPH-1644 (10.88), IS-18551 (11.33) and SPH-1635 (11.33) in early planting. More number of ear head worms in early sown crop was reported as compared to late sown crop. In early sown crop the lowest ear head worms were noticed in IS 2312 (0.22), IS-18551 (0.66), DJ-6514 (2.00), SPH1629 (2.77) and SPH-1635 (3.00). Maximum ear head worms were recorded in CSH-16 (8.22).

Patidar (2010) recorded more number of ear head bug per three plant in early sown crop as compared to late sown crop. The lowest bug (7.89) was noticed in SPV 2000 followed by IS 2205 (8.33) and SPV 1908 (8.66). More number of ear head worms was recorded in early sown crop as compared to late sown crop. In early sown crop the lowest (2.00) number were noticed in IS 2312 followed by DJ 6514 (2.66). Maximum number of ear head worm was noticed in SPH 1662 (10.44).

Patel (2011) the lowest number of ear head bug were recorded in resistance checks IS 2205, IS 2312 and IS 18551. Among the entries, lowest bugs (7.33) were recorded in SPV 2077 followed by SPH 1686 (7.67) and SPV 2082 (9.00). Maximum bugs were received in SPH 1655 (27.33) whereas, minimum number of ear head bug was both in resistance checks IS 18551(1.33) and IS 2312(1.33) followed by IS 2205 with 1.67. Among the test entry lowest number of worm (2.00) were recorded in both SPV 2081 and SPV 2082 followed by SPV 2077 (2.67). The maximum number of bugs were noticed in SPH 1629(2) (11.00).

Shivanand *et.al* (2011) screened 15 sorghum genotypes for resistance to ear head caterpillar under field conditions. The genotypes having dense and compact ear heads had highest incidence of ear head caterpillar followed by semi compact and loose ear heads genotypes. The entries CSH-14 and SVD-9606 had lowest incidence of 0.45 and 0.52 larvae per ear head as well as lowest grain yield damage of 5.34% and 6.52%, respectively, were proved resistant genotypes. Whereas, CSH-5, CS-3541 and DSH-3 recorded highest number of 2.98, 2.92 and 2.85 larvae per ear head with grain damage of 44.70, 39.20 and 38.20 per cent, respectively showed susceptible tendency.

Chapter-III

MATERIALS AND METHODS

This chapter includes details of the materials used and methodology followed during the course of investigation. The experiment carried out during Kharif season, 2016 at the college research Farm, in R.V.S.K.V.V. University Gwalior (M.P.). The details of location of the experimental site, weather conditions, soil characteristics, experimental materials used, experimental procedures adopted during the course of investigation and statistical methods employed are presented in this chapter.

***`REACTION OF GENOTYPES AGAINST MAJOR INSECT PESTS OF SORGHUM [*Sorghum bicolor* (L.) Moench]'**

The materials and methods used in following experiment are given below:

3.1 Experimental Site:

The present studies were conducted at college research farm, R.V.S.K.V.V University Gwalior during kharif season of 2016. Gwalior is situated in Northern part of Madhya Pradesh at an elevation of 211.52 meters from mean sea level and lies between latitude and longitude 26º14' North and 78º15' East, respectively.

3.2 Climate: The climate of Gwalior is tropical. The rainy season normally starts from middle of June after commencement of south-west monsoon and last up to September. Maximum precipitation of rains occurred in the month of July and August. Winter season runs from November to mid-February and hot summer season from April to mid-June. October is the transitory month of summer. Table 3.1 meteriological data

STD Week	STD Week period	Temperature		Relative humidity (%)		Rainfall (mm)	Evaporation (mm.)
No	2015-2016	max	min	morning	evening	weekly	Weekly
29	July 16-22	33.1	26.6	81.2	64.7	029.2	4.1
30	July 23-29	34.2	25.9	90.5	76.5	121.0	4.4
31	July –aug 30-5	32.0	25.0	94.8	73.1	118.0	1.5
32	Aug 6-12	32.4	25.6	92.4	76.0	081.2	2.8

STD Week	STD Week period	Temperature		Relative humidity (%)		Rainfall (mm)	Evaporation (mm.)
No	2015-2016	max	min	morning	evening	weekly	Weekly
33	Aug 13-19	32.1	25.5	90.2	73.5	065.0	2.2
34	Aug 20-26	30.9	24.5	88.7	70.8	024.0	3.2
35	Aug-sep27-2	34.0	26.0	88.7	70.8	010.0	3.8
36	Sept 3-9	33.4	25.6	74.1	57.7	001.0	5.8
37	Sept 10-16	34.6	25.9	78.4	55.2	000.0	4.4
38	Sep 17-23	35.0	24.8	89.0	61.0	009.2	4.3
39	Sep 24-30	34.6	23.7	85.8	50.1	000.0	4.6
40	Oct 1-7	35.0	25.1	87.0	56.5	014.0	3.5
41	Oct 8-14	35.6	21.1	65.6	29.8	000.0	5.0
42	Oct 15-21	35.2	16.2	80.1	22.6	000.0	5.0
43	Oct 22-28	35.0	17.1	69.7	24.0	000.0	5.4
44	Oct –Nov 29-4	32.1	13.5	92.1	29.4	000.0	5.5

The rainfall has been received during the months of July to August and few showers during December to late spring (Table 3.1). The meteorological data on various parameters as observed during the period of experimentation collected from the Department of Agricultural Meteorology college of agriculture Gwalior is presented.

3.3 Soil:

The soil of experimental site was alluvial clay loam texture. The available nitrogen, phosphorus and potassium content of soil was 200.7kg, 10.1 kg and 260.9kg respectively low, medium low to medium, respectively. The water holding capacity of soils is medium.

3.4 Experimental details:

Details of the experiment:

(i). Design : RBD(Randomized Block Design)

(ii). No. of Replication : 3

(iii). No. of Treatment : 20 (genotypes)

(iv)Details of treatment (genotypes)

1.ICSV25335	11.ICSV 25308
2.ICSSH 87	12.ICSV25333
3.ICSSH 86	13.ICSV 15006
4.ICSV 25306	14.SPV 2326
5.ICSSH 82	15.SPV 2327
6.ICSSN 79	16.SPV 2328
7.ICSSH 88	17.DHBM 1
8.DHBM 5	18.DHBM 3
9.DHBM 4	19.SSV 84
10.DHBM 2	20.CSH 22SS

(v). plot size : 5 m length of two rows each

(vi)Spacing :

Row to Row : 0.45m

Plant to plant ; 0.12

(vii) Seed rate : 10 kg/ha

(viii) Fertilizer doses: 80 kg N2 : 40 kg P2O5 : 40 kg K2O / ha

(ix) Date of sowing : 20.07.2016

3.5 Methods of observations:

following parameters were recorded:

3.5.1Shoot fly (*Atherigona soccata* ;Rondani)

Table 3.2 observations to be recorded:

s.no	Observation to be recorded	DAE
1.	No. of eggs of shoot fly	14&21
2.	No. of tillers produced	35
3.	Dead heart produced	14&21

The maggot cuts the growing point, resulting in wilting and drying of the central leaf known as "dead hearts" and the damaged plants produce side tillers, which may also be attacked. Observations on dead heart percent were recorded to characterize shoot fly damage. The shoot fly incidences were recorded 14 and 21 days after emergence (DAE) of the crop plants. The total number of plants and total number of plants showing dead heart symptoms were recorded in each genotype in replication wise and subjected to suitable transformations (arc sine transformation) for onward statistical analysis. The percentage of dead heart was computed using the formula.

$$\text{Shoot fly dead hearts(\%)} = \frac{\text{No. of plant showing dead heart}}{\text{Total no. of plants in plots}} \times 100$$

3.5.2 Stem borer (*Chilopartellus*; swinhoe)

Table 3.3 observations to be recorded:

s.no	Observation to be recoded	DAE
1.	Percent leaf injury	30&45
2.	Dead heart	30&45
3.	Stem tunneling	At the harvesting time
4.	Peduncle tunneling	At the harvesting time

5.	No.of holes caused by larvae	At the harvest time
6.	No.of larve per plant	At the harvest
7.	No.of pupae per plant	At the harvest

I. Stem Borer Leaf injury (SBLI) Percent;

Observations on leaf injury were recorded at 30 days after emergence of the crop plants. The total number of plants and total number of plants showing leaf injury symptoms were recorded in each genotypes replication wise and then subjected to suitable transformation for onward analysis. The percentage of leaf injury was computed using the following formula

$$\text{Stem Borer Leaf injury (\%)} = \frac{\text{No of plants showing leaf injury}}{\text{Total no of plants}} \times 100$$

II. Stem Borer Dead heart (SBDH) Percent:

stem borer infestation is appears as small round holes due to feeding by the young larvae and these larvae migrate to the base of the plant, bore into the shoot, and damage the growing point resulting in the production of a dead heart. Observations on dead hearts due to stem borer attack in each genotype were also recorded at 30& 45 days after emergence of crop. Total number of plants and total number of plants showing dead heart symptoms were recorded in each genotypes replication wise and then subjected to suitable transformation for onward analysis.

$$\text{Stem borer dead hearts (\%)} = \frac{\text{No.of plants showing dead hearts}}{\text{Total no. of plants}} \times 100$$

III. Stem Borer Stem tunneling (SBST);

Stem borer larvae also feed inside the stem and cause extensive tunneling. Observation was recorded at the time of harvesting on five randomly selected plants per plot. The selected plants were split open longitudinally with the help of knife and total stem length and total tunneled length (by stem borer) was measured and then subjected to suitable transformation for onward analysis. The percentage tunneling was computed using the formula

$$\text{Stem Borer Stem tunneling (\%)} = \frac{\text{Length of the tunnel}}{\text{Total length}} \times 100$$

iv. Peduncle tunneling:

stem borer larva causes extensive tunneling in the peduncle damage caused by the stem borer to the peduncle was recorded at the time of harvesting on randomly selected five plants. The damage was recorded by using the following formula

$$\text{peduncle tunneling(\%)} = \frac{\text{length of peduncle}}{\text{Total length}} \times 100$$

(v)No. of holes:

Number of holes caused by stem borer larva in the stem was recorded from randomly selected plants.

(v)No. of larvae:

The number of larvae present inside the stem was counted in randomly selected five plants in each plot after harvest.

(vi)No. of pupae:

A. Series of holes by stem borer attack

B Stem borer making tunnel in the stem

C. Dead heart formed due to stem borer

D. Stem borer making tunnel in the

Plate-2: Damage caused by Stem Borer at different crop stages

Chapter - IV
RESULTS

The present experiment entitled "**Reaction of genotypes against major insect pests of sorghum [*Sorghum bicolor* (L.) Moench]''** genotypes against major insect pests" was conducted during Kharif 2016 at the college research farm of R.v.s.k.v.v university Gwalior (M.P.). The observations were recorded for the insect pests viz., sorghum shoot fly (*Atherigona soccata* Rondani), stem borer (*Chilo partellus* Swinhoe), ear head worms (*Cryptoblabes gnidiella* Mab.) and ear head bug (*Calocoris angustatus* Leth.). Results of the experiments are tabulated, analyzed and concluded as per the objectives of the study.

Twenty genotypes were evaluated for resistance against shootfly (*Atherigona soccata*, Rondani) stem borer (*Chilo partellus,* Swinhoe), ear head bugs (*Calocoris angustatus* Leth.) and ear head worm (*Cryptoblabes gnidiella* Mab.).

The present investigations were conducted to find out the less susceptible genotype against shoot fly (*Atherigona soccata* Rondani) stem borer (*Chilo partellus* Swinhoe) ear head bug (*Calocoris angustatus* Leth) and ear headworm (*Cryptoblabes gnidiella*) of sorghum. The results obtained are presented here with.

4.1 Reaction of genotypes against Shoot fly:

Observations were recorded on following parameter for infestation of shoot fly. such as the number of eggs per plant was recorded on 14 and 21 days after emergence (DAE). While the number of tillers produced by the plants were also recorded at 35 DAE to know the incidence of shoot fly. Observations on per cent dead hearts produced by the shoot fly were recorded at 14 and 21 DAE are presented in respective tables.

4.1.1 Number of Shoot fly eggs per plant :

The incidence of shoot fly on test genotypes were recorded by counting the number of eggs per plant at 14 and 21 DAE. Significant difference was observed among the genotypes for number of eggs laid per plant.

The minimum number of eggs at 14 DAE (1.3 eggs/plant) were recorded in genotype ICSSH 86 which was significantly less than rest of the genotypes followed by ICSV25335 (1.45eggs/plant).However the maximum number of eggs were recorded on genotype ICSV 25333 (4.2eggs/plant) which was significantly more than rest of the genotypes except ICSV15506 (4.1eggs/per plant) and SPV 2326(4.1eggs/plant)

Table 4.1.1: Number of eggs laid by shoot fly in different genotypes:

S.No	Genotypes	No.of eggs per plant at 14DAE	No.of eggs per plant at 21DAE	Average of 14&21 DAE no. of eggs per plant
1	**ICSV 25335**	1.45(1.39)*	1.6(1.45)*	1.52(1.42)*
2	**ICSSH 87**	1.84(1.53)	1.8(1.52)	1.82(1.52)
3	**ICSSH 86**	1.3(1.34)	1.41(1.38)	1.35(1.36)
4	**ICSV 25306**	2.6(1.76)	2.3(1.67)	2.45(1.71)
5	**ICSSH 82**	2.6(1.76)	2.6(1.7)	2.6(1.73)
6	**ICSSN 79**	3(1.87)	3(1.87)	3(1.87)
7	**ICSSH 88**	3.2(1.92)	3.1(1.90)	3.15(1.91)
8	**DHBM 5**	3.15(1.91)	3.3(1.95)	3.22(1.93)
9	**DHBM 4**	3.4(1.97)	3.2(1.92)	3.3(1.94)
10	**DHBM 2**	3.1(1.90)	4(2.12)	3.55(2.01)
11	**ICSV 25308**	2.9(1.84)	4.4(2.21)	3.65(2.02)
12	**ICSV 25333**	4.2(2.17)	5.4(2.43)	4.8(4.6)
13	**ICSV 15006**	4.1(2.14)	5.3(2.41)	4.7(2.27)
14	**SPV 2326**	4.1(2.14)	5.2(2.39)	4.65(2.26)
15	**SPV 2327**	4(2.12)	5(2.35)	4.5(2.23)
16	**SPV 2328**	3.8(2.07)	4.8(2.30)	4.3(2.18)
17	**DHBM 1**	3.6(2.02)	4.6(2.26)	4.1(2.14)
18	**DHBM 3**	3.5(2.00)	4.52(2.24)	4.01(2.12)
19	**SSV 84**	3.3(1.95)	4(2.12)	3.65(2.03)
20	**CSH 22 SS**	3(1.87)	4.2(2.17)	3.6(2.02)
	SEm±	**(0.01)**	**(0.01)**	**(0.01)**
	CD	**(0.03)**	**(0.02)**	**(0.025)**

Values in parenthesis are $\sqrt{n+0.5}$ values

Similarly at 21 DAE the different genotypes differed significantly with respect to number of eggs per plant. the minimum and lowest number of eggs were recorded on genotype ICSSH 86(1.4eggs/plant) which was found significantly less than rest of the genotypes followed by ICSV 25335(1.6eggs/per plant),on genotype ICSSH 87 (1.8eggs/plant). However maximum number of eggs were recorded on genotype ICSV25333 (5.4eggs/plant)which was significantly more than rest of the genotypes except ICSV15006(5.3eggs/plant), SPV2326(5.2eggs/plant) and SPV2327 (5eggs/plant).

4.1.2 No. of tillers produced by Shoot fly

S.NO	GENOTYPES	35 DAE
1	**ICSV 25335**	1.5(1.41)*
2	**ICSSH 87**	1.6(1.45)
3	**ICSSH 86**	1.2(1.30)
4	**ICSV 25306**	2(1.58)
5	**ICSSH 82**	3(1.87)
6	**ICSSN 79**	2.5(1.73)
7	**ICSSH 88**	2.7(1.79)
8	**DHBM 5**	3.2(1.92)
9	**DHBM 4**	2.1(1.61)
10	**DHBM 2**	3.6(2.02)
11	**ICSV 25308**	4(2.12)
2	**ICSV 25333**	6(2.55)
13	**ICSV 15006**	5.4(2.43)
14	**SPV 2326**	5.2(2.39)
15	**SPV 2327**	5.3(2.41)
16	**SPV 2328**	4.2(2.17)
17	**DHBM 1**	4.4(2.21)
18	**DHBM 3**	4.6(2.26)
19	**SSV 84**	4.8(2.30)
20	**CSH 22 SS**	4.3(2.19)
	SEm±	**(0.01)**
	CD	**(0.02)**

Values in parenthesis are $\sqrt{n + 0.5}\ values$

Data recorded on number of tillers produced per plant as a result of shoot fly infestation at 35 DAE (days after emergence). The minimum number of tillers were recorded on genotype ICSSH 86 (1.2tillers/plant) which was found significantly less than the rest of the genotypes, followed by genotype ICSV 25335(1.5tillers/plant) and ICSSH 87(1.6tillers/plant).However the maximum and highest number of tillers were recorded in the genotype ICSV 25333 (6tillers/plant) which was significantly more than rest of the genotypes except ICSV 15006 (5.4tillers/plant) ICSV15006,(5.3tillers/plant) and SPV 2327 (5.2tillers/plant).

4.1.3 Per cent dead hearts caused by shoot fly in different genotypes:

Data were recorded on the incidence of shoot fly on sorghum shoots in the form of per cent dead hearts at 14 and 21 DAE (days after emergence) and were expressed in percentage dead heart on various genotypes.

The minimum dead heart percentage at 14 DAE was recorded on genotype ICSSH 86(8.45) it was significantly less than rest of the genotypes followed by ICSV 25306(8.47) and DHBM3 (8.65).However the maximum and significantly higher percentage of dead heart was recoded in genotype ICSV 25333(39.01),which showed significantly higher dead hearts as compared than rest of the genotypes except ICSSH82 (30.7),ICSSH 87(28.43) and genotype SPV 2326(28.43).

Similarly at 21 DAE the minimum and lower percentage of dead hearts was recorded in genotype ICSSH 86(14.02) which was significantly less than rest of the genotypes, followed by DHBM4(14.15) and DHBM1(14.22). However the maximum and significantly higher dead heart percentage was recorded on genotype ICSSH88(49.9)which was significantly more than rest of the genotypes. except ICSV25333(46.17) and ICSV15006(46.07).

Table: 4.1.3 per cent dead hearts caused by shoot fly in different genotypes

S.no	Genotypes	Per cent dead heart at 14 DAE	Per cent dead heart at 21 DAE	Average of 14&21 DAE
1	**ICSV 25335**	22.87(28.57)*	33.58(35.41)*	28.27(31.99)*
2	**ICSSH 87**	28.43(32.22)	37.29(37.64)	32.86(34.93)
3	**ICSSH 86**	8.45(16.87)	14.02(21.97)	11.23(19.42)
4	**ICSV 25306**	8.47(16.90)	17.1(24.42)	12.78(20.66)
5	**ICSSH 82**	30.7(33.64)	42.23(40.53)	36.46(37.08)
6	**ICSSN 79**	14.22(22.14)	23.4(28.92)	18.81(25.53)
7	**ICSSH 88**	25.75(30.49)	49.9(44.94)	37.82(37.71)
8	**DHBM 5**	14.22(22.14)	22.05(28.00)	18.13(25.07)
9	**DHBM 4**	12.2(20.43)	14.15(22.08)	13.17(21.25)
10	**DHBM 2**	11.53(19.83)	17.3(24.57)	14.41(22.2)
11	**ICSV 25308**	16.3(23.81)	24.95(29.96)	20.6(26.88)
12	**ICSV 25333**	39.01(38.65)	46.17(42.80)	42.59(40.72)
13	**ICSV 15006**	11.33(19.66)	46.07(42.75)	28.7(31.02)
14	**SPV 2326**	28.43(32.22)	30.72(33.65)	29.57(32.93)
15	**SPV 2327**	19.78(26.40)	22.07(28.02)	20.9(27.2)
16	**SPV 2328**	22.05(28.00)	17.3(24.57)	19.6(26.2)
17	**DHBM 1**	17.3(24.57)	14.22(22.15)	15.76(23.36)
18	**DHBM 3**	8.65(17.06)	15.09(22.85)	11.87(19.95)
19	**SSV 84**	17.3(24.57)	17.09(24.41)	17.19(24.49)
20	**CSH 22 SS**	23.07(28.70)	23.07(28.70)	23.07(28.7)
	SEm±	(**0.29)**	**(0.30)**	**(0.29)**
	CD	(**0.83)**	(**0.85)**	**(0.84)**

*Values in parenthesis are arcsign values

4.2.Reaction of genotypes against stem borer:

Genotypes under test were evaluated for the incidence of stem borer (*Chillo partellus*) on the basis of leaf injury, dead heart, and tunneling caused by borer in stem and peduncle number of larva and pupae formed in the stem and data were tabulated as follows

4.2.1 per cent leaf injury produced by stem borer damage

S.no	Genotypes	Per cent leaf injury at 30 DAE	Per cent leaf injury at 45 DAE	Average of 30&45 DAE
1	**ICSV 25335**	20.87(27.18)*	32.53(34.77)*	26.7(30.97)*
2	**ICSSH 87**	29.23(32.73)	32.63(34.83)	30.93(33.78)
3	**ICSSH 86**	24.4(29.60)	30.53(33.54)	27.4(31.57)
4	**ICSV 25306**	27.2(31.43)	31.73(34.28)	29.4(32.85)
5	**ICSSH 82**	36.5(37.17)	38.8(38.53)	37.65(37.85)
6	**ICSSN 79**	23.53(29.01)	23.83(29.22)	23.68(29.11)
7	**ICSSH 88**	16.3(23.80)	22.96(28.62)	19.63(26.21)
8	**DHBM 5**	17.7(24.87)	24.76(29.83)	21.23(27.35)
9	**DHBM 4**	29.03(32.60)	32.63(34.83)	30.83(33.71)
10	**DHBM 2**	25.61(30.40)	34.88(36.20)	30.24(33.3)
11	**ICSV 25308**	16.6(24.03)	23.26(28.83)	19.93(26.43)
12	**ICSV 25333**	18.63(25.56)	29.23(32.73)	23.93(29.14)
13	**ICSV 15006**	20.05(26.60)	31.51(34.15)	25.78(30.37)
14	**SPV 2326**	16.13(23.67)	28.43(32.22)	22.28(27.94)
15	**SPV 2327**	12.09(20.34)	22.44(28.27)	17.2(24.30)
16	**SPV 2328**	17.7(24.87)	23.06(28.70)	20.38(26.78)
17	**DHBM 1**	23.58(29.05)	29.71(33.03)	26.6(31.04)
18	**DHBM 3**	22.51(28.32)	22.81(28.52)	22.6(28.42)
19	**SSV 84**	20.07(26.61)	31.53(34.16)	25.8(30.38)
20	**CSH 22 SS**	20.33(26.80)	33.03(35.08)	26.6(30.94)
	SEm±	**(0.20)**	**(0.21)**	**(0.20)**
	CD	**(0.57)**	**(0.61)**	**(0.59)**

*Values in parenthesis are arc transformation value

4.2.1 Per cent leaf injury caused by stem borer

The test sorghum genotypes differed significantly with respect to per cent leaf injury caused by stem borer at 30&45 days after emergence.

The minimum per cent leaf injury was recorded at 30 DAE on genotype SPV2327(12.09) which was significantly less than rest of the genotypes except on SPV2326(16.13), and ICSSH88(16.3).However the maximum and highest leaf injury per cent was recorded on ICSSH 82(36.5) which was significantly more than rest of the genotypes except ICSSH87(29.23) and DHBM 4(29.03).

Similarly at 45 DAE the per cent leaf injury caused by stem borer in test genotypes differed significantly. The minimum leaf injury was recorded in genotype SPV2327 (22.44) which was significantly less than rest of the genotypes followed by DHBM3 (22.81) and ICSSH88 (22.96). the maximum per cent of leaf injury caused by stem borer was recorded in genotype ICSSH 82(38.8)which was significantly more than rest of the genotypes except DHBM2(34.88), CSH 22 SS(33.03)and ICSSH 87(32.63).

4.2.2 Per cent dead hearts produced by stem borer:

The data recorded on dead heart caused by stem borer in different genotypes under test revealed that minimum dead heart percentage at 30 DAE was observed in the genotype SPV 2328 (14.33) which was significantly less than rest of the genotypes followed by DHBM3(19.7) and ICSV 25335(21.07). However the maximum dead heart percentage was recorded in genotype ICSSH82 (40.41) which was significantly more than rest of the genotypes except ICSSN79 (39.65) and DHBM5 (34.13)

The data recorded on dead heart caused by stem borer in different genotypes under test revealed that minimum dead heart percentage at 45 DAE was observed in the genotype SPV 2328(20.5) which was significantly less than rest of the genotypes followed by genotype DHBM3 (24.13) and DHBM 4(26.1).However the maximum and higher dead heart percent was recorded in ICSSH 82 (46.3) which was significantly more than rest of the genotypes except ICSSN 79 (45.09) and DHBM2 (43.06).

4.2.2 Per cent dead hearts produced by stem borer

S.no	Genotypes	Per cent dead heart at 30DAE	Per cent dead heart at 45DAE	Average of 30&45 DAE
1	**ICSV 25335**	21.07(27.32)*	35.5(36.57)*	28.28(31.94)*
2	**ICSSH 87**	21.5(27.62)	35.16(36.37)	28.33(31.9)
3	**ICSSH 86**	28.57(32.31)	34.81(36.15)	31.69(34.23)
4	**ICSV 25306**	24.08(29.38)	36.24(37.01)	30.16(33.19)
5	**ICSSH 82**	40.41(39.47)	46.13(42.78)	43.27(41.12)
6	**ICSSN 79**	39.65(39.03)	45.09(42.18)	42.37(40.60)
7	**ICSSH 88**	30.93(33.79)	40.26(39.38)	35.59(36.58)
8	**DHBM 5**	34.13(35.75)	38.4(38.29)	36.26(37.02)
9	**DHBM 4**	24.76(29.84)	26.1(30.72)	25.43(30.28)
10	**DHBM 2**	30.43(33.48)	43.06(41.01)	36.74(37.24)
11	**ICSV 25308**	27.23(31.45)	33.5(35.36)	30.36(33.40)
12	**ICSV 25333**	27.7(31.75)	31.07(33.87)	29.38(32.81)
13	**ICSV 15006**	30.24(33.36)	31.88(34.37)	31.06(33.86)
14	**SPV 2326**	22.53(28.33)	39.3(38.82)	30.91(33.57)
15	**SPV 2327**	26.06(30.69)	31.3(34.02)	28.68(32.35)
16	**SPV 2328**	14.33(22.23)	20.5(26.92)	17.41(24.57)
17	**DHBM 1**	33.63(35.44)	38.3(38.23)	35.96(36.83)
18	**DHBM 3**	19.7(26.34)	24.13(29.42)	21.91(27.88)
19	**SSV 84**	24.51(29.67)	32.48(34.74)	28.49(32.20)
20	**CSH 22 SS**	24.7(29.80)	27.93(31.90)	26.31(30.85)
	SEm±	**(0.20)**	(**0.16)**	**(0.18)**
	CD	**(0.59)**	**(0.45)**	**(0.52)**

*Values in parenthesis are arc transformation values

4.2.3 Per cent stem tunneling by stem borer

Table 4.2.3 stem and peduncle tunneling by stem borer in different genotypes

s.no	Genotypes	% Stem Tunneling	% Peduncle Tunneling
1	**ICSV 25335**	26.98(31.29)*	32.78(34.92)*
2	**ICSSH 87**	28.45(32.23)	35.58(36.62)
3	**ICSSH 86**	25.24(30.15)	20.14(26.66)
4	**ICSV 25306**	29.41(32.84)	23.17(28.77)
5	**ICSSH 82**	17.34(24.60)	21.84(27.85)
6	**ICSSN 79**	19.61(26.28)	13.81(21.80)
7	**ICSSH 88**	37.11(37.53)	11.28(19.61)
8	**DHBM 5**	14.64(22.48)	10.14(18.55)
9	**DHBM 4**	24.34(29.56)	14.34(22.25)
10	**DHBM 2**	17.78(24.96)	36.24(37.01)
11	**ICSV 25308**	14.44(22.32)	13.84(21.83)
12	**ICSV 25333**	27.21(31.44)	8.04(16.81)
13	**ICSV 15006**	15.28(23.00)	8.38(16.81)
14	**SPV 2326**	7.48(15.84)	4.56(12.24)
15	**SPV 2327**	20.21(26.71)	14.61(22.46)
16	**SPV 2328**	13.08(21.19)	24.51(29.67)
17	**DHBM 1**	12.09(20.34)	17.09(24.41)
18	**DHBM 3**	15.09(22.85)	19.05(25.87)
19	**SSV 84**	7.43(15.80)	25.09(30.06)
20	**CSH 22 SS**	20.07(26.61)	31.09(33.89)
	SEm±	**(0.24)**	(**0.28)**
	CD	(**0.70)**	**(0.81)**

*Values in parenthesis are arc transformation values

Data recorded on stem tunneling caused by stem borer at harvest revealed that all the genotypes differ significantly with respect to per cent stem tunneling caused by the borer. The minimum stem tunneling was recorded in genotype SSV84 (7.43) which was significantly less than rest of the genotypes followed by genotype SPV2326(7.48).However the maximum and higher stem tunneling was recorded in genotype ICSSH88(37.11) which was significantly more than rest of the genotypes except ICSV 25306(29.41) and ICSSH 87(28.45).

Per cent peduncle tunneling by stem borer:

. Data recorded on peduncle tunneling caused by the stem borer at harvest revealed that all the genotypes differ significantly with respect to per cent peduncle tunneling caused by the borer. The minimum peduncle tunneling was recorded in SPV2326 (4.56) which was found significantly less than rest of the genotypes followed by ICSV 25333(8.04), and ICSV15006 (8.38). However the Maximum attack was observed in genotype DHBM2 (36.24) which was significantly more than rest of the genotypes except ICSSH 87(35.58) .

4.2.4 (a) Number of holes caused by stem borer:

The different sorghum genotypes were also observed for the presence of number of borer holes in each stem. All the genotypes differ significantly. The minimum number of holes caused by stem borer was recorded in the genotype SPV 2328(0.1) which was significantly less than rest of the genotypes. but it was at par within genotype SPV2326(0.3) in ICSV 15006(0.3).However the maximum and higher number of holes per plant was recorded in genotype ICSV 25306(1.29 holes per plant) which was significantly more than rest of the genotypes .except ICSV 25335(1.26).

(b) Number of larvae per plant:

The different sorghum genotypes were also observed for the presence of Number of stem borer larvae in each stem. All the genotypes differed significantly. The minimum number of larva per plant was recorded in genotype DHBM 3 (0.1larve per plant) which was significantly lower than all the genotypes followed by in genotype SPV 2327(0.25 larva per plant) and SPV2328(0.29 larva per plant) and the remaining genotypes were significant to each other. However the maximum and higher attack was recorded in genotype ICSV25335(1.45 larva per plant)which was significantly more than rest of the genotypes except ICSV 25306(1.43larve per plant).

Table 4.2.4 Number of holes, larva and pupae of stem borer in various genotypes

s.no	Genotypes	NO.OF HOLES	NO.OF LARVE	NO.OF PUPAE
1	**ICSV 25335**	1.26(1.29)*	1.45(1.39)*	0(0.71)*
2	**ICSSH 87**	0.76(1.09)	0.55(1.02)	0.36(0.93)
3	**ICSSH 86**	0.93(1.15)	0.79(1.13)	0(0.71)
4	**ICSV 25306**	1.29(1.31)	1.43(1.39)	0.1(0.77)
5	**ICSSH 82**	0.8(1.10)	0.7(1.09)	0.2(0.84)
6	**ICSSN 79**	0.59(1.02)	0.58(1.04)	0.1(0.77)
7	**ICSSH 88**	0.3(0.89)	0.3(0.89)	0.1(0.77)
8	**DHBM 5**	0.73(1.07)	0.5(1.00)	0(0.71)
9	**DHBM 4**	0.53(0.98)	0.39(0.94)	0.1(0.77)
10	**DHBM 2**	0.76(1.09)	0.5(1.00)	0.1(0.77)
11	**ICSV 25308**	0.5(0.98)	0.38(0.94)	0.23(0.85)
12	**ICSV 25333**	0.36(0.90)	0.65(1.07)	0.35(0.93)
13	**ICSV 15006**	0.3(0.89)	0.52(1.01)	0(0.71)
14	**SPV 2326**	0.3(0.89)	0.45(0.97)	0(0.71)
15	**SPV 2327**	0.5(1.00)	0.25(0.86)	0.26(0.88)
16	**SPV 2328**	0.1(0.77)	0.29(0.89)	0(0.71)
17	**DHBM 1**	0.9(1.14)	0.45(0.97)	0.1(0.77)
18	**DHBM 3**	0.73(1.08)	0.1(0.77)	0.1(0.77)
19	**SSV 84**	0.36(0.91)	0.7(1.09)	0.2(0.84)
20	**CSH 22 SS**	0.9(1.14)	0.1(0.77)	0(0.71)
	SEm±	**(0.09)**	**(0.01)**	**(0.03)**
	CD	**(0.25)**	**(0.04)**	**(0.10)**

Values in parenthesis are $\sqrt{n \quad 0.5}$ values

(c) Number of pupae per plant:

The different sorghum genotypes differed significantly with respect to number of pupae per plant. There were no pupae recorded in genotypes SPV2326, ICSV 25335,ICSSH 86,DHBM5, ICSV 15006, SPV 2328,CSH 22SS. Minimum and equal pupal population(0.1pupae per plant) was recorded in genotype DHBM1,DHBM3,ICSSH 88,ICSSN 79,ICSV 25306,DHBM4,DHBM 2 which were significantly less than ICSSH 82,SSV84.However the maximum and significant pupal population was recorded in genotype ICSSH87 (0.36 pupal population per plant) which found significantly higher than rest of the genotypes.

4.3 Reaction of different genotypes against different ear head pests:

A. Incidence of ear head bug per cob (*calocoris angustatus* Leth):

The different sorghum genotypes differed significantly with respect to number of ear head bugs. The minimum and lowest number of ear head bug population was recorded on genotype ICSSH 88(4.47bugs per plant) which was found significantly less than rest of the genotypes. followed by ICSV 25308(4.98bugs per plant) .However the maximum and highest number of ear head bug was recorded on genotype DHBM4 (7.8bugs per plant)which was significantly more than rest of the genotypes except ICSV 25306(7.47bugs per plant) and ICSV 25333(7.27bugs per plant).

B. Incidence of ear head worm per cob (*Cryptoblabes gnidiella* Mab)

The different sorghum genotypes differed significantly with respect to number of ear head worms. The minimum and significant lower number of worms was recorded on genotype ICSSH 86 (5 worms per ear head) which was significantly less than rest of the genotypes followed by ICSSH 87(6.67 worms per ear head) .However the maximum and higher attack was recorded on genotype ICSV15006(10.33 worms/ear head) which was significantly more than rest of the genotypes except ICSV 25335 (9.67worms per ear head) and ICSV 2306(9.09worms per ear head).

Table 4.3: Reaction of genotypes against different ear head pests of sorghum

s.no	Genotypes	Ear head bug/cob	Ear head worm/cob
1	**ICSV 25335**	5.14(2.37)*	9.67(3.18)*
2	**ICSSH 87**	5.27(2.39)	6.67(2.67)
3	**ICSSH 86**	6.98(2.72)	5(2.34)
4	**ICSV 25306**	7.47(2.82)	9.09(3.09)
5	**ICSSH 82**	5.6(2.46)	7(2.73)
6	**ICSSN 79**	5.83(2.51)	7.67(2.86)
7	**ICSSH 88**	4.47(2.22)	8.63(3.02)
8	**DHBM 5**	5.47(2.44)	8.33(2.97)
9	**DHBM 4**	7.8(2.88)	9.35(3.13)
10	**DHBM 2**	6.47(2.63)	9(3.08)
11	**ICSV 25308**	4.98(2.32)	8.09(2.93)
12	**ICSV 25333**	7.27(2.78)	7.67(2.85)
13	**ICSV 15006**	6.21(2.59)	10.33(3.29)
14	**SPV 2326**	6.32(2.60)	6.67(2.67)
15	**SPV 2327**	6.14(2.57)	7.78(2.88)
16	**SPV 2328**	5.3(2.40)	8.33(2.97)
17	**DHBM 1**	6.32(2.61)	8.09(2.93)
18	**DHBM 3**	6.9(2.71)	7.33(2.80)
19	**SSV 84**	5.9(2.53)	8.09(2.93)
20	**CSH 22 SS**	5.09(2.35)	7.67(2.85)
	SEm ±	**(0.05)**	**(0.04)**
	CD	**(0.16)**	**(0.12)**

Values in parenthesis are $\sqrt{n \quad 0.5}$ values.

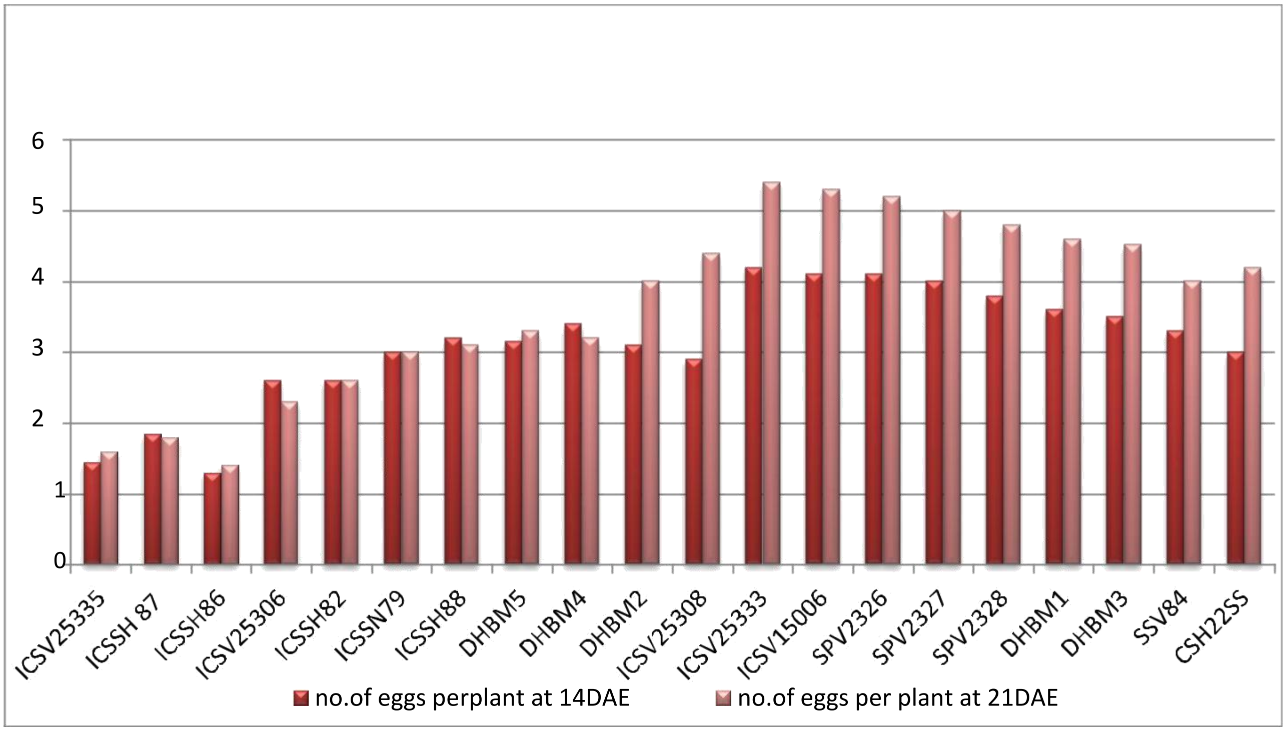

fig 4.1.1 No. of eggs laid by shoot fly in different genotypes.

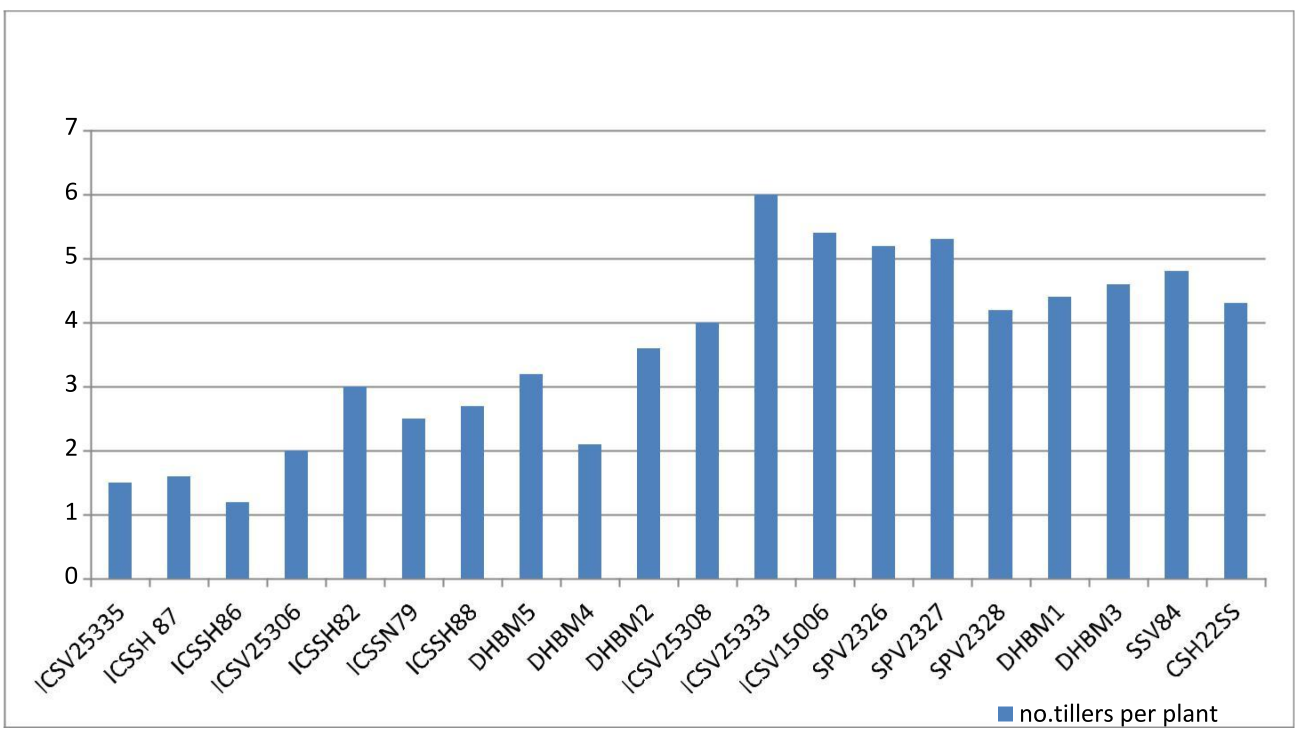

fig.4.1.2 No.of tillers produced by shootfly

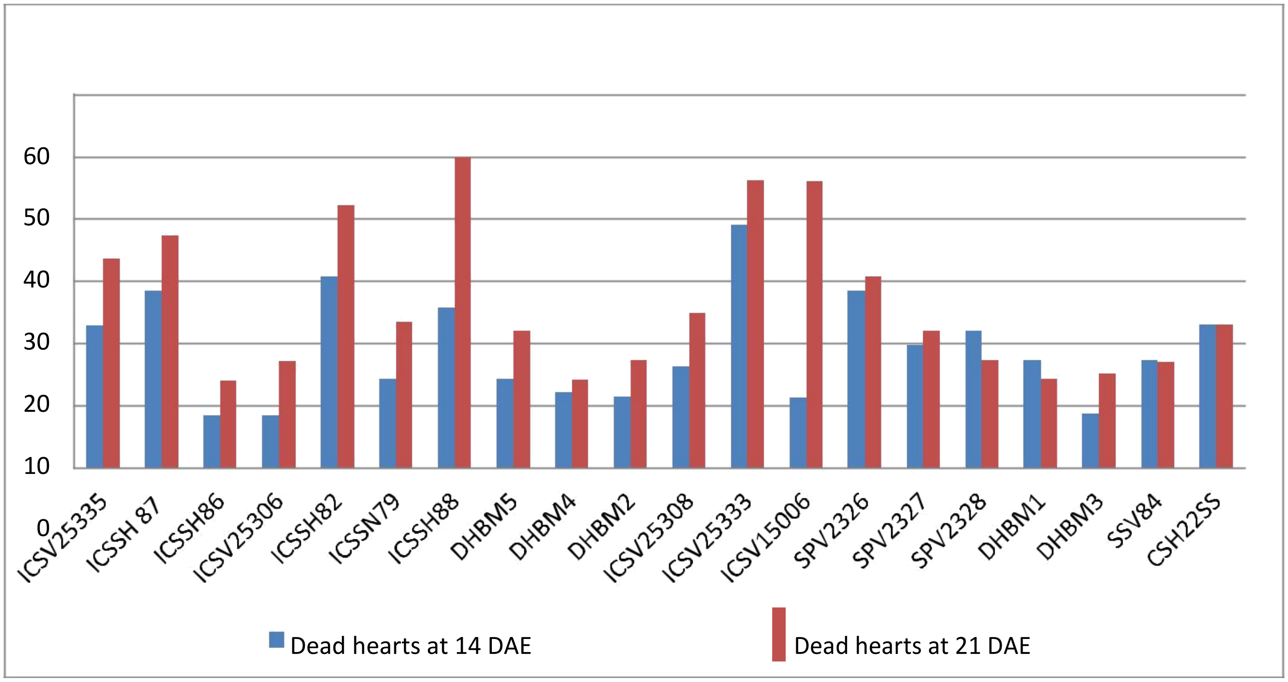

Fig. 4.1.3 per cent dead hearts produced by shoot fly at 14 &21 DAE

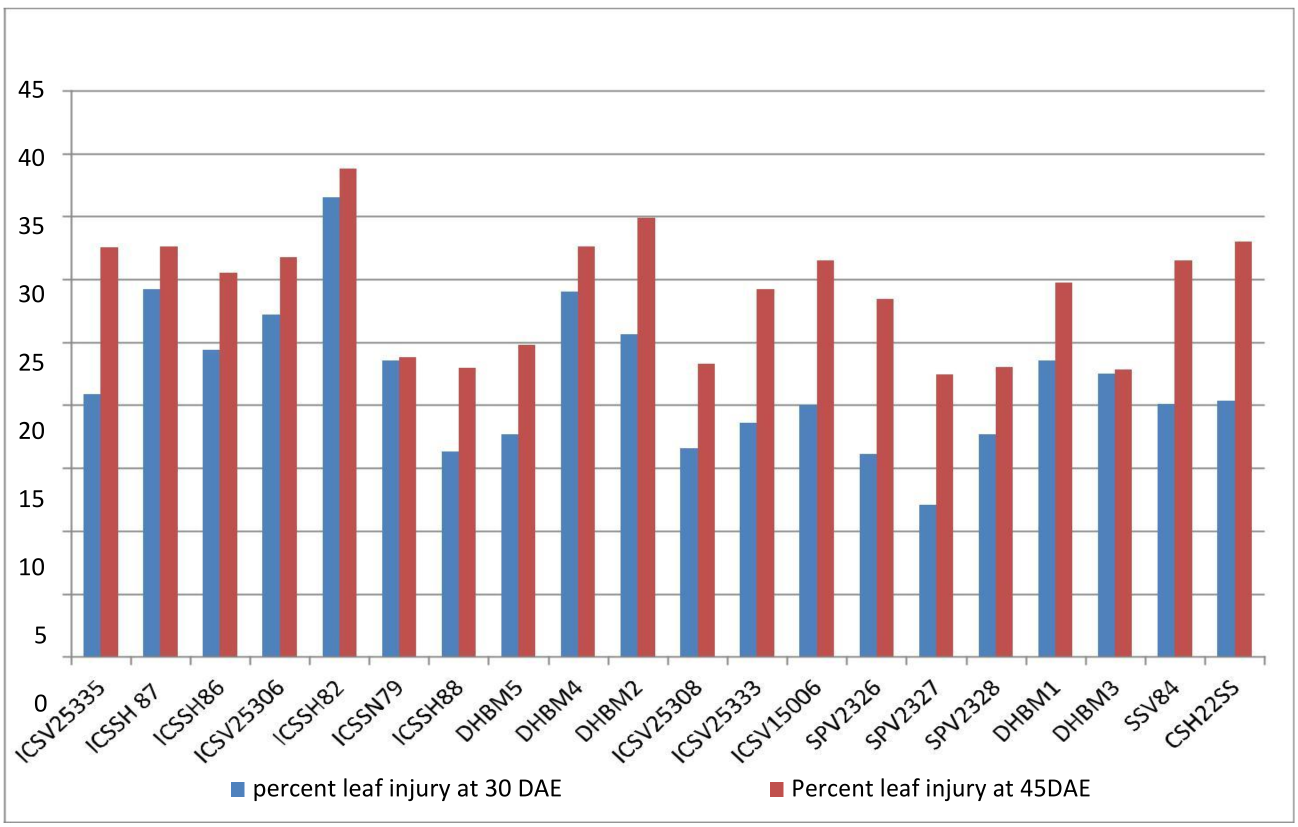

fig. 4.2.1 per cent leaf injury caused by stemborer

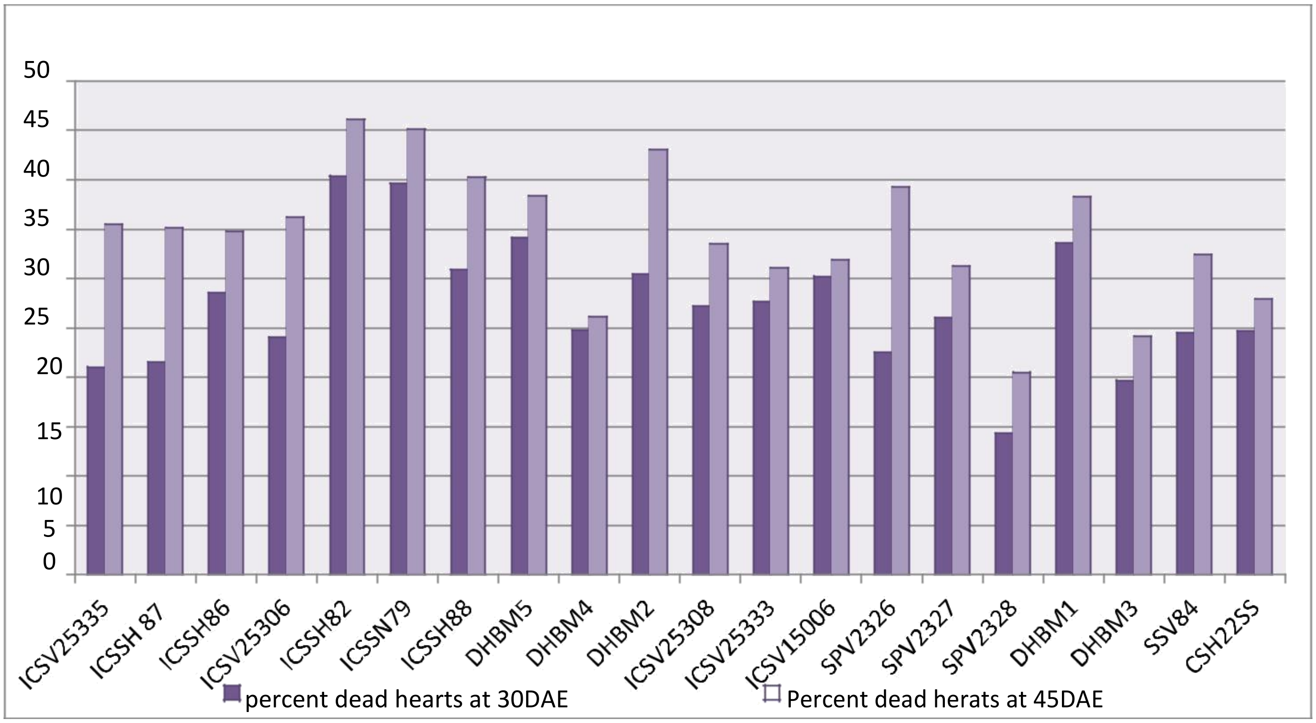

fig.4.2.2 per cent dead hearts caused by stem borer

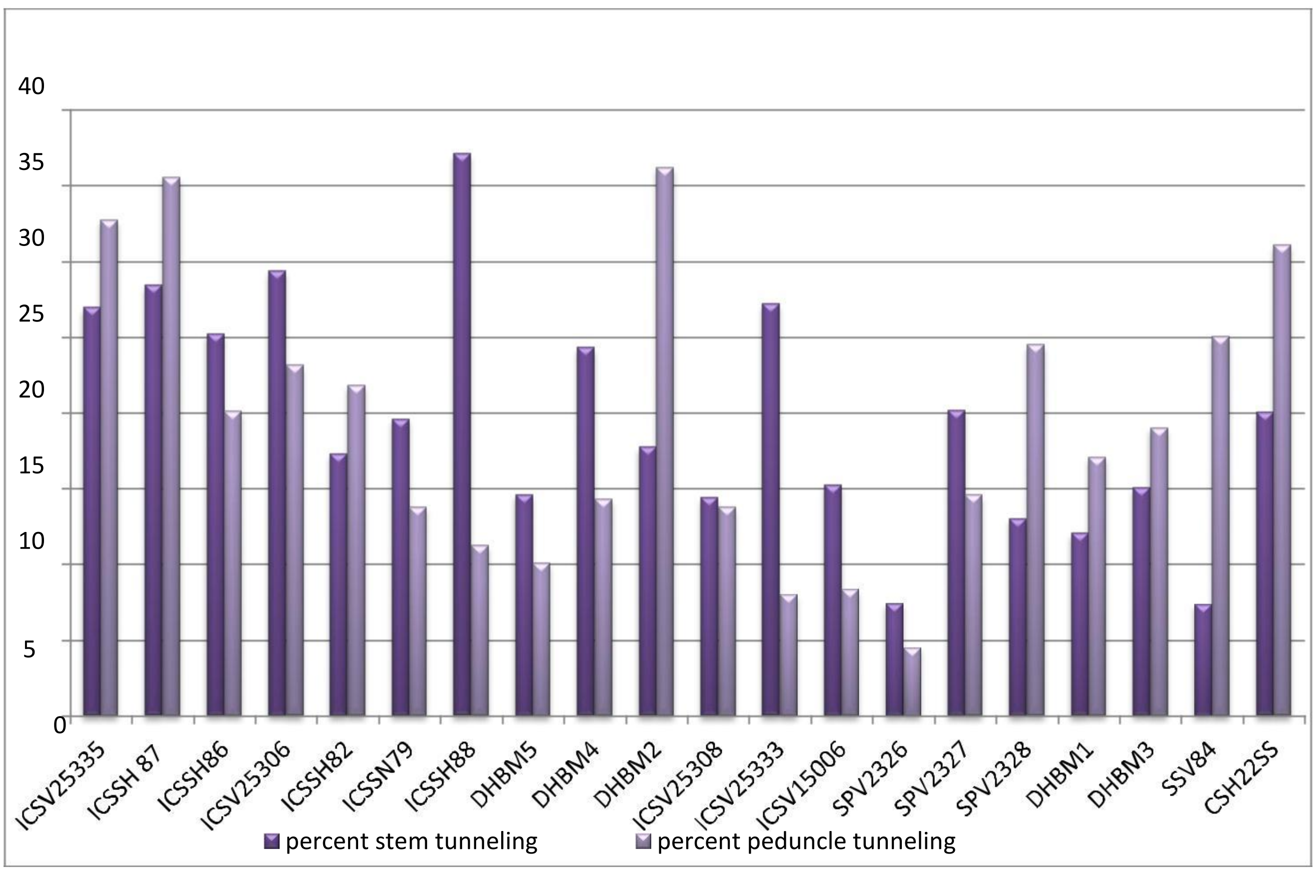

fig.4.2.3 per cent stem tunneling and peduncle tunneling caused by stem borer

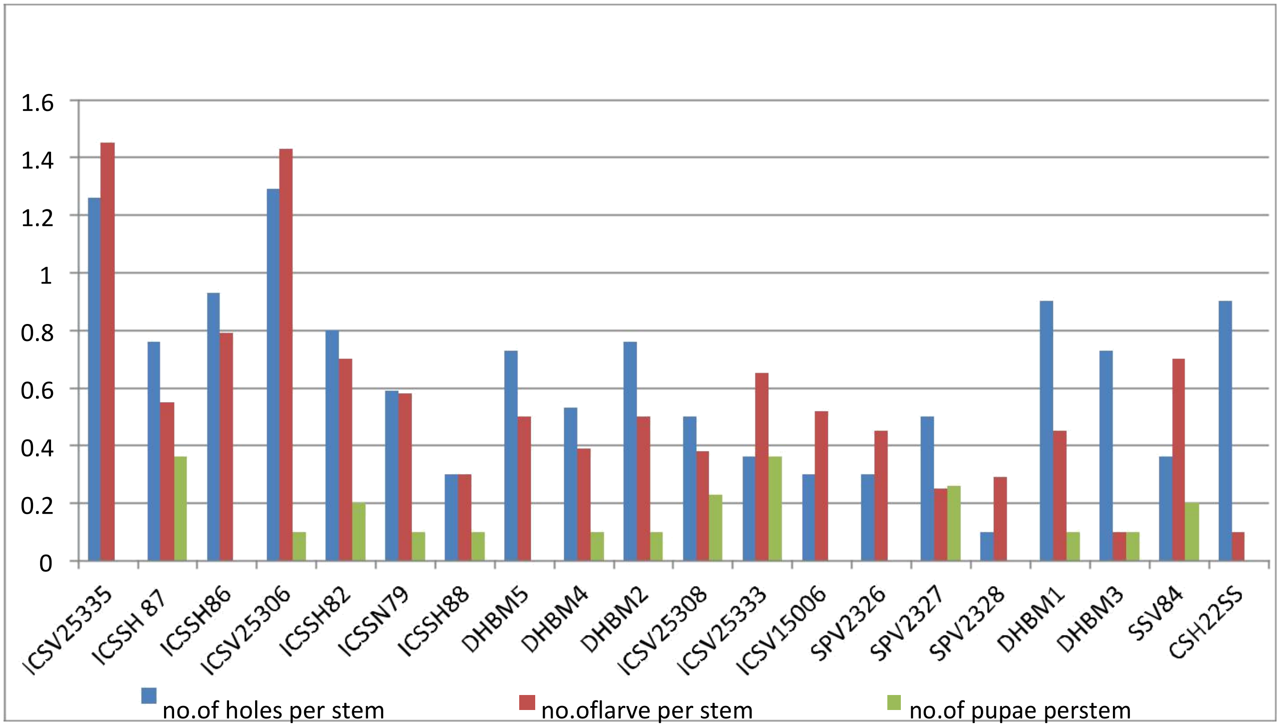

fig. 4.2.4 No holes,no.of larve & no.of pupae of stemborer

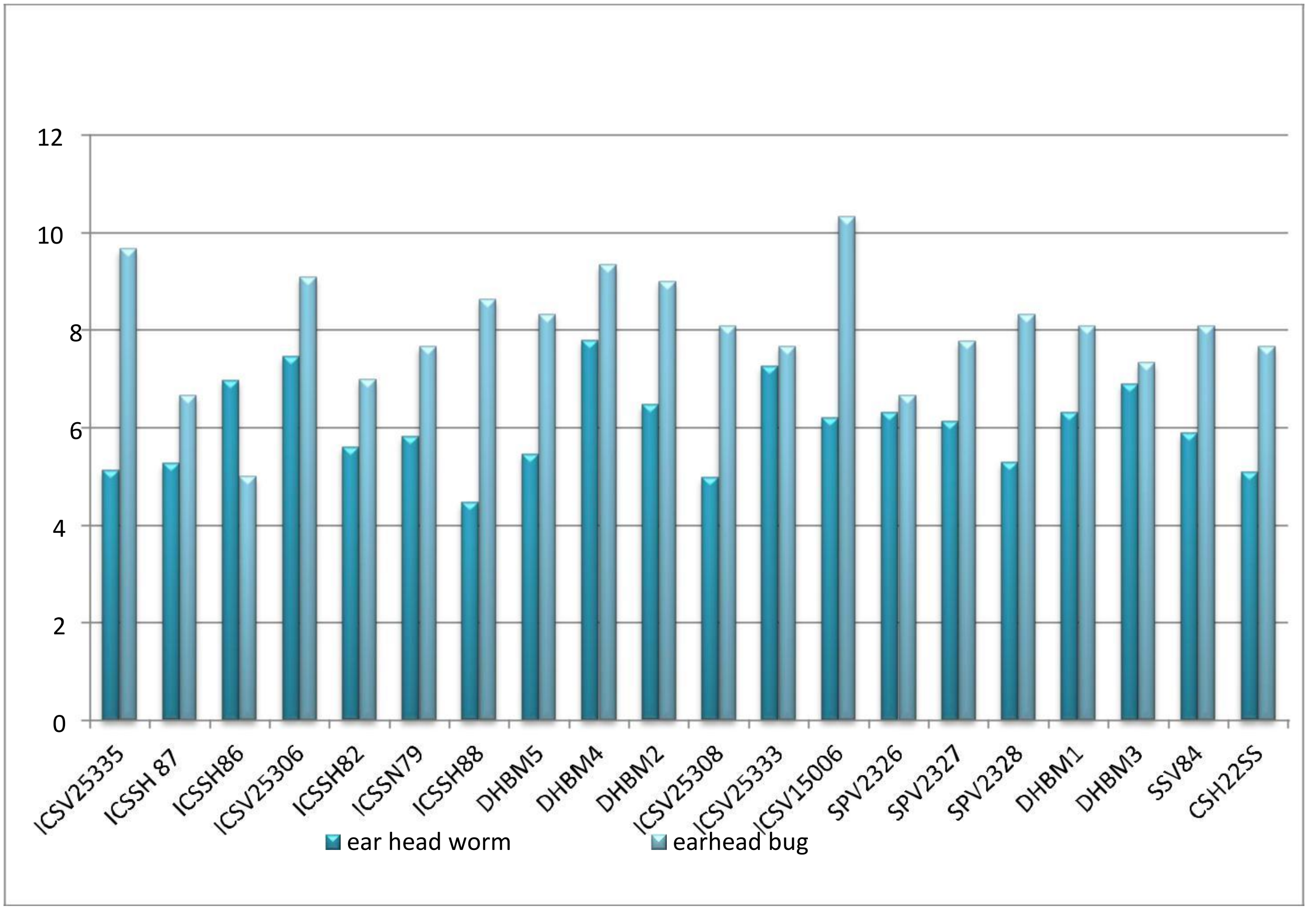

fig 4.3 reaction of sorghum genotypes against ear head pests

Chapter- V

DISCUSSION

The present investigations on**, "Reaction of genotypes against major insect pests of sorghum [*Sorghum bicolor* (L) Moench]**" were conducted to find out the less susceptible genotype against shoot fly, stem borer and ear head pests. The experimental findings of the study were discussed in this chapter:-

5.1 Reaction of genotypes against shoot fly:

(A). Number of eggs of shoot fly:

The incidence of shoot fly on the sorghum was recorded by counting the number of eggs laid by shoot fly at 14 and 21 days after emergence. At 14 days after emergence the number of eggs/plant were ranged from 1.3 to 4.2 in different genotypes with significant difference among them. Minimum number of eggs were recorded in genotype ICSSH 86 followed by ICSV 25335, ICSSH 87 and ICSV 25306. Whereas the maximum number of shoot fly eggs were recorded in genotype ICSV 25333 followed by ICSV 15006, SPV 2326 and SPV 2327.

At 21days after emergence the number of shoot fly eggs/ plant ranged from 1.41 to 5.4 in different genotypes with significant difference among them. Minimum number of eggs were recorded in genotype ICSSH 86 followed by ICSV 25335, ICSSH 87 and ICSV 25306. Maximum number of eggs were recorded in genotype ICSV 25333 followed by ICSV 15006, SPV 2326 and SPV 2327.

On the basis of average of the both of the observations i.e., 14 and 21DAE the different genotypes differed significantly with respect to number of eggs. The minimum number of eggs 1.35 eggs/ plant were recorded in genotype ICSSH 86 which was found significantly less than rest of the genotypes except ICSV 25335. However the maximum number of eggs 4.8 eggs/ plant were recorded in genotype ICSV 25333 which was found significantly more than all the genotypes except 4.7 eggs/ plant in ICSV15006.

The present findings were also in accordance with the findings reported by Jotwani *et al*. (1971) who reported less than one egg per seedling in resistant varieties, compared with a maximum of 5.73 eggs per seedling on the susceptible variety. The studies conducted by Teli *et al.* (1983) on relative susceptibility of 20 hybrids and varieties of sorghum to shoot fly showed that average number of egg per plant varied from 0.60 to 0.84 and dead hearts ranged from 19.99 per cent to 84.78 per cent in different cultivars. Similar findings were reported by Deshpande *et al*. (2003) where percent dead hearts, per cent oviposited plants and number of eggs per plant were positively correlated with each other. Kumar *et al.* (2003) evaluated 29 genotypes belonging to seven different groups of sorghum for their resistance to sorghum shoot fly. Ovipositional non-preference or antixenosis was expressed by the resistant controls (IS 2312 and IS 18551) and elite resistant lines (ICSV 700, ICSV 705, ICSV 708, ICSV 93088, ICSV 93089, ICSV 93090, ICSV 93091 and PB 14390-4) as these recorded less number of eggs compared to other genotypes. In contrast the susceptible controls (CSV 1 and DJ 6514) and forage sorghum genotypes (GSSV 148, SR 350-1-16 and SSG 59-3) were the most preferred groups for shoot fly oviposition.

(B). Number of tillers per plant:

The shoot fly infested plant produces synchronous tillers. The numbers of tillers produced by plant were recorded at 35 days after emergence .The number of tillers ranged from 1.2 to 6. The minimum number of tillers was recorded in genotype ICSSH 86 followed by ICSV 25335, ICSSH 87, ICSV 25306 and the rest of the genotypes are significant to each other. Maximum number of tillers was found in genotype ICSV 25333 followed by ICSV 15006, SPV 2327, SPV 2326. The present were also in accordance with the findings reported by Kimhaeko *et al.* (2010) who reported that tillering appearance in sorghum was related to the surrounding environment and internal plant competition for assimilates regulates the number of tillers production in sorghum. Dhillon *et al*. (2005) reported that tiller and dead hearts occurrence was low in the sorghum genotypes containing A4M cytoplasm. Lafarge *et al.* (2002) reported that tiller emergence in sorghum was mainly due to assimilate supply of light and density of plants per meter square. The main plants and tillers production of SFCR 151, ICSV

705, SFCR 125, and, IS 18551 experienced lower shoot fly dead hearts at 28 days after seedling emergence due to host plant resistance and varied climatic conditions were reported by Dhillon *et al.* (2005).

(C). Number of dead hearts produced by shoot fly

Significant differences were observed among the dead hearts caused by shoot fly at 14 and 21 days after emergence. At 14 days after emergence the dead heart percentage ranged from 8.45 to 39.01 per cent in different genotypes with significant difference among them. The minimum attack was observed in ICSSH 86 which was found significantly less than all the genotypes followed by ICSV 25306, DHBM3, ICSV 15006. The maximum dead hearts were observed in genotype ICSV 25333 indicates their higher susceptibility to shoot fly followed by ICSSH 82, ICSSH 87.

At 21 days after emergence the per cent dead hearts ranged from 14.02 to 49.9 percent in different genotypes with significant difference among them. The minimum dead hearts were recorded in genotype ICSSH86 which was found significantly less attacked than all the genotypes followed by DHBM4, DHBM 1.The maximum dead hearts were recorded in genotype ICSSH88 indicated higher susceptibility to shoot fly followed by ICSV 25333, ICSV 15006.

On the basis of average of the both of the observation i.e. 14 and 21 DAE the different genotypes differed significantly with respect to per cent dead hearts. The minimum dead heart (11.23%) was recorded in genotype ICSSH 86 which was found significantly less than rest of the genotypes except DHBM3 (11.87%). However, the maximum dead hearts (42.59%) were recorded in genotype ICSV 25333 which was found significantly more than all the genotypes except (37.82%) was recorded in ICSSH

- The present findings were also in accordance with the findings reported by Chamarthi *et al.* (2011a and 2011b) where sorghum genotypes, ICSV 700, exhibited antixenosis for oviposition, and suffered less dead heart due to sorghum shoot fly, *Atherigona soccata*. Remaining genotypes SPH 1737 8.65 per cent, SPH 1748, 8.65 per cent, SPH 1776, 8.65 per cent, SPV 2270, 8.65 per cent, were found promising with less infestation, However maximum dead hearts were recorded in CSH 25 (40.03 and 51.90%) at both stage. Vyas *et al.* (2014) and Vyas *et al.* (2014a) also worked on different genotypes of sorghum and found that entries SPV 1852, SPV 2003, SPH 1622, SPV 200, SPH 1654, SPV 462, CSV 15, SPV 2013 and SPH 16151 recorded significantly minimum shoot fly damage.

Similar findings were reported by Singh and Grewal, (1997) that 8.5 to 76.5% dead hearts caused by shoot fly. Kumar *et al.* (2003) reported that, the genotypes ICSV 708 and ICSV 705 recorded the lowest number of dead hearts, while CSV 1 and DJ 6514 recorded the highest dead heart formation.

The above finding of various scientists is in support of present investigation.

5.2 Reaction of genotypes against stem borer

(A). Per cent leaf injury caused by stem borer

The per cent leaf injury caused by stem borer was recorded at 30 and 45 days after emergence. Significant difference was recorded among the genotypes tested. At 30 days after emergence the per cent leaf injury ranged from 12.09 to 29.03. Minimum plant infestation was recorded in genotype SPV 2327 which showed less infestation among all the genotypes followed by SPV 2326, ICSV 25308. Whereas, maximum infestation showed in genotype ICSSH 82 followed by ICSSH 87, DHBM 4.

At 45 days after emergence significant difference was recorded among the different genotypes. Per cent leaf infestation ranged from 22.44 to 38.8. Minimum leaf injury was recorded in genotype SPV 2327 which recorded less infestation among all the genotypes followed by DHBM3, ICSSH 88. Highest and maximum leaf injury percent was recorded in genotype ICSSH 82 which showed higher infestation than rest of the genotypes followed by DHBM 2, CSH22SS.

On the basis of average of the both of the observations i.e., 30 and 45 DAE the different genotypes differed significantly with respect to per cent leaf injury. The minimum leaf injury (17.2%) was recorded in genotype SPV 2327 which found significantly less than rest of the genotypes except (19.63%) was recorded in ICSSH 88.

However, the maximum leaf injury (37.65%) was recorded in genotype ICSSH 82 which was found significantly more than all the genotypes.

The present findings were also in accordance with the findings reported by Bhadviya (1995) who screened 13 sorghum varieties against stem borer, and found that leaf injury ranged from 1.63 to 4.98 per cent. Sarailoo (1986) screened 80 genotypes for stem borer and recorded that leaf feeding injury of 0.3 and 3.5 percent. Whereas, Gour (1995) recorded that stem borer leaf injury ranged from 1.58 to 5.46 per cent. . Vyas *et al.* (2014) reported that entry CHS 20, HC 308, CSH 21 MF and SPV 1853 recorded minimum leaf injury. Vyas *et al.* (2014a) reported that minimum leaf injury in entry SPH 1648, SPV 1870 and SPH 1615.

(B) Per cent dead heart caused by stem borer

The per cent dead hearts caused by stem borer were recorded at 30 and 45 days after emergence. At 30 days after emergence the percent dead hearts ranged from 14.33 to 40.41 percent. The minimum dead heart percentage due to stem borer was recorded in genotype SPV2328 which showed very less amount of infestation among the remaining genotypes followed by DHBM 3, ICSV 25335, ICSSH 87.The maximum dead heart percentage was recorded in genotype ICSSH 82 which recorded maximum dead hearts among all the genotypes followed by ICSSN 79, DHBM 5.

At 45 days after emergence the recorded dead heart percentage showed significant difference between each other. The percentage dead hearts caused by stem borer varies from 20.5 to 46.13 percent. Minimum dead hearts were recorded in genotype SPV2328 which was significantly less infested among all the genotypes followed by DHBM3, DHBM 4. Maximum and higher percentage of dead hearts were recorded in genotype ICSSH 82 followed by ICSSN 79, DHBM 2. .

On the basis of average of the both of the observations i.e., 30 and 45DAE the different genotypes differed significantly with respect to per cent dead hearts. The minimum number of dead heart (17.41%) was recorded in genotype SPV 2328 which was found significantly less than rest of the genotypes except 921.91%) was recorded in DHBM 3. However the maximum dead hearts (43.27%) was recorded in genotype

ICSSH 82 which was found significantly more than all the genotypes except (42.37%) was recorded in ICSSN79. The present study is in accordance with Kishore *et al.* (2002) who found eleven lines showed resistant against shoot fly, thirteen lines against stem borer and two entries namely, SPV 1518 and SPV 1572 were identified as multiple resistance to both shoot fly and stem borer. Vyas *et al.* (2014) reported that SPV 1616, SPV 1907, CSV 15, CSV 17, SPV 1870, SPV 12016, SPH 1615 and SPH 1596 recorded minimum stem borer dead hearts. Kishore (2001) observed that resistance to stem borer in five entries viz., PGN 1, PGN 64, PGN 20, AKENT 20 and KC 1. Teli *et al.* (1983) reported 19.99 to 84.78% dead heart in different cultivars. The variation in per cent dead heart formation caused by stem borer might be due to different genotypes tested by different workers and variation in climatic condition of the tested station.

(C). Per cent stem tunneling and peduncle tunneling due to stem borer

Stem borer stem tunneling and also stem borer peduncle tunneling differ significantly. The observations were recorded at the time of harvest. Stem tunneling in different genotypes ranged from 7.43 to 37.11 per cent. The minimum number of tunnels was recorded in genotype SSV 84 which showed less infestation among all the genotypes followed by SPV 2326, DHBM 1. The maximum and more stem tunneling were recorded in the genotype ICSSH88 followed by ICSV 25306, ICSSH 87 peduncle tunneling was recorded at harvesting, minimum peduncle tunneling was recorded in genotype SPV 2326 which showed significantly less attack than all the genotypes. Maximum and higher attack of peduncle tunneling was recorded in genotype DHBM2. The present findings were also in accordance with the findings reported by Parmar (2012)who reported that tunneling per cent range to be from 0.59 (SPH 1689) to 14.07 (SPH 1674). Bhadviya (1995) reported 2.0 to 35.58% stem tunneling and 5.2 to 35.0% peduncle tunneling in different varieties of sorghum. Gour (1995) also reported 0.51 to 12.71% stem tunneling among different varieties. The stem tunneling might be associated with the presence of silica content and stem hardening in the genotypes. Verma *et al.* (1988) reported 27.73 to 61.40 per cent peduncle tunneling in different cultivar of sorghum.

(D). Number of holes, larva and pupae caused by stem borer

Significant difference were observed in different genotypes with regard to number of holes/ plant .The number of holes among different genotypes ranged from 0.1 to 1.29 Minimum and equal number of holes was recorded in genotype SPV 2328 which was found lesser than rest of the genotypes but was at par with SPV 2326, ICSV 15006, and ICSSH88.Maximum number of holes were recorded in genotype ICSV25306 followed by ICSV 25335 showed higher susceptibility to shoot fly.

Significant difference were observed in different genotypes with regard to number of larva/ plant. The number of larva among the different genotype varied from 0.1 to 1.45. Minimum number of larva was recorded in genotypeCSH22 SS, DHBM3, SPV 2327 which were found less attacked by stem borer. Maximum and higher attack was observed in genotype ICSV 25335 followed by ICSV 25306.

Significant difference was observed between the number of pupae of sorghum stem borer. There were no pupae recorded in genotypes ICSV 25335, ICSSH 86, DHBM 5, ICSV 15006, SPV 2326, SPV 2328, CSH 22SS. Minimum and and equal pupal population (0.1) was recorded from the genotypes DHBM3, DHBM1,DHBM2, DHBM4, ICSSH 88, ICSSN 79, ICSV 25306 which were found significantly less than the pupal population of remaining genotypes. Maximum and higher pupal population was recorded in genotype ICSSH 87 followed by ICSV 25333 which showed susceptibility to the stem borer by bearing higher number of pupae per plant.

The present findings were also in accordance with the findings reported by Patel et al. (1996) found that IS 2205 to be most resistant on the basis of dead hearts, leaf injury, stem tunneling, peduncle tunneling and exit holes.

Similar finding were reported by Chaturvedi (2000) that varieties IMS 9B, ICSV-705, ISSV-951 and CSV-15 to be less susceptible against stem borer on the basis of plant infestation, number of holes, larval/ pupal population and stem and peduncle tunneling caused by stem borer.

5.3 Reaction of genotypes against ear head pests

At milky stage the ear head bug population ranged from 5.09 to 7.8 bugs per cob. The minimum number of ear head bugs were recorded in genotype CSH22 SS followed by ICSV 25335. Maximum numbers of ear head bugs were found in genotype DHBM 4 which showed susceptibility to ear head bug.

Ear head worm population ranged from 5 to 10.33 bugs per cob. The minimum numbers of ear head worms were recorded in genotype ICSSH 86 which was less susceptible than remaining genotypes followed by ICSSH 87, SPV 2326. Maximum number of ear head worms were observed in the genotype ICSV 15006 which was recorded as highly susceptible to ear head worm followed by ICSV 25335, ICSV 25306.

The present study is in accordance with the findings reported by Gagre (1990) found that incidence of ear head bug on sorghum varieties in the range of 5.99 to 34.49 per cob. This variation in level of infestation may be due to different climate conditions of test station. Similar finding by Parmar (2012) who reported that minimum number of ear head bug was (3.19 bug per three plant) in IS 2205. Patidar (2010) reported that ear head worm ranged from 2.00-10.44 worm/ 3plants. Mote and Kadam (1984) found that, 24 genotypes were free from ear head damage, but SPV 472, Swarna, SPH 196, CSH 1, CSH 6 and CSH 9 were moderately resistant (score 1.1 to 2.0).

Chapter - VI
SUMMARY, CONCLUSION AND SUGGESTIONS FOR FURTHER WORK

A field experiment entitled, "Reaction of genotypes against major insect pests of sorghum'' [*Sorghum bicolor* (L.) Moench] were conducted during Kharif crop season 2016 at the college Research Farm of R.V.S.K.V.V agricultural university, Gwalior. In the present investigations twenty genotypes were screened to find out the less susceptible genotype against shoot fly, stem borer and ear head pests. Observations were recorded on number of eggs laid by shoot fly, number of tillering produced by shoot fly, per cent dead heart caused by shoot fly, per cent leaf infested and dead heart caused by stem borer, stem tunneling an peduncle tunneling by stem borer, number of holes, number of larvae/pupa, number of ear head bugs and worms per ear head. The results obtained during the course of research have been summarized below:-

Shoot fly (*Atherigona soccata* ;Rondani):

The incidence of shoot fly in sorghum was determined by counting number of eggs at 14 and 21DAE, counting the number of tillers at 35DAE and counting dead hear at 14 and 21 DAE. at 14 days after emergence. The number of eggs/plant ranged from 1.3 to 4.2 percent in different genotypes with significant difference among them. Minimum number of eggs were recorded in genotype ICSSH 86 followed by ICSV 25335, ICSSH 87 and ICSV 25306. whereas the maximum number of shoot fly eggs were recorded in genotype ICSV 25333 followed by ICSV 15006,SPV 2326. At 21days after emergence the number of shoot fly eggs per plant ranged from 1.41 to 5.4 in number. Minimum infestation occurred in in genotype ICSSH 86 followed by ICSV 25335,ICSSH 87 and ICSV 25306. Maximum number of eggs were recorded in genotype ICSV 25333 followed by ICSV 15006,SPV 2326 and SPV 2327.

Number of tillers recorded at 35 DAE The number of tillers ranged from 1.2 to 6 per cent. the minimum number of tillers was recorded in genotype ICSSH 86 followed by ICSV25335,ICSSH 87,ICSV 25306. Maximum number of tillers were found in genotype ICSV 25333 followed by ICSV 15006, SPV 2327 and SPV 2326.

The dead heart percentage ranged from 8.45 per cent to 39.01 per cent in different genotypes at 14 days after emergence. The minimum attack was observed in ICSSH 86 followed by ICSV 25306, DHBM3 and ICSV 15006. Maximum dead hearts was observed in genotype ICSV 25333. At 21 days after emergence the per cent dead hearts ranged from 14.02 to 49.9 per cent. Minimum dead hearts were recorded in genotype ICSSH86 which was found significantly less attacked than all the genotypes followed by DHBM4,DHBM 1. Maximum dead hearts were recorded in genotype ICSSH88 indicates higher susceptibility to shoot fly followed by ICSV 25333, ICSV 15006.

Stem borer (*Chillo partellus;* Swinhoe):

Per cent leaf injury caused by stem borer was recorded at 30and 45 DAE. At 30 days after emergence the percent leaf injury ranged from 12.09 to 29.03. Minimum plant infestation was recorded in genotype SPV2327. Maximum infestation showed in genotype ICSSH 82 followed by ICSSH 87, DHBM 4. At 45 days after emergence. per cent leaf infestation ranged from 22.44 to 38.8.Minimum leaf injury was recorded in genotype SPV2327. Whereas maximum leaf injury per cent was recorded in genotype ICSSH 82.

The per cent dead hearts caused by stem borer were recorded at 30 and 45 days after emergence. At 30 days after emergence the percent dead hearts ranged from 14.33 to 40.41 per cent. The minimum dead heart percentage due to stem borer was recorded in genotype SPV2328. Followed by DHBM 3, ICSV 25335, ICSSH 87. Maximum dead heart percentage was recorded in genotype ICSSH 82. At 45 days after emergence the percentage dead hearts caused by stem borer varies from 20.5 to 46.13 percent. Minimum dead hearts were recorded in genotype SPV2328. Maximum and higher percentages of dead hearts were recorded in genotype ICSSH 82 followed by ICSSN 79 and DHBM 2.

Stem tunneling in different genotypes ranged from 7.43 to 37.11 per cent. The minimum and less number of tunnels was recorded in genotype SSV84 which showed less infestation among all the genotypes followed by SPV2326 and DHBM1. The maximum and more stem tunneling were recorded in the genotype ICSSH88 followed by ICSV 25306 and ICSSH 87.

Minimum peduncle tunneling was recorded in genotype SPV2326 which showed significantly less attack than all the genotypes. Maximum and higher attack of peduncle tunneling was recorded in genotype DHBM2 followed by ICSSH87.

The number of holes among different genotypes ranged from 0.1 to 1.29. Minimum and equal number of holes was recorded in genotype SPV2328. Maximum number of holes were recorded in genotype ICSV25306 followed by ICSV25335 showed higher susceptibility to shoot fly. the number of larva among the different genotype varies from 0.1 to 1.45. Minimum number of larva was recorded in genotypeCSH22 SS. Maximum attack was observed in genotype ICSV25335. Minimum equal pupal population (0.1) was recorded from the genotypes DHBM3, DHBM1, whereas maximum and higher pupal population was recorded in genotype ICSSH 87.

Ear head pests (*Calocoris angustatus* Leth; *Crypto balbus gnidiella* Mab):

Ear head bug population ranged from 5.09 to 7.8 per cob. The minimum number of ear head bugs were recorded in genotype CSH22 SS. Maximum number of ear head bugs were found in genotype DHBM-4. Ear head worm population ranged from 5 to 10.33 per cob. The minimum number of ear head worms were recorded in genotype ICSSH86. . Maximum number of ear head worms were observed in the genotype ICSV15006 which shows highly susceptible to ear head worm followed by ICSV25335 and ICSV 25306.

Conclusion:

- Among the tested genotypes, ICSSH 86 was found least susceptible to the shoot fly followed by ICSV 25335 ,DHBM 3 and ICSV15006.
- Genotypes SPV 2327 showed least susceptibility to per cent leaf injury caused by stem borer followed by SPV2326 and DHBM 3.
- Genotypes SPV2328 showed least susceptibility to dead hearts caused by stem borer followed by DHBM 3 and ICSV 25335.
- Genotypes SPV2326 showed least susceptibility to stem tunneling and peduncle tunneling caused by stem borer.
- Genotypes least susceptible to ear head pests are ICSSH 88 followed by ICSSH86 and ICSSH87.

Suggestions for further work:

- Genotypes found less susceptible in the present studies may be screened with some newly developed genotypes, to found out the source of resistance against major pests of sorghum.
- Physiological and biochemical assessment studies of genotypes should be conducted for antibiosis mechanism against sorghum pest.
- Investigation on morphological characters conferring resistance to key pests needs to be intensified.

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APPENDICES

Appendix: i (shoot fly no. of eggs at 14DAE)					
Source of variat	**DF**	**SS**	**MSS**	**Fcal**	**Ftab**
Replication	2	0.051	0.025	67.583	3.245
Treatment	19	3.149	0.166	443.346	1.867
Error	38	0.014	0.000	**SEm±**	**0.01**
Total	59	3.213		**C.D at 0.05%**	**0.03**

Appendix: ii (shoot fly no. of eggs at 21DAE)					
Source of variat	**DF**	**SS**	**MSS**	**FCAL**	**F TAB**
Replication	2	0.0395	0.020	160.6	3.245
Treatment	19	6.1524	0.324	2636.8	1.867
Error	38	0.0047	0.000	**SEm±**	**0.01**
Total	59			**C.D at 0.05%**	**0.02**

Appendix:iii (shoot fly no.of tillers)					
Source of variat	**DF**	**SS**	**MSS**	**FCAL**	**F TAB**
Replication	2	0.0361	0.018	90.9	3.245
Treatment	19	8.0457	0.423	2133.2	1.867
Error	38	0.0075	0.000	**SEm±**	**0.01**
Total	59			**C.D at 0.05%**	**0.02**

Appendix: iv (shoot fly dead heart(%) at 14 DAE)

Source of variat	DF	SS	MSS	FCAL	F TAB
Replication	2	0.623	0.311	48.09	3.245
Treatment	19	50.920	2.680	413.80	1.867
Error	38	0.246	0.006	**SEm±**	**0.29**
Total	59			**C.D at 0.05%**	**0.83**

Appendix:v (shoot fly dead heart% at 21 DAE)

Source of variat	DF	SS	MSS	FCAL	F TAB
Replication	2	0.4166	0.2083	34.51	3.245
Treatment	19	70.993	3.7365	619.05	1.867
Error	38	0.2294	0.0060	**SEm±**	**0.30**
Total	59			**C.D at 0.05%**	**0.85**

Appendix: vi (stem borer leaf injury% at 30 DAE)

Source of variat	DF	SS	MSS	FCAL	F TAB
Replication	2	26.044	13.02	61.75	3.2448
Treatment	19	887.49	46.710	221.49	1.8673
Error	38	8.014	0.211	**SEm±**	**0.20**
Total	59			**C.D at 0.05%**	**0.57**

Appendix:vii (stem borer leaf injury % at 45 DAE)

Source of variat	DF	SS	MSS	FCAL	F TAB
Replication	2	18.28	9.141	68.00	3.2448
Treatment	19	532.64	28.033	208.56	1.8673
Error	38	5.11	0.134	**SEm±**	**0.21**
Total	59			**C.D at 0.05%**	**0.61**

Appendix: viii (Stem borer dead heart % at 30 DAE)

Source of variat	DF	SS	MSS	FCAL	F TAB
Replication	2	18.493	9.247	74.10	3.2448
Treatment	19	1006.3	52.964	424.44	1.8673
Error	38	4.742	0.125	**SEm±**	**0.20**
Total	59			**C.D at 0.05%**	**0.59**

Appendix:ix (stem borer dead heart % at 45 DAE)

Source of variat	DF	SS	MSS	FCAL	F TAB
Replication	2	19.64	9.819	31.47	3.2448
Treatment	19	1009.9	53.15	170.36	1.8673
Error	38	11.86	0.312	**SEm±**	**0.16**
Total	59			**C.D at 0.05%**	**0.45**

Appendix: x (stem borer stem tunneling % at the harvest)					
Source of variat	**DF**	**SS**	**MSS**	**FCAL**	**F TAB**
Replication	2	28.1	14.064	69.99	3.245
Treatment	19	1843.2	97.012	482.8	1.867
Error	38	7.635	0.201	**SEm±**	**0.24**
Total	59			**C.D at 0.05%**	**0.70**

Appendix: xi (stem borer peduncle tunneling % at the harvest)					
Source of variat	**DF**	**SS**	**MSS**	**FCAL**	**F TAB**
Replication	2	30.2	15.10	14.17	3.2448
Treatment	19	2711.4	142.7	133.9	1.867
Error	38	40.5	1.066	**SEm±**	**0.28**
Total	59			**C.D at 0.05%**	**0.81**

Appendix: xii (no.of holes per plant)					
Source of variat	**DF**	**SS**	**MSS**	**FCAL**	**F TAB**
Replication	2	2.5856	1.2928	56.676	3.2448
Treatment	19	1.1125	0.0586	2.5669	1.867
Error	38	0.8668	0.0228	**SEm±**	0.09
Total	59			**C.D at 0.05%**	0.25

Appendix: xiii (number of larve per plant)					
Source of variat	**DF**	**SS**	**MSS**	**FCAL**	**F TAB**
Replication	2	0.1762	0.0881	151.50	3.2448
Treatment	19	1.5032	0.0791	136.02	1.8673
Error	38	0.0221	0.0006	**SEm±**	0.01
Total	59			**C.D at 0.05%**	0.04

Appendix: xiv. (no.of pupae per plant)					
Source of variat	**DF**	**SS**	**MSS**	**FCAL**	**F TAB**
Replication	2	0.0009	0.0005	0.1389	3.245
Treatment	19	0.3072	0.0162	4.8403	1.867
Error	38	0.1269	0.0033	**SEm±**	0.03
Total	59			**C.D at 0.05%**	0.10

Appendix: xv (no. of ear head bugs)					
Source of variat	**DF**	**SS**	**MSS**	**FCAL**	**F TAB**
Replication	2	1.9718	0.986	111.399	3.2448
Treatment	19	1.8155	0.096	10.79681	1.8673
Error	38	0.3363	0.009	**SEm±**	**0.05**
Total	59			**C.D at 0.05%**	**0.16**

Appendix: xvi (no. of ear head worms)

Source of variat	DF	SS	MSS	FCAL	F TAB
Replication	2	1.457	0.728	131.8	3.245
Treatment	19	2.707	0.142	25.79	1.867
Error	38	0.210	0.006	**SEm±**	**0.04**
Total	59			**C.D at 0.05%**	**0.12**

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Dead heart caused by shoot fly (*Atherigona soccata*)

Tillers produced by shootfly (*Atherigona soccata*)

A. Series of holes by stem borer attack

B Stem borer making tunnel in the stem

C. Dead heart formed due to stem borer

D. Stem borer making tunnel in the

Plate-2: Damage caused by Stem Borer at different crop stages