STUDIES ON EARHEAD BUGS IN SORGHUM

BY

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99A30D

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Dedicated to My Mother,

supereme spirit

Smt. Sumitra Devi Prasad

CERTIFICATE - I

This is to certify that this dissertation entitled, **"Studies on earhead bugs in sorghum"** submitted for the degree of **Doctor of Philosophy** in the subject of **Entomology** of Chaudhary Charan Singh Haryana Agricultural University, Hisar, is a bonafide research work carried out by **Mr. Dalip Kumar, Admn. No. 99A30D** under my guidance and supervision and that no part of this dissertation has been submitted for any other degree.

The assistance and help received during the course of investigations have been fully acknowledged.

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CERTIFICATE - II

This is to certify that this dissertation entitled, **"Studies on earhead bugs in sorghum"**, submitted by **Mr. Dalip Kumar, Admn. No. 99A30D** to the Chaudhary Charan Singh Haryana Agricultural University, Hisar, in partial fulfilment of the requirements for the degree of **Doctor of Philosophy** in the subject of **Entomology** has been approved by the Student's Advisory Committee after an oral examination on the same in collaboration with an External Examiner.

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CONTENTS

CHAPTER-I

INTRODUCTION

The genus *Sorghum* belongs to the family Gramineae, it includes both cultivated and wild species for grain, fodder, feed, syrup, commercial and other purposes. All the cultivated form are grouped under a single species *Sorghum bicolor* (L.) Moench. Originated in Eastern Africa, sorghum is presently grown in all six continents extending about 40° on either side of the equator.

It is relatively undeveloped crop, with a great potential. The variability of grain type and plant type is remarkable. Grain yield can be increased well beyond present levels, (given proper conditions, a farmer can now easily harvest 4000 to 5000 kg/ha, Anonymous, 1980) while the adaptation of sorghum to a wide range of ecological conditions will be its greatest assest in the World. This ability to give a useful yield of grain under difficult agronomic conditions which makes sorghum such a valuable cereal. Sorghum ranks fourth in acreage

and production among the world's major cereal crops. Among the sorghum growing countries India has the largest share (32.3%) of world's area and ranks second in production after USA. In India, it is the third most important cereal crop after rice and wheat and is grown on about 13 million hectare with an average production of 11 million metric tonnes (Anonymous, 1999) and in Haryana, it occupies an area of 1.04 lacs hectare with production of about 22 thousand tonnes. It is grown both as human food as well as animal feed and fodder purposes (Anonymous, 2003).

Africa and Asia, which produce one third of the grain crop, insects, mites and other pests have taken their toll. Insect-pests continue to compete with human beings for the sorghum crop, and acknowledge of both old and new pests has accumulated at a faster rate in the recent years as the crop has received increasing attention (Young and Teetes, 1977). In these areas the use of insecticides has generally not been found economically feasible, because of insecticides being costly affair for farmers with limited resources. It is highly drought resistant crop grown both in *Kharif* (Monsoon) and *Rabi* (Winter) season. During *Kharif*, sowing is done with the onset of monsoon. Advancing date of planting returns good yield and (also escapes shoot fly attack) most sorghum pests can be avoided. Sorghum grains have multipurpose aspects as it is eaten as *Chapatti* (Bread), biscuit, sweet corn, pop sorghum,

sankatti or *mudda* or *kali*, used for brewing to make beer, stockfeed for pigs and poultry, used as fuel, extracting dye, making basket and fish trap and construction of hut roof (Doggett, 1970).

As the sorghum is an important cereal crop in the semi-arid tropics, grain yields on farmers field are generally low, partly due to insect-pest damage. In India, nearly 32.1 per cent of the actual produce is lost due to insect-pests (Borad and Mittal, 1983). Losses to earhead caused by midge and earhead bugs alone varies from 15 to 30 per cent (Ballard, 1916) to 75 per cent (Puttarudriah, 1947) in local sorghum while in commercial cultivars damage ranges from 5.8 to 84.3 per cent (Rao and Azam, 1987) to 43 to 93 per cent for earhead bug (Sharma and Lopez, 1989). Recently, Sharma *et al.* (1997b) reported avoidable losses in sorghum due to insects have been estimated to be over 32 per cent in India, 9 per cent in USA and 20 per cent in Africa. In monetary term, the losses due to insect pests have been estimated to be over US dollar 1000 million annually. There are over 150 insect species known to damage sorghum plant from germination to crop harvest (Seshu Reddy and Davies, 1979; Jotwani *et al.*, 1980). In Haryana, the important insect pests, which damage this crop are : shoot fly, sorghum stem borer, sorghum midge, earhead borers and head bugs. Damage due to earhead insect-pests is one of the important

limiting factors in the successful seed production of sorghum in northern India.

Among the important insect-pests reported damaging sorghum earhead are : sorghum midge, earhead bugs and earhead caterpillars. Various earhead bugs reported damaging this crop from India and abroad are, *Calocoris angustatus, Dolycoris indicus, Creontiades pallidus, Eurystylus immaculatus, Campylomma* spp. and *Taylorilygus vosseri* (Teetes *et al.*, 1983). Of which *C. angustatus* is most important species in India and *E. immaculatus* in West-Africa. Both nymph and adult bugs suck the juices from the immature developing grains, resulting in shrivelling of grain thereby affecting both yield and quality. Often the damaged seeds are infected with fungus that causes the seed to turn black and results in further deterioration in the quality of the seed. Damaged seeds rarely develop fully and are considerably smaller, softer and lighter in weight than the undamaged seed and subject to loss during harvesting (Wood and Stark, 1972).

Though, the earhead bugs can be controlled with little success through the use of different insecticides, the other component of management have not been tested against these pests. The development of resistant varieties is one of the effective and economic method of controlling pests and also considered as an important component of Integrated Pest Management (Panda and Khush, 1995).

A number of grain sorghum genotypes have been identified as resistant to earhead bugs by various workers (Hiremath, 1987; Natarajan *et al.*, 1988a; Sharma and Lopez, 1991; Sharma *et al.*, 2003) and also Hiremath (1986) reported that grain sorghum proved to be most preferred host of *C. angustatus.* However, very little work on these aspects have even been taken up in forage and dual purpose sorghum in Haryana so far. Keeping in view of the above facts, the present studies were taken up on earhead bugs infesting dual purpose sorghum with the following objectives :

1. Screening of dual purpose sorghum genotypes against earhead bugs.
2. To study the nature and extent of damage caused by earhead bugs in dual purpose sorghum under protected and unprotected conditions.
3. Population dynamics of earhead bugs and natural enemies associated with them in some selected/ promising genotypes of sorghum.
4. Role of morphological and physio-chemical characteristics in imparting resistance/ susceptibility in some selected/ promising sorghum genotypes.

CHAPTER-II

REVIEW OF LITERATURE

Compared to temperate zones, insect problems in the tropics are generally more severe and this is particularly so in the case of sorghum, which is the world's fourth most important cereal. Recommendations for Integrated Pest Management (IPM) in sorghum in different parts of the world involve cultural practices, natural enemies, host-plant resistance (HPR) and management through insecticides. In rainfed agriculture, the sowing date can not be manipulated to avoid pest damage. Insecticides are costly and are beyond the reach of resourceless poor farmers. The statement of Wilson and Huffakar (1976) reflects much of a paradigm upon which IPM is built "biological control, together with plant resistance are the core around which pest control in crops and forests should be built". In this context, HPR assume a central role in our efforts to increase production and productivity of sorghum.

HPR does not involve any direct costs to the farmers, it is environment friendly, and is compatible with other components of pest management. Insect resistant cultivars should yield more than the susceptible cultivars in the presence of pests (Doggett *et al.*, 1970). Role of HPR in pest management in sorghum has been discussed earlier by Jotwani (1978), Teetes (1985) and Sharma (1985b, 1993).

Screening of sorghum genotypes

Developing a resistant genotype in any crop plant, breeding for insect resistance is of immense value for selection of resistant source. Screening is pre-requisite condition for any such programme. Host plant resistance in itself is an excellent pest suppressing method and when integrated with other method of insect control, it offers a sound approach to deal with insect-pests. Insect resistant varieties provide pest control at essentially no cost to farmers. This approach holds great potential for sorghum.

A major efforts in identification of resistance to headbugs has been made in India (Sharma and Lopez, 1990b, 1991, 1992 a,b). Sorghum genotypes, IS-17610, IS17645, IS-21443 and IS 17618 were identified to have moderate levels of resistance to *Calocoris angustatus.*

In a study conducted on host plant resistance it had been observed that the pest susceptible cultivar (CSH 11) had higher grain damage rating than resistant

ones (IS 17610, IS 21443) due to *C. angustatus* attack on sorghum (Sharma *et al.*, 1995a).

According to Kumari *et al.* (2000) under multi-choice field conditions, IS 14334, IS 19955, IS 20740, IS 21444, IS 23748 and IS 17610 were not preferred by adult at the half anthesis stage and IS 14334, IS 19955, IS 21444 and IS 17610 had lower *C. angustatus* number at the milk stage.

Kishore (1996) reported development of new sources of resistance such as lines PGS 3, PGS 6, PGS 12 and varieties, P 311 and SPV 1015 (PGS I) for *Atherigona soccata, Chilo partellus, Contarinia sorghicola* and *Calocoris angustatus*. In search of sources of resistance, Sharma *et al.* (1994a)find out resistant genotypes CSM 388, IS 14332, Malisor 84-7, Sakoika, S29 and Kamboinse local as resistant and had a lower percentage of damaged grain against attack of *Eurystylus immaculatus*.

Head bug, *C. anguslatus* population increase was lower for first, second and/or third generation when bugs were reared on IS 2761, IS 19955, IS 14334, IS 23748, IS 16357, IS 17610 and IS 21444 as compared with susceptible control CSH 1, CSH 5 and CSH 9 (Sharma *et al.*, 1993a).

According to Sharma and Lopez (1993a) IS 2761, IS 17645 and IS 9692 showed low nymphal survival. IS 17610, IS 17645 and IS 9692 suffered low grain damage whereas CSH 5, IS 9692, IS 17610, IS 17618, IS 17645

and CSH 1 showed tolerance to feeding in decreasing order of consistency. Only IS 17610, IS 17618 and IS 17645 were able to maintain level of resistance under the head cage condition against *C. angustatus* (Sharma and Lopez, 1992a).

Natarajan *et al.* (1988a) graded sorghum entries for their resistance to *C. angustatus* using cultivar, CSH 5 as control, the lines IS 2205, IS 2394, IS 4663 and IS 5604 were the most resistant with 0-0.1 insect/panicle.

Out of 30 genotypes, SPV 472, Swarna, SPH 196, CSH 1, CSH 6, CSH 9 were moderately resistant against *C. angustatus* attack on sorghum panicle (Mote and Kadam, 1984).

Sundararaju and Rangarajan (1977) spotted the sources of resistance, SPV 102 had lowest population of *C. angustatus* and CSV 6 had the least shrivelled grain in sorghum.

Kishore (2000) identified cultivars with multiple pest resistance source in sorghum as CSH 9, CSV 14R, SPV 1015, ICSV 197, ICSV 88032, P 311, SPV 1413 and SPV 1450. Further, they advocated a strategy for the future that there should be the identification of multiple resistance source and transferring the resistance genes into high yielding varieties and hybrids. Development of new germplasm like PFGS-97, PFGS-98 and PFGS-100 with multiple resistance is a new step in this direction (Kishore, 2001).

Out of 10,000 sorghum germplasm lines evaluated against *C. angustatus,* IS 2761, IS 17645, IS 9692, IS 6989, IS 23061 were observed to be less susceptible (Ramesh, 1992). So far about 36000 sorghum germplasm entries have been screened against headbug complex in the world (Sharma *et al.*, 2003).

Losses – Quantitative and Qualitative

In India, nearly 32.1 per cent of the actual produce is lost due to insect pests (Borad and Mittal, 1983). Puttarudriah (1947) was first to report that the midge and earhead bugs were jointly responsible for 75 per cent losses in seed yield. Damage varying from 48 to 99 per cent due to earhead insect-pests had been reported by different workers in this crop (Taley *et al.*, 1971; Gowda, 1975; Rao, 1975). Avoidable losses ranging from 6.6-84.0 per cent in different parts of India have been computed (Leuschner and Sharma, 1983) and a loss of 14 per cent in sorghum by pentatomid, *Oebalus mexicana* had been recorded (Galvan *et al.*, 1995). It had been observed that with an increase in panicle size, grain damage decreased in cultivars, CSH 1 and CSH 5 against attack of *C. angustatus* in sorghum (Sharma and Lopez, 1994). Avoidable losses were greater in IS 9692 (66%), followed by commercial cultivar, CSH 11 (38.4 and 55.7 during 1988 and 1989, respectively), IS 21443 (29.1%) and IS 17610 (8.2%) (Sharma and Lopez, 1993b).

Mote and Jadhav (1990) studied incidence and losses caused by sorghum head bug and estimated that

when damage increased by 1 grade, there was a corresponding decrease of 12.55g in grain weight per earhead, 4.43g in 1000 grain weight and 15.49 per cent in seed germination. A decrease of 1.0g in 1000 grain weight resulted in 4.66 per cent decrease in seed germination.

In Niger, a indigenous sorghum variety, Mota Galmi, suffered 14 per cent yield loss and 19 per cent grain vitrosity reduction in which *Eurystylus marginatus* density averaged 80 individual/panicle. Damage resulted both from oviposition and feeding and they also reported that an increase in pest numbers resulted in an increased damage within a variety (Steck *et al.*, 1989). Grain weight losses of 31.54 g/panicle were recorded when three females of *C. angustatus* per panicle were allowed to oviposit for 3 days after panicle emergence (Natarajan *et al.*, 1988b).

The maximum reductions in yield occurred when panicles were infested from milk stage to maturity (28 days) in case of panicle feeding bugs in sorghum i.e. *Oebalus pugnax, Nezara viridula, Chlorochoa ligata* or *Leptoglossus phyllopus* (Hall and Teetes, 1982b). They further observed that damage to earhead by bugs was responsible for the reduction in yield and germination of sorghum seeds depend on the bug species and the infestation period during development and number of bugs per panicle. They observed that the maximum

reductions in yield occurred when panicles were infested from milky stage to maturity (Hall and Teetes, 1982a).

An avoidable loss to the tune of 53.6 per cent in grain yield due to timely adaptation of control measures in case of insect-pest attacking sorghum earheads was observed by Bhanot *et al.* (1982).

In case of rice stink bug (*Oebalus pugnax* F.), being primarily seed feeders, seed damaged by rice stink bugs in grain sorghum were smaller and lighter in weight than undamaged seed causing reduction in yield and per cent germination. Percentage of seeds per panicle with feeding punctures and the number of punctures per seed generally increased as infestation levels of rice stink bug increased (Hall and Teetes, 1982c).

Chemical control

To check the incidence of Mexican stink bug damaging sorghum, 4-12 application of pesticides were required and it was effectively managed with methyl parathion (Galvan *et al.*, 1995).

Sharma and Lopez (1993b) had reported that two to four sprays of demeton-S-methyl (Metasystox) were required to control *C. angustatus* infesting IS 9692 (Moderately susceptible), CSH 11 (Commercial) whereas only one spray was sufficient on IS 17610 and IS 21443 (Resistant) and they concluded that it was not economical to spray insecticides on the resistant cultivar, IS 17610.

Sharma and Lopez (1989) assessed avoidable losses and had shown that grain yield in plots protected with 2-5 insecticidal sprays (Carbaryl at 500g a.i./ha) between the half anthesis and dough stages was significantly higher than in untreated plots and damage due to *C. angustatus* resulted in poor grain quality in terms of germination, 1000-grain mass, grain hardiness and percentage floaters and avoidable losses were maximum in cv. ICSV 1 (88.6%), followed by CSH 1 (69.9%) and CSH 5 (53.9% and 55.0% during 1986 and 1987, respectively) in sorghum.

To control sorghum earhead bugs economically, Rao and Azam (1987) conducted field trials in Andhra Pradesh to assess the performance of cheaper control methods and found that maximum reduction in the pest population was recorded in plots treated with malathion (90.5%), followed by phosalone (82.8%) and carbaryl (75.9%). Tapping of earheads in the water-kerosene mixture (10:1) resulted in a reduction of 58 per cent. Owing to health hazardiness of other chemical i.e. BHC (HCH), malathion is recommended for control of mirid.

To control, insect pest attacking sorghum earheads, Bhanot *et al.* (1982) in field tests had shown that application of 0.07 per cent endosulfan at 90 per cent emergence of earheads and second application after 15 days resulted in 115.4 per cent yield increase as compared to no treatment.

Pesticides derived from plant origin have the potential to play a major role in pest management in sustainable agriculture production. They are renewable, non-persistent in the environment and relatively safer to natural enemies, non-target organisms and human beings. Ramamurthy and Rajaram (2001) determined the effect of plant extracts on the sorghum earhead bug (*C. angustatus*) and indicated that 2 and 3 per cent Neem seed kernel extract and 1 and 2 per cent neem oil were as effective as 0.1 per cent malathion. They also observed that when neem oil used at 3 and 2 per cent and 3 and 2 per cent neem seed kernel extract recorded highest grain yield per hectare.

Sharma *et al.* (1999) also utilized extracts from neem (*Azadirachta indica*) and custard apple (*Annona squamosa*) and found effective against *C. angustatus*.

Population density

Studies on population build-up sorghum earhead bugs had been conducted by several workers and is summarized as follows: Malgwi *et al.* (2000) evaluated population of head bugs and damage on sorghum, revealed that *Campylomma* sp. and *Psallus* sp. had their highest population densities during complete anthesis stage (CAS) while *Eurystylus oldi* and *Adelphocoris apicalis* had their highest population densities at medium dough stage (MDS).

Similarly, Raja Sekhar (1997) recorded the incidence of sorghum earhead bug, *Calocoris angustatus*

on sorghum in relation to sowing date revealed that bug population at milky stage and morning and evening relative humidities and number of rainy days indicated positive and significant relationship in two cultivars CSH 1 and ICSV-1.

Sharma and Lopez (1990a) studied biology and population dynamics of sorghum head bugs and concluded that during rainy season, rainfall, temperature and relative humidity were generally positively associated with populations of *C. angustatus, Creontiades pallidus* and *E. bellevoyei* and during the post rainy season, higher temperature (>32°C) and moisture deficit had a negative association with number of these bugs. However, these factors were positively associated with number of *Campylomma* (Sharma and Lopez, 1994).

Prabhakar *et al.* (1986) studied seasonal prevalence of delphacid, *Peregrinus maidis,* the pentatomids, *Nezara virudula, Dolycoris indicus, Lygaeus pandurus* and mirid *Calocoris angustatus* on sorghum, the populations of all these pests except *D. indicus* were found to be highly correlated with average minimum temperature and population of *C. angustatus* was significantly correlated with the average relative humidity. Correlation studies between the bug population at the milky stage and maximum temperature indicated a significant negative relationship and a significant positive relationship with relative humidity (Hiremath and Thontadarya, 1984 a,b).

In studies on the influence of weather factors on sorghum earhead bug, a positive correlation between population of *C. angustatus* and morning and evening relative humidity existed whereas maximum and minimum temperature and wind velocity had negative correlation with all stages of the earhead (Ramamurthy and Gopalan, 1993).

Balasubramanian and Balasubramanian (1979) observed that the population of sorghum earhead bug was also greatly influenced by weather factors, particularly the number of rainy days during season exhibiting negative correlation.

Natural enemies

Several natural enemies associated with earhead bugs had been reported by Hiremath (1989) and these were: formicids (*Camponotus compressus, C. paria*), reduviid (*Rhinocoris fuscipes*), the lygaeid (*Geocoris tricolor*), the mantid (*Hierodula* sp.), erythraeids, 16 species of spiders and the entomogenous fungus, *Cephalosporium* sp. Several parasites / parasitoids were recorded parasitizing sorghum earhead bug belonging to families, Eulophidae, Encyrtidae, Pteromalidae and Cynipidae. Out of these *Lysiphlebus testaceipes* was the most abundant parasite of green bug. They also recorded movement of *Aphelinus asychis* a parasite of green bug, *Schizaphis graminum* in sorghum and *Aphis helanthi*, an alternate host for parasite for off-time survival (Jackson *et al.*, 1970, 1971).

Kishore (2000) stated that use of bio-pesticides and natural enemies such as *Trichogramma* spp., *Aprostocetus* spp., *Cotesia flavipes,* Nuclear Polyhedrosis Viruses (NPV) and *Bacillus thuringiensis* (*B.t.*) and application of bioinoculants like *Azospirillum* and *Azotobactor* as seed treatment are newly emerging trends which are being utilized in integrated control for suppressing insect-pests of sorghum.

Gravena (1979) recorded natural enemies of greenbug, of which predators were *Scymnus* spp., *Cycloneda sanguinea* (L.) and *Chrysopa cincta* (S) and primary parasites *Aphidius colemani* (V.) and *Diaeretiella rapae* (M.).

Rice and Wilde (1989) recorded convergent lady beetle, *Hippodamia convergens* as predator of the green bug, *Schizaphis graminum* on sorghum. Fernandes *et al.* (1997) observed dispersal of a braconid, *Lysiphlebus testaceipes,* an important biological control agent of *Schizaphis graminum* on sorghum panicles.

Grain mould

Sharma *et al.* (1995) reported that bug damaged grain become completely tanned and also these grains are infected by the grain molds. This lead to both quantitative and qualitative losses.

Sharma *et al.* (2000) also revealed during the study of inheritance of resistance to head bugs and its interaction with grain molds in *Sorghum bicolor* that head bug damage increases the severity of grain molds,

which renders the grain unfit for human consumption and correlated grain mold severity with head bug damage in grain. The grains were more susceptible to damage by bugs during early seed development. Bugs sucked the milky juices from the immature developing grains and were not only responsible for causing the damage to these grains, but such damaged grains were also invaded by the fungus, *Alternaria* sp. (Wood and Starks, 1972).

The interaction between head bugs (*Eurystylus* sp.) and grain mould (GM) on sorghum cultivars revealed that insect damage increased the number of fungus colonies associated with the grain which ultimately results in lower germination, 1000-grain mass and yield (Marley and Malgwi, 1999).

Head bug damage also increases the severity of grain molds caused by species belonging to the genera *Fusarium, Curvularia, Phoma* and *Alternaria* (Sharma *et al.*, 1992a, 1994b).

MORPHOLOGICAL CHARACTERS

Grain colour

Sharma and Lopez (1990b, 1991, 1992 a,b) identified resistant genotype of sorghum i.e. IS 17610, IS 17645, IS 21443 and IS 17618 and found that most of sources of resistance have coloured grain against *C. angustatus*. Number of *C. angustatus* increased with an increase in panicle size in the susceptible cultivars CSH 1 and CSH 5 (Sharma & Lopez, 1994).

Panicle compactness

Type of panicle compactness had a positive relationship with population of head bugs. The increase in the population of *Calocoris angustatus* was lower in genotypes with loose panicles and panicle compactness was positively associated with numbers of *Eurystylus immaculatus* and grain damage (Sharma *et al.* (1994b).

Sharma (1985a) observed that the degree of susceptibility was influenced by the growth stage of the panicle and bug population and grain damage were influenced by panicle size. He further stated that loose panicle types tended to support lower populations than other types.

Stage and part of sorghum

To ascertain stage and part of sorghum earhead preferred for oviposition by sorghum earhead bug, Hiremath and Thontadarya (1984a,b) in field cage study indicated that the pre-flowering stage of sorghum earheads was preferred for oviposition by females of *C. angustatus*. In initial stages of the earhead, the top portion was preferred, and as growth progressed the pre-flowering portion towards the bottom of the earhead was preferred. They further stated that milky stage of the earhead was preferred to pre-flowering, a 3rd flowering, flowering and ripening stages. The adults dominated during pre-flowering and a 3rd flowering stages, whereas nymphs dominated during milky and ripening stages. Hall and Teetes (1982a,b) also were of same opinion in case

of damage done by rice stink bug in sorghum panicle that damage to seed during early grain development is more by pest. According to Sharma and Lopez (1989), head bug density at half anthesis, complete-anthesis, milk and dough stage was significantly and negatively associated with grain yield.

Biochemical constituents

Sharma and Lopez (1990b, 1991, 1992a,b) found that most of resistant sources of sorghum genotypes have high tannin content in case of *C. angustatus.* Moderately susceptible cultivar IS 9692 has high tannin content (Sharma *et al.*, 1995). Santos and Carmo (1974) also reported that tannin contents in sorghum genotypes imparted resistance against sorghum midge.

Sharma *et al.* (1993b) detected that amount of tannins and proteins were generally more in midge resistant lines compared with susceptible ones while soluble sugars were low in the midge resistant lines as antibiosis component of resistance.

In resistant rice varieties to rice green leaf hopper, total phenol contents were higher than susceptible one (Viswanathan and Kalode, 1990).

A significant negative correlation has also been reported by Butter *et al.* (1992) between population density of whitefly and phenol contents of cotton and aphid population and phenol contents of *B. juncea* (Sachan and Sachan, 1991).

CHAPTER-III

MATERIALS AND METHODS

The present investigations on "Studies on earhead bugs in sorghum" were carried out at the Research area, Forage Section, Department of Plant Breeding and the laboratory work was done in the Departments of Entomology, Plant Breeding, Zoology and Aquaculture, Chaudhary Charan Singh Haryana Agricultural University, Hisar during 2000-01 to 2002-03. The materials and methods used are described as under:

Screening of sorghum genotypes against head bugs

Forage sorghum genotypes collected from various sources were evaluated under field conditions for generating information and knowledge regarding resistance/tolerant source against head bugs under Hisar conditions.

Sources of genotypes

One hundred and fifty forage and dual purpose sorghum genotypes were collected from Forage Section, Department of Plant Breeding, CCSHAU, Hisar, All India Coordinated Sorghum Improvement Project (AICSIP),

Hyderabad and International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Hyderabad.

Preliminary screening

The trials were laid on 13th July, 2001 *Kharif* season in forage research area with row to row and plant to plant spacings of 50 and 10-12 cm, respectively in Randomized Block Design with three replications and a plot size of 3 metre row length. Recommended agronomic practices (Anonymous, 2000) were followed to raise the healthy crop except plant protection. All these selected sorghum genotypes including IS 18551, DJ 6514 and IS 2205 as resistant checks, while ICSV 1, CSH 5 and CSH 9 as susceptible checks were grown for screening against head bugs. The methods for recording the incidence of the head bugs were as follows:

Observations

i) Fifteen plants i.e. 5 plants per replication from each genotype were selected. At initiation of 50 per cent flowering, number of head bugs present on each panicle were counted from 15 panicles at weekly intervals till the harvest of the crop.

ii) Observations were also recorded on grain damage rating (GDR) (scale 1-9 ratings) at maturity as per the method adopted by Sharma *et al.* (1992b). The method is briefly described below:

Scale	Damage
1=	All grains fully developed with few feeding punctures.
2=	Grains fully developed, with feeding punctures.
3=	Grains showing slight tanning/browning.
4=	Most grains with feeding punctures, and a few showing slight shrivelling.
5=	Grains showing slight shrivelling and browning.
6=	Grains showing more than 50 per cent shrivelling and turning brown or tanned.
7=	Most of the grains highly shrivelled with a dark brown colouration.
8=	Grain highly shrivelled and slightly visible outside the glumes.
9=	Most of the grains highly shrivelled and slightly visible outside the glumes.

Re-evaluation of promising genotypes against head bugs under field conditions

Based on the first year observations, genotypes with less than 18.8 mean number of head bugs per 5 panicles or with less than the 5 grain damage rating (GDR) were selected for re-evaluation during 2002 *Kharif* season alongwith standard checks mentioned earlier. The sorghum genotypes were sown on 20th July, 2002 in randomized block design with three replications and plot size of three metre row length (MRL). The observations on number of head bugs were recorded in similar fashion as during the first year of studies, *viz.*, five randomly selected plants/replication were selected from each genotype to

record the number of head bugs per earhead at initiation of 50 per cent flowering.

Studies on the nature and extent of damage caused by earhead bugs under protected and unprotected conditions

Preparation of sets

To study the nature and extent of damage caused by head bugs under protected and unprotected conditions, four forage sorghum varieties *viz.*, HC 260, HC 171, HC 308 and HC 136 were selected based on maturity, panicle type and susceptibility. The crop was sown on 13th July, 2001 and 6th August, 2002 with four replications using randomized block design in a plot size of 100 metre square (10 x 10 m).

The crop of each variety was divided into two set of conditions i.e. protected and unprotected. Pre-spraying population of head bugs was observed under both the conditions. The crop was protected by spraying 0.07 per cent endosulfan 35 EC.

Time at which protection employed

Crop was protected by spraying endosulfan 35 EC @ 0.07 per cent on 1st October, 2001 and on 28th October, 2002 as soon as the head bugs population reached at economic threshold level of 2 adult bugs or 20 nymphs/panicle. Pre-spraying population of head bugs was recorded on 30th September, 2001 and on 27th October, 2002. Second spray was applied 15 days after the first spray.

Recording of earhead bugs population

In each set of condition i.e. protected and unprotected, the post spraying population of head bugs was recorded three days after spraying the crop. Number of head bugs i.e. nymphs and adults per 20 earheads per replication were recorded in each variety.

Observation on avoidable losses

At the time of harvesting, the earheads were thrashed separately from both type of plots i.e. protected as well as unprotected plots. Avoidable losses in grain yield were then worked out in per cent by comparing grain yield contributing parameters in each variety.

$$\text{Per cent avoidable yield loss} = \frac{X-Y}{X} \times 100$$

Where :

X= Yield in protected plot.

Y= Yield in unprotected plot.

Extent of damage

To record the extent of damage caused by head bugs, the sorghum earheads were exposed for different periods. In each replication, 15 earheads were randomly selected for observation and these earheads were exposed to earhead bugs for different exposure periods of 7, 14, 21 and 28 days, respectively. During 2001 season, the exposure period for three forage varieties, HC 308, HC 136 and HC 171 for 7, 14, 21 and 28 days after 50 per cent of flowering was from 19-25th September, 26th September to 2nd October, 3rd October to 9th October and from 10th to

16th October, 2001 and for variety, HC 260 these exposure periods were from 11 to 17 September; 18 to 24th September; 25th September to 1st October and 2nd to 8th October, 2001. During 2002 cropping season, earheads were exposed for period of 7, 14, 21 and 28 days from 13 to 19th October, 20th to 26th October; 27th October to 2nd November and from 3rd to 09 November, 2002 for varieties, HC 308, HC 171 and HC 136 and for variety, HC 260, the exposure periods were from 5th to 11th October; 12th to 18th October; 19th to 25th October and 26th October to 1st November, 2002, respectively, initiating from 50 per cent flowering. After each exposure period, these exposed panicle were further protected from being damaged by earhead bugs by covering it with muslin cloth bags and it is being ensured before covering that there were no insect-pest present in/on earhead. At the time of harvest, sorghum earheads were thrashed separately for each exposure period to record the per cent grain damage. At each successive exposure periods in each variety the extent of damage done by head bugs was worked out in per cent.

Nature of damage

To record the nature of damage, the forage sorghum varieties selected for these studies were: HC 260, HC 171, HC 136 and HC 308 and were sown on 13th July, 2001 and 6th August, 2002 and were monitored regularly to observe the first presence/ appearance of earhead bug on sorghum panicle to record the actual time of feeding, actual stage of panicle emergence and when head bugs

start feeding on panicle after their appearance was studied under Hisar conditions.

To study the population dynamics of earhead bugs and natural enemies associated with them in some selected/ promising genotypes of sorghum

Studies on population dynamics of earhead bugs

Based on preliminary screening, ten sorghum genotypes were selected on the basis of head bugs infestation and grain damage rating (GDR) by visual observation method given by Sharma *et al.* (1992b). Ten sorghum genotypes selected for these studies were ICSV 714, AKENT 7-1, ICSV 711, SPH 1352 and DJ 6514 from resistant group while IS 2312, IS 112, SR 1048-1, SRF 2102 and SFCR 1111 were from susceptible group. These genotypes were sown on 20th July, 2002 with three replications in a plot size of 3 metre row length. The observations on population dynamics of head bugs on these varieties were recorded at weekly intervals and then observations on morphological and biochemical aspects were also recorded and correlation among these were also worked out.

The total number of earhead bugs per plant were recorded at interval of one week on 5 randomly selected plants in each replication of each variety. The first observation was recorded on 20th September at initiation of 50 per cent flowering and successive observations were recorded at one week interval on 27 September, 4 October, 11 October and 18 October in cropping season of 2002.

Data on abiotic factors were also collected and correlationship with head bug incidence was worked out. The data on abiotic factors was from the preceding week of the observation on number of earhead bugs on panicle.

Studies on natural enemies of earhead bugs

To ascertain the presence of natural parasitoids, if any, in each variety the newly hatched and matured nymphs from 5 randomly selected earheads were collected thrice at an interval of 10 days with the initiation of 50 per cent flowering. The earheads were well cleaned and wrapped in moist cotton swab at the base and were kept in battery jars (size 12 x 25 cm) alongwith field collected earhead bugs. These battery jars were kept covered with muslin cloth and were observed critically for any mortality of earhead bugs, emergence of parasitoids of earhead bugs at an interval of 2-3 days. Per cent parasitization was calculated as under :

$$\text{Parasitization}(\%) = \frac{\text{Number of parasitoids emerged}}{\text{Number of earhead bugs}} \times 100$$

To study the role of morphological and physio-chemical characters in selected/promising genotypes

One hundred and fifty sorghum genotypes screened preliminary were clustered into five groups on the basis of infestation by sorghum earhead bugs.

Morphological characters

On morphological characters observations were recorded at maturity and for recording the morphological parameters, in each genotype 5 plants were selected randomly per repeat. Following morphological characteristics were recorded.

Type of earhead

The type of earhead i.e. compact, semi-compact or loose in each variety was recorded at maturity simply by visual observation.

Colour of glume

The colour of glumes of panicle of sorghum genotypes was observed visually.

Colour of grain

The colour of grains was recorded after securing the matured panicle of each sorghum genotypes, harvested and thrashed separately.

Size of earhead

The size i.e. length and breadth of earhead of each individual sorghum genotype was measured with the help of measuring tape.

Test weight

To get the test weight of each sorghum genotype, the 1000-grains were counted manually and then their weight was recorded on electronic balance (AFCOSET FX-300: The Bombay Burmah Trading Corporation Ltd.).

Biochemical constituents

To analyse the chemical constituents of 10 selected sorghum genotypes, the panicles of each entry from

susceptible and resistant group were collected at milky stage and at maturity. The panicles were then dried in shade for approximately 2 weeks and then panicle were thrashed for grains. The grains of each genotype were stored in paper envelopes and oven dried at 60°C for 2-3 days.

The grains taken from each genotype were then grinded in a electro-grinder and stored in paper envelopes and were again kept in an oven at 50°C for one day to ensure complete drying for estimation of biochemical constituents *viz.*, protein contents (A.O.A.C., 1995); Total soluble sugars (Dubois *et al.*, 1956); Reducing sugars (Walter, 1924); Non-reducing sugars (The difference between total sugars and reducing sugars); Tannin content (Burns, 1971); Total Phenols (Swain and Hills, 1959); Ortho dihydroxy phenols (Johnson and Schaal, 1952); Flavanols (Balba *et al.*, 1974).

The above mentioned biochemical constituents of grains of ten selected genotypes were subjected to work out correlation with population dynamics i.e. incidence of earhead bugs.

CHAPTER-IV

RESULTS AND DISCUSSION

The results of investigation of "Studies on earhead bugs in sorghum" have been put in array in this chapter and discussed in view of the work done by earlier workers.

Preliminary screening of dual purpose sorghum genotypes against earhead bugs during *kharif*, 2001

One hundred and fifty sorghum genotypes having different plant characters and maturity periods, mostly dual purpose, were evaluated against earhead bugs during *kharif* season of 2001 under field condition in order to know their reaction to this pest.

For this purpose, one hundred and fifty genotypes of sorghum were sown in the 2nd week of July to get maximum population of headbugs. Infestation/levels in case of headbugs were determined on the basis of number of head bugs per 5 panicles. The earhead bugs observed feeding on sorghum earhead were: *Calocoris* sp., *Dolycoris indicus*, *Piezodorus rubrofasciatus*, *Clavigrella*

Fig.1(A). *Calocoris angustatus,*

Fig.1(B). *Dolycoris indicus*

Fig.1(C). *Piezodorus rubrofasciatus* (Fab.)

Fig.1(D) *Clavigrella* sp.

Fig.1(A-D). Sorghum earhead bugs observed feeding on sorghum panicle.

sp. and *Creontiades pallidus* (Fig.1 A to D). The data presented in Table 1a reveal that infestation by earhead bug complex in different genotypes of sorghum varied from 0.0 to 30.9 mean number of earhead bugs/5 panicles (Average of 5 observations) during *kharif,* 2001.

The minimum infestation *viz.*, 0.0 earhead bugs/5 panicles were observed in genotypes, SPV 1573, SPV 1580, SDSL 92131, GD 65174-1, Khawang Pahawang, IS 25596 and IS 20016. In Category-I, no earhead bug was observed on these genotypes throughout the season and this may be due to the reason that these genotypes have loose panicle type of earheads, which do not allow the earhead bugs to get established on such panicles.

The data related to earhead bug infestation revealed a variation of 0.0 to 30.9 earhead bug/5 panicles in tested sorghum genotypes with the mean of 12.46 earhead bugs/5 panicle. In group-II, there were 37 sorghum genotypes in which infestation by head bugs ranged from 0.1 to 7.5 bugs/5 panicles, being maximum (7.5 bugs/5 panicles) in GSSV 312 and ICSV 93046 and minimum (1.0 head bug/5 panicles) being on RSU 158, followed by SU 699 (1.2) and 3.8 head bug/5 panicles in RSE 9715, RSU 283, AKENT 15, AKENT 8-3 and IS 22893 as compared to resistant check IS 188551 and DJ 6514 having 3.7 and 6.0 head bugs/5 panicles, respectively. These genotypes were also accessed on the basis of grain damage rating (GDR), GDR in these genotypes was 1 and

2 and genotypes GSSV 312 and ICSV 93046 had GDR of 2.

In group III, the grain damage rating score was 3 and 4 secured by fifty one sorghum genotypes and the earhead bug infestation varied from 7.6 to 15.0 earhead bugs/5 panicles and lowest (7.6) being in GD 65195 and IS 11119 followed by 168-UU-1022 and IS 2123 (7.7) and maximum (13.9) number of head bugs/5 panicles were observed in 168-IU-1021 as compared to 5.9 and 23.56 mean number of earhead bugs/5 panicles observed in resistant check (IS 18551, DJ 6514 and IS 2205) and susceptible check (ICSV 1, CS5 and CSH 9).

In group-IV, there were forty three sorghum genotypes in which infestation varied from 15.1 to 22.5 earhead bugs/5 panicles lowest (15.1 earhead bugs) being in RSV 204 and SR 1048-1 and maximum (22.4 earhead bugs/5 panicles) in IS 2312 as compared to 23.56 in susceptible check (ICSV 1, CSH 5 and CSH 9).

The mean number of head bugs/5 panicles in group-V and group VI ranged from 22.6 to 30.0 and >30.1, respectively. In group-V, the maximum and minimum being observed in genotypes SFCR 1070 and SR 2458, respectively and in group-VI, there was only one sorghum genotype in which the infestation was above 30.0 i.e. (30.9) earhead bugs/5 panicles.

It is clear from Table 1b that as infestation level increased, the grain damage rating also increased, the lowest GDR (1) was observed only in those sorghum

Table 1a. Categorization of sorghum genotypes on the basis of infestation of earhead bugs

Kharif, 2001

Group	Mean number of earhead bugs/5 panicles (Range)	Grain damage rating (GDR)	No. of sorghum genotypes	Sorghum genotypes
I	0.0	1	7	SPV 1573, SPV 1580, SDSL 92131, GD 65174-1, Khawang Pahawang, IS 25596, IS 20016
II	0.1-7.5	1, 2	30	RSU 158, SU 699, IS 18551, RSE 9715, RSU 283, AKENT 15, AKENT 8-3, IS 22893, 463-A, ICSV 700, ICSV 705, IS 2269, 168-II-112, GMSB 76, SPH 1183, SPV 1605, 168-UU-1006, SFCR 1047, AKENT 10-2, SPH 1375, ICSV 711, RSU 202, ICSV 714, AKENT 7-1-1, DJ 6514, SPH 1352, RSE 9741, SPV 1574, GSSV 312, ICSV 93046
III	7.6-15.0	3, 4	51	GD 65195, IS 11119, 168-UU-1022, IS 2123, 168-II-122, 168-II-108, GMSB-4, GMSB 131, GMSB 69, IS 6566, GMSB 5, ICSV 112, AKENT 16, IS 2205, SPV 1576, IS 4663, SPH 1280, GMSB 15, DSFR 3, SPV 1565, SPH 1349, SPH 1350, AKENT 14, ICSV 745, RSE 9745, SPV 1570, IS 2122, GD 65055, SPH 1334, SPV 1577, GD 65022, GD 65040, SU 700, IS 1044, CSV 457, DSFR 2, BT X 623, SPH 1376, SU 52, SR 2460, RSE 9727, SPV 1569, SPV 1567, SR 2704, AKMS 14-A, SU 45, SPH 1372, SRF 2102, CSV 16, SPH 1329, 168-IU-1021
IV	15.1-22.5	5, 6	43	RSV 204, SR 1048-1, GD 65004, CH 3, GD 65006,GD 65019, 200-UU-1011, SPV 1579, SRF 1665, S-35, Amarnath, SU 663, 296-B, SR 2460-I, CSH 16, SPH 1335, SPV 1562, SR 1436, CSV 15, SPV 1581, SPV 1575, SPV 1563, Swati, NT 52, ICSV 708, ICSR 93034, CSH 14, 200-1011, ICSV 717, SPH 1353, IS 112, SPH 1354, SRF 203, SPV 1568, 200-IU-1005, SR 833-2-3, CSH 17, SPH 1355, SPV 1571, SPH 1347, SPH 1341, SPV 1578, IS 2312.
V	22.6-30.0	7, 8	18	SFCR 1070, SFCR 1143, ICSV-1, RSE 9728, SFCR 1105, AKENT 10-1, SR 770-2, CSH 5, 27B, CSH 9, RSE 9744, DSFR-5, SRF 2549, 296-A, SR 2459, CSH 7, SPH 1374, SR 2458
VI	30.0 & above	8	1	SFCR 1111

Table 1b. Sorghum genotypes categorized on the basis of head bugs infestation and grain damage rating (GDR)

Kharif, 2001

Sr. No.	Sorghum genotypes	Mean no. of earhead bugs/5 panicles	GDR
1.	SPV 1573	0.0	1
2.	SPV 1580	0.0	1
3.	SDSL 92131	0.0	1
4.	GD 65174-1	0.0	1
5.	Khawang Pahawang	0.0	1
6.	IS 25596	0.0	1
7.	IS 20016	0.0	1
8.	RSU 158	1.0	1
9.	SU 699	1.2	1
10.	IS 18551	3.7	1
11.	RSE 9715	3.8	2
12.	RSU 283	3.8	2
13.	AKENT 15	3.8	2
14.	AKENT 8-3	3.8	2
15.	IS 22893	3.8	2
16.	463-A	3.9	2
17.	ICSV 700	3.9	2
18.	ICSV 705	4.0	2
19.	IS 2269	4.0	2
20.	168-II-112	4.0	2
21.	GMSB 76	4.1	2
22.	SPH 1183	4.1	2
23.	SPV 1605	4.3	2
24.	168-UU-1006	4.4	2
25.	SFCR 1047	4.4	2
26.	AKENT 10-2	4.4	2
27.	SPH 1375	4.6	2
28.	ICSV 711	5.2	2
29.	RSU 202	5.3	2
30.	ICSV 714	5.4	2
31.	AKENT 7-1-1	5.9	2

Contd.....

Sr. No.	Sorghum genotypes	Mean no. of earhead bugs/5 panicles	GDR
32.	DJ 6514	6.0	2
33.	SPH 1352	6.1	2
34.	RSE 9741	6.5	2
35.	SPV 1574	6.7	2
36.	GSSV 312	7.5	2
37.	ICSV 93046	7.5	2
38.	GD 65195	7.6	3
39.	IS 11119	7.6	3
40.	168-UU-1022	7.7	3
41.	IS 2123	7.7	3
42.	168-II-122	7.8	3
43.	168-II-108	7.9	3
44.	GMSB-4	7.9	3
45.	GMSB 131	8.0	3
46.	GMSB 69	8.1	3
47.	IS 6566	8.1	3
48.	GMSB 5	8.2	3
49.	ICSV 112	8.2	3
50.	AKENT 16	8.2	3
51.	IS 2205	8.2	3
52.	SPV 1576	8.4	3
53.	IS 4663	8.4	3
54.	SPH 1280	8.4	3
55.	GMSB 15	8.5	3
56.	DSFR 3	8.5	3
57.	SPV 1565	8.5	3
58.	SPH 1349	8.6	3
59.	SPH 1350	8.6	3
60.	AKENT 14	9.0	3
61.	ICSV 745	9.1	3
62.	RSE 9745	9.2	3
63.	SPV 1570	9.3	3
64.	IS 2122	9.9	3
65.	GD 65055	10.0	3
66.	SPH 1334	11.0	3

Contd.....

Sr. No.	Sorghum genotypes	Mean no. of earhead bugs/5 panicles	GDR
67.	SPV 1577	11.1	3
68.	GD 65022	11.3	4
69.	GD 65040	11.4	4
70.	SU 700	11.4	4
71.	IS 1044	11.5	4
72.	CSV 457	11.6	4
73.	DSFR 2	11.6	4
74.	BT X 623	11.8	4
75.	SPH 1376	11.8	4
76.	SU 52	12.0	4
77.	SR 2460	12.1	4
78.	RSE 9727	12.2	4
79.	SPV 1569	12.3	4
80.	SPV 1567	12.3	4
81.	SR 2704	12.4	4
82.	AKMS 14-A	12.5	4
83.	SU 45	12.5	4
84.	SPH 1372	12.7	4
85.	SRF 2102	12.8	4
86.	CSV 16	13.6	4
87.	SPH 1329	13.8	4
88.	168-IU-1021	13.9	4
89.	RSV 204	15.1	5
90.	SR 1048-1	15.1	5
91.	GD 65004	15.2	5
92.	CH 3	15.2	5
93.	GD 65006	15.3	5
94.	GD 65019	15.4	5
95.	200-UU-1011	15.4	5
96.	SPV 1579	15.4	5
97.	SRF 1665	15.5	5
98.	S-35	15.5	5
99.	Amarnath	15.6	5
100.	SU 663	15.6	5
101.	296-B	15.8	5
102.	SR 2460-I	15.8	5

Contd.....

Sr. No.	Sorghum genotypes	Mean no. of earhead bugs/5 panicles	GDR
103.	CSH 16	15.9	5
104.	SPH 1335	16.0	5
105.	SPV 1562	16.0	5
106.	SR 1436	16.1	5
107.	CSV 15	16.3	5
108.	SPV 1581	16.3	5
109.	SPV 1575	16.5	5
110.	SPV 1563	16.6	5
111.	Swati	17.0	5
112.	NT 52	17.1	5
113.	ICSV 708	17.2	5
114.	ICSR 93034	17.5	5
115.	CSH 14	17.6	5
116.	200-1011	17.6	5
117.	ICSV 717	17.7	5
118.	SPH 1353	18.0	5
119.	IS 112	18.6	5
120.	SPH 1354	19.0	6
121.	SRF 203	19.0	6
122.	SPV 1568	19.1	6
123.	200-IU-1005	19.1	6
124.	SR 833-2-3	19.2	6
125.	CSH 17	19.5	6
126.	SPH 1355	19.8	6
127.	SPV 1571	19.9	6
128.	SPH 1347	20.1	6
129.	SPH 1341	20.1	6
130.	SPV 1578	21.8	6
131.	IS 2312	22.4	6
132.	SFCR 1070	22.7	7
133.	SFCR 1143	22.8	7
134.	ICSV-1	23.0	7
135.	RSE 9728	23.1	7
136.	SFCR 1105	23.1	7
137.	AKENT 10-1	23.1	7

Contd.....

Sr. No.	Sorghum genotypes	Mean no. of earhead bugs/5 panicles	GDR
138.	SR 770-2	23.2	7
139.	CSH 5	23.7	7
140.	27B	23.9	7
141.	CSH 9	24.0	7
142.	RSE 9744	24.1	7
143.	DSFR-5	25.6	7
144.	SRF 2549	25.7	8
145.	296-A	26.5	8
146.	SR 2459	26.7	8
147.	CSH 7	26.9	8
148.	SPH 1374	27.1	8
149.	SR 2458	29.0	8
150.	SFCR 1111	30.9	8
Mean	--	**12.46**	--
Resistant check			
1.	IS 18551	3.7	1
2.	DJ 6514	6.0	2
3.	IS 2205	8.2	3
Mean	--	**5.96**	--
Susceptible check			
1.	ICSV 1	23.0	7
2.	CSH 5	23.7	7
3.	CSH 9	24.0	7
Mean	--	**23.56**	--

genotypes which had loose panicle type of earheads, while resistant check i.e. IS 18551, DJ 6514 and IS 2205 secured GDR 1,2 and 3, respectively. Of the total 150 test entries evaluated, there were thirty seven genotypes which had GDR score of 1 and 2. In category III, fifty one genotypes had a GDR of 3 and 4. There were forty three sorghum genotypes in category-IV which had GDR of 5 and 6 while in category-V, 18 genotypes secured a GDR of 7 and 8. There was only one sorghum genotype which had a GDR score of 8 and in comparison, the susceptible check (ICSV 1, CSH 5 and CSH 9) secured a GDR of 7, while none of test entries could score a GDR 9.

Due to the attack of earhead bug complex, the grain damage rating and mean number of earhead bugs/5 panicles were maximum (8 and 30.9 earhead bugs/5 panicles) in sorghum genotype SFCR 1111 (Table 1b).

Evaluation of promising sorghum genotypes against earhead bug complex during *kharif*, 2002

One hundred and nine (excluding resistant and susceptible) sorghum genotypes, which had GDR of 5, were selected for re-evaluation against head bug complex during cropping season of *Kharif*, 2002.

One hundred and fourteen (including resistant and susceptible checks) sorghum genotypes were sown in the 2nd week of July, 2002 for their reaction against earhead bug complex. The data presented in Table 2a reveals that in different genotypes, the mean infestation ranged from 0.0 to 22.5 earhead bugs/5 panicles. The minimum (1.2

Table 2a. Categorization of sorghum genotypes on the basis of infestation of earhead bugs

Kharif, 2002

Group	Mean number of earhead bugs/5 panicles (Range)	Grain damage rating (GDR)	No. of sorghum genotypes	Sorghum genotypes
I	0.0	1	2	RSU 158, SU 699
II	0.1-7.5	1, 2	55	IS 18551, 463-A, AKENT 15, IS 2269, RSE 9715, IS 22893, ICSV 700, AKENT 8-3, RSU 283, ICSV 705, AKENT 10-2, IS 2205, SFCR 1047, SPH 1375, 168-UU-1006, SDH 1183, SPV 1605, 168-II-112, GMSB 76, DJ 6514, ICSV 714, ICSV 711, AKENT 7-1-1, RSU 202, SPH 1352, IS 2123, GMSB-4, SPV 1576, SPV 1574, 168-UU-1022, ICSV 93046, DSFR 3, IS 11119, GSSV 312, RSE 9741, GD 65195, 168-II-108, 168-II-122, SPV 1565, GMSB 131, SPH 1280, ICSV 745, GMSB 15, AKENT 16, ,IS 4663, , ICSV 112, SPH 1349, SPH 1350, GMSB 69, GMSB 5, GD 65040, SPV 1577, SU 700, IS 2122, IS 1044
III	7.6-15.0	3, 4	52	SPH 1334, GD 65055, GD 65022, SPV 1570, CSV 457, AKMS 14-A, IS 6566, SPV 1567, SPH 1376, DSFR 2, SR 2460, SRF 2102, RSE 9727, 168-IU-1021, SU 45, BT X 623, CSV 16, SR 1048-1, SU 52, SPV 1579, SPV 1569, SPH 1372, SR 2704, RSV 204, S-35, SPH 1329, AKENT 14, SRF 1665, SU 663, 200-UU-1011, GD 65019, RSE 9745, GD 65006, SR 2460-I, GD 65004, 296-B, 200-1011, CSV 15, ICSV 708, CSH 16, SPV 1563, ICSR 93034, SPH 1335, SPV 1581, SR 1436, Swati, SPV 1575, SPV 1562, Amarnath, CSH 14, CH 3, IS 112
IV	15.1-22.5	5	5	ICSV 717, NT 52, SPH 1353, ICSV 1, CSH 5

Table 2b. Sorghum genotypes categorized on the basis of head bugs infestation and grain damage rating (GDR)

Kharif, 2002

Sr. No.	Sorghum genotypes	Mean no. of earhead bugs/5 panicles	GDR
1	RSU 158	0.0	1
2	SU 699	0.0	1
3	IS 18551	1.2	1
4	463-A	1.3	1
5	AKENT 15	1.4	1
6	IS 2269	1.4	1
7	RSE 9715	1.5	1
8	IS 22893	1.7	1
9	ICSV 700	1.7	1
10	AKENT 8-3	1.8	1
11	RSU 283	2.0	1
12	ICSV 705	2.1	1
13	AKENT 10-2	2.2	1
14	IS 2205	2.2	1
15	SFCR 1047	2.4	1
16	SPH 1375	2.4	1
17	168-UU-1006	2.5	1
18	SPH 1183	2.6	1
19	SPV 1605	2.6	1
20	168-II-112	2.7	1
21	GMSB 76	2.8	1
22	DJ 6514	2.8	1
23	ICSV 714	2.9	1
24	ICSV 711	3.0	1
25	AKENT 7-1-1	3.0	1
26	RSU 202	3.2	1
27	SPH 1352	3.3	1
28	IS 2123	4.1	2
29	GMSB-4	4.2	2
30	SPV 1576	4.2	2
31	SPV 1574	4.3	2
32	168-UU-1022	4.3	2

Contd.....

Sr. No.	Sorghum genotypes	Mean no. of earhead bugs/5 panicles	GDR
33	ICSV 93046	4.4	2
34	DSFR 3	4.6	2
35	IS 11119	4.7	2
36	GSSV 312	4.9	2
37	RSE 9741	5.0	2
38	GD 65195	5.0	2
39	168-II-108	5.2	2
40	168-II-122	5.4	2
41	SPV 1565	5.6	2
42	GMSB 131	5.8	2
43	SPH 1280	5.9	2
44	ICSV 745	6.1	2
45	GMSB 15	6.2	2
46	AKENT 16	6.4	2
47	IS 4663	6.4	2
48	ICSV 112	6.5	2
49	SPH 1349	6.5	2
50	SPH 1350	6.6	2
51	GMSB 69	6.8	2
52	GMSB 5	6.9	2
53	GD 65040	7.1	2
54	SPV 1577	7.3	2
55	SU 700	7.3	2
56	IS 2122	7.4	2
57	IS 1044	7.5	2
58	SPH 1334	7.6	3
59	GD 65055	7.7	3
60	GD 65022	7.8	3
61	SPV 1570	7.9	3
62	CSV 457	8.1	3
63	AKMS 14-A	8.3	3
64	IS 6566	8.9	3
65	SPV 1567	8.9	3
66	SPH 1376	9.2	3

Contd.....

Sr. No.	Sorghum genotypes	Mean no. of earhead bugs/5 panicles	GDR
67	DSFR 2	9.3	3
68	SR 2460	9.4	3
69	SRF 2102	9.6	3
70	RSE 9727	9.7	3
71	168-IU-1021	9.8	3
72	SU 45	10.1	3
73	BT X 623	10.3	3
74	CSV 16	10.3	3
75	SR 1048-1	10.7	3
76	SU 52	10.9	3
77	SPV 1579	11.0	3
78	SPV 1569	11.1	3
79	SPH 1372	11.2	3
80	SR 2704	11.3	4
81	RSV 204	11.4	4
82	S-35	11.6	4
83	SPH 1329	11.7	4
84	AKENT 14	11.9	4
85	SRF 1665	11.9	4
86	SU 663	11.9	4
87	200-UU-1011	12.0	4
88	GD 65019	12.1	4
89	RSE 9745	12.2	4
90	GD 65006	12.3	4
91	SR 2460-I	12.6	4
92	GD 65004	12.7	4
93	296-B	12.9	4
94	200-1011	13.1	4
95	CSV 15	13.2	4
96	ICSV 708	13.5	4
97	CSH 16	13.6	4
98	SPV 1563	13.6	4
99	ICSR 93034	13.7	4
100	SPH 1335	13.8	4

Contd.....

Sr. No.	Sorghum genotypes	Mean no. of earhead bugs/5 panicles	GDR
101	SPV 1581	13.9	4
102	SR 1436	14.1	4
103	Swati	14.1	4
104	SPV 1575	14.2	4
105	SPV 1562	14.5	4
106	Amarnath	14.7	4
107	CSH 14	14.7	4
108	CH 3	14.9	4
109	IS 112	14.9	4
110	ICSV 717	15.2	5
111	NT 52	15.6	5
112	SPH 1353	15.9	5
113	ICSV 1	17.3	5
114	CSH 5	18.1	5
Mean	--	**8.00**	--
Resistant check			
1.	IS 18551	1.2	1
2.	IS 2205	2.2	1
3.	DJ 6514	2.8	1
Mean	--	**2.06**	--
Susceptible check			
1.	ICSV 1	17.3	5
2.	CSH 5	18.1	5
Mean	--	**17.7**	--

earhead bugs/5 panicles) infestation was observed in genotype IS 18551 and the maximum (15.9 bugs) being in SPH 1353. There was no infestation (0 earhead bug/5 panicles) in genotypes RSU 158 and SU 699. In these genotypes, the mean infestation was 8.00 earhead bugs/5 panicles, and there were 61 sorghum genotypes with less than mean and 53 genotypes with more than mean (8.00 earhead bugs/5 panicles) infestation.

In group-II, there were fifty sorghum genotypes in which the mean infestation ranged from 0.1 to 7.5 earhead bugs/5 panicles, the minimum (1.2 earhead bugs/5 panicles) was observed in genotype IS 18551 and maximum (7.5 earhead bugs) being observed in genotype IS 1044 as compared with 2.06 bugs/5 panicles in resistant genotypes (IS 18551, IS 2205 and DJ 6514). In group-III there were 52 genotypes and infestation ranged from 7.6 to 15.0 earhead bugs/5 panicles. The minimum (7.6 earhead bugs/5 panicles) infestation was observed in SPH 1334 followed by GD 65055 (7.7) and GD 65022 (7.8) and the maximum (14.9 earhead bugs/5 panicles) was observed in IS 112 as compared to 17.7 bugs/5 panicles in susceptible genotypes. In group-IV, there were only five sorghum genotypes, which had mean infestation of 15.1 to 22.5 earhead bugs/5 panicles. Out of 114 genotypes evaluated, 27 genotypes had GDR score of 1, 30 genotypes had a score of 2 while in remaining genotypes, GDR score of 3,4 and 5 was observed in 22, 30 and 5 sorghum genotypes, respectively (Table 2b).

Classification of sorghum genotypes on the basis of infestation of earhead bugs (Pooled data for *Kharif*, 2001 and 2002)

One hundred and fourteen sorghum genotypes were screened both during *kharif*, 2001 as well as during *kharif*, 2002 to know their reaction to earhead bug infestation and the pooled data presented in Table 3a reveal that in different sorghum genotypes, the mean infestation ranged from 0.0 to 22.50 earhead bugs/5 panicles. The minimum (0.6 earhead bugs/5 panicles) infestation was observed in genotype SU 699 and maximum (16.95 bugs) being in SPH 1353. In all these genotypes, the mean infestation was 9.27 earhead bugs/5 panicles and there were 58 sorghum genotypes in which mean number of earhead bugs/5 panicles were lesser than the average mean and in 56 genotypes more than average mean (9.27 earhead bugs/5 panicles) infestation.

In pooled data, in Category-I, no sorghum genotype was included in this group, which was free from bug infestation. In group-II there were forty eight sorghum genotypes in which the mean infestation ranged from 0.1 to 7.50 earhead bugs/5 panicles, the minimum (0.6 earhead bugs/ 5 panicles) infestation was observed in genotype SU 699 and maximum (7.45 earhead bugs/5 panicles) was observed in genotypes GMSB 69 as compared with 4.01 bugs/5 panicles in resistant genotypes (IS 18551, IS 2205 and DJ 6514). In these genotypes, the grain damage rating (GDR) varied between

Table 3a. Categorization of sorghum genotypes on the basis of infestation of earhead bugs – Pooled data for 2001 and 2002

Group	Mean number of earhead bugs/5 panicles (Range)	Grain damage rating (GDR)	No. of sorghum genotypes	Sorghum genotypes
I	0.0	--	--	NIL
II	0.1-7.5	1.0 - 2.50	48	SU 699,RSU 158, IS 18551, 463-A, AKENT 15, RSE 9715, IS 2269, IS 22893, AKENT 8-3, ICSV 700, RSU 283, ICSV 705, SPH 1183, 168-II-112, AKENT 10-2, SFCR 1047, 168-UU-1006, SPV 1605, GMSB 76, SPH 1375, ICSV 711, ICSV 714, RSU 202, DJ 6514, AKENT 7-1-1, SPH 1352, IS 2205, SPV 1574, RSE 9741, IS 2123, ICSV 93046, 168-UU-1022, GMSB-4, IS 11119, GSSV 312, SPV 1576, GD 65195, DSFR 3, 168-II-108, 168-II-122, GMSB 131, SPV 1565, SPH 1280, AKENT 16, GMSB 15, ICSV 112, IS 4663, GMSB 69
III	7.51-15.00	2.51– 4.50	48	SPH 1349, GMSB 5, ICSV 745, SPH 1350, IS 6566, SPV 1570, IS 2122, GD 65055, SPV 1577, GD 65040, SPH 1334, SU 700, IS 1044, GD 65022, CSV 457, AKMS 14-A, DSFR 2, AKENT 14, SPH 1376, SPV 1567, RSE 9745, SR 2460, RSE 9727, BT X 623, SRF 2102, SU 45, SU 52, SPV 1569, 168-IU-1021, SR 2704, CSV 16, SPH 1372, SPH 1329, SR 1048-1, SPV 1579, RSV 204, S-35, SRF 1665, 200-UU-1011, SU 663, GD 65019, GD 65006, GD 65004, SPH 1335, SR 2460-I, 296-B, CSV 15, CSH 16
IV	15.01-22.5	4.51 – 6.00	18	CH 3, SPV 1563, SPV 1581, SR 1436, Amarnath, SPV 1562, 200-1011, ICSV 708, SPV 1575, Swati, ICSR 93034, CSH 14, NT 52, ICSV 717, IS 112, SPH 1353, ICSV 1, CSH 5

Table 3b. Sorghum genotypes classified on the basis of head bugs infestation and grain damage rating (GDR) - Pooled data for 2001 and 2002

Sr. No.	Sorghum genotypes	Mean no. of earhead bugs/5 panicles	GDR
1.	SU 699	0.6	1.0
2.	RSU 158	1.00	1.0
3.	IS 18551	2.45	1.0
4.	463-A	2.60	1.5
5.	AKENT 15	2.60	1.5
6.	RSE 9715	2.65	1.5
7.	IS 2269	2.70	1.5
8.	IS 22893	2.75	1.5
9.	AKENT 8-3	2.80	1.5
10.	ICSV 700	2.80	1.5
11.	RSU 283	2.90	1.5
12.	ICSV 705	3.05	1.5
13.	SPH 1183	3.35	1.5
14.	168-II-112	3.35	1.5
15.	AKENT 10-2	3.40	1.5
16.	SFCR 1047	3.40	1.5
17.	168-UU-1006	3.45	1.5
18.	SPV 1605	3.45	1.5
19.	GMSB 76	3.45	1.5
20.	SPH 1375	3.50	1.5
21.	ICSV 711	4.10	1.5
22.	ICSV 714	4.15	1.5
23.	RSU 202	4.25	1.5
24.	DJ 6514	4.40	1.5
25.	AKENT 7-1-1	4.45	1.5
26.	SPH 1352	4.70	1.5
27.	IS 2205	5.20	2.0
28.	SPV 1574	5.50	2.0
29.	RSE 9741	5.75	2.0
30.	IS 2123	5.90	2.5
31.	ICSV 93046	5.95	2.5
32.	168-UU-1022	6.00	2.5
33.	GMSB-4	6.05	2.5
34.	IS 11119	6.15	2.5
35.	GSSV 312	6.20	2.5
36.	SPV 1576	6.30	2.5

Contd.....

Sr. No.	Sorghum genotypes	Mean no. of earhead bugs/5 panicles	GDR
37.	GD 65195	6.30	2.5
38.	DSFR 3	6.55	2.5
39.	168-II-108	6.55	2.5
40.	168-II-122	6.60	2.5
41.	GMSB 131	6.90	2.5
42.	SPV 1565	7.05	2.5
43.	SPH 1280	7.15	2.5
44.	AKENT 16	7.30	2.5
45.	GMSB 15	7.35	2.5
46.	ICSV 112	7.35	2.5
47.	IS 4663	7.40	2.5
48.	GMSB 69	7.45	2.5
49.	SPH 1349	7.55	2.5
50.	GMSB 5	7.55	2.5
51.	ICSV 745	7.60	2.5
52.	SPH 1350	7.60	2.5
53.	IS 6566	8.50	3.0
54.	SPV 1570	8.60	3.0
55.	IS 2122	8.65	2.5
56.	GD 65055	8.85	3.0
57.	SPV 1577	9.20	2.5
58.	GD 65040	9.25	3.0
59.	SPH 1334	9.30	3.0
60.	SU 700	9.35	3.0
61.	IS 1044	9.50	3.0
62.	GD 65022	9.55	3.5
63.	CSV 457	9.85	3.5
64.	AKMS 14-A	10.40	3.5
65.	DSFR 2	10.45	3.5
66.	AKENT 14	10.45	3.5
67.	SPH 1376	10.50	3.5
68.	SPV 1567	10.60	3.5
69.	RSE 9745	10.70	3.5
70.	SR 2460	10.75	3.5
71.	RSE 9727	10.95	3.5
72.	BT X 623	11.05	3.5
73.	SRF 2102	11.20	3.5
74.	SU 45	11.30	3.5
75.	SU 52	11.45	3.5

Contd.....

Sr. No.	Sorghum genotypes	Mean no. of earhead bugs/5 panicles	GDR
76.	SPV 1569	11.70	3.5
77.	168-IU-1021	11.85	3.5
78.	SR 2704	11.85	4.0
79.	CSV 16	11.95	3.5
80.	SPH 1372	11.95	3.5
81.	SPH 1329	12.75	4.0
82.	SR 1048-1	12.90	4.0
83.	SPV 1579	13.20	4.0
84.	RSV 204	13.25	4.5
85.	S-35	13.35	4.5
86.	SRF 1665	13.70	4.5
87.	200-UU-1011	13.70	4.5
88.	SU 663	13.75	4.5
89.	GD 65019	13.75	4.5
90.	GD 65006	13.80	4.5
91.	GD 65004	13.95	4.5
92.	SPH 1335	14.09	4.5
93.	SR 2460-I	14.20	4.5
94.	296-B	14.35	4.5
95.	CSV 15	14.75	4.5
96.	CSH 16	14.75	4.5
97.	CH 3	15.05	4.5
98.	SPV 1563	15.10	4.5
99.	SPV 1581	15.10	4.5
100.	SR 1436	15.10	4.5
101.	Amarnath	15.15	4.5
102.	SPV 1562	15.25	4.5
103.	200-1011	15.35	4.5
104.	ICSV 708	15.35	4.5
105.	SPV 1575	15.35	4.5
106.	Swati	15.55	4.5
107.	ICSR 93034	15.60	4.5
108.	CSH 14	16.15	4.5
109.	NT 52	16.35	5.0
110.	ICSV 717	16.45	5.0
111.	IS 112	16.75	4.5

Contd.....

Sr. No.	Sorghum genotypes	Mean no. of earhead bugs/5 panicles	GDR
112.	SPH 1353	16.95	5.0
113.	ICSV 1	20.15	6.0
114.	CSH 5	20.90	6.0
Mean	--	**9.27**	--
Resistant check			
1	IS 18551	2.45	1.0
2	DJ 6514	4.40	1.5
3	IS 2205	5.20	2.0
Mean	--	**4.02**	--
Susceptible check			
1	ICSV 1	20.15	6.0
2	CSH 5	20.90	6.0
Mean	--	**20.52**	--

1.0 and 2.5. Three sorghum genotypes *viz.*, SU 699, RSU 158 and IS 18551 had lowest GDR rating of 1.0. There were 25 sorghum genotypes in which the grain damage rating of 2.5 was observed (Table 3b). In group-III, there were 48 genotypes and the mean infestation ranged from 7.51 to 15.0 earhead bugs/ 5 panicles. The minimum (7.55 earhead bugs/5 panicles) infestation was observed in genotype SPH 1349 followed by GMSB 5 (7.55) and ICSV 745 (7.60) and the maximum (14.75 earhead bugs/5 panicles) was observed in CSH 16 as compared to 20.52 bugs/5 panicles in susceptible genotypes. In group-III, the grain damage rating varied from 2.51 to 4.50 in different sorghum genotypes (Table 3b). There were seven and twenty five sorghum genotype which exhibited a GDR of 3.0 and 4.5, respectively. In group-IV, there were eighteen sorghum genotypes, which had mean infestation of 15.01 to 22.5 earhead bugs/5 panicles. The minimum (15.05 bugs/5 panicles) infestation was observed in CH 3 followed by SPV 1563, SPV 1581 and SR 1436 (15.10 bugs) and maximum (16.95 bugs/5 panicles) in genotype SPH 1353. In this group, the grain damage rating (GDR) varied from 4.50 to 6.0. There were three sorghum genotypes *viz.*, NT 52, ICSV 717 and IS 112 which had GDR of 5.0 and two entries (ICSV 1 and CSH 5) exhibited GDR of 6.0(Table 3b).

It is evident from the data given in Table 1, that as the level of infestation in different sorghum genotypes increased from 0.0 to 30.9 earhead bugs/5 panicles,

there was a corresponding increase in the grain damage ratings also. Similar observations have been made by Natarajan *et al.* (1988a) and Sharma *et al.* (1992a).

Mote and Jadhav (1990) had confirmed the earlier findings that when damage increased by 1 grade, there was a corresponding decrease in grain weight loss per earhead in sorghum.

It is evident from the data that as number of bugs/panicle increased, there was a corresponding increase in grain damage rating. When the mean infestation ranged from 0.0 to 7.5 bugs/5 panicles, GDR of 1 and 2 was observed and as the infestation level increased from 7.6 to 15.0 and 15.1 to 22.5 bugs/5 panicles, GDR also increased from 3 to 5. This kind of trend had been observed by Sharma *et al.* (1992a) and Kishore (2000). Mote and Kadam (1984). Sharma and Lopez (1990b) identified CSH 1, CSH 5 and CSH 9 as pest tolerant genotypes without loss in grain yield. Hiremath (1987) also observed a positive correlation between population and damage grade index.

Studies on nature of damage

It has been reported by several workers that both, nymphs and adults of earhead bugs infest the panicle as soon as they emerged from the boot leaf stage and suck sap from the developing grains (Fig. 2 A to C) (Sharma *et al.*, 1992b, 1997a, Teetes *et al.*, 1983; Young and Teetes, 1977).

Fig.2(A). Sorghum earhead bug infested sorghum grains

Fig.2(B). Bug infested sorghum earhead

Fig.2(C) Healthy sorghum earhead

For this experiment, four sorghum varieties i.e. HC 136, HC 171, HC 260 and HC 308 were sown in the month of July, 2001. During 2001, the earhead bugs were first observed 64 to 66 days after sowing of varieties. At this stage panicles just started emerging from boot leaves. However, in case of variety HC 260, the bugs were first observed when anthesis started in panicles. While during 2002, head bugs were observed 66 to 68 days after sowing in varieties HC 171, HC 308 and HC 136 as the panicles started emerging from boot leaves in field. This year, the bugs were simultaneously observed in variety HC 260 at the same time i.e. 66 to 68 days after sowing.

During anthesis period, only adults were observed in panicles and nymphs, if present were scanty and they can be counted easily that confirms for anthesis period to be considered as preferred time for oviposition by earhead bugs. The similar observations were recorded by Sharma and Lopez (1989) and Hall and Teetes (1982 a,b).

The number of earhead bugs i.e. adults and nymph were maximum at milky stage of panicle indicating a preference for milk stage of panicle. During initial stage of panicle, the apex part of panicle was most preferred for oviposition by adult females of earhead bugs and then they moved towards lower end of panicle as flowering portion progressed to bottom. It confirms the findings of Hiremath and Thontadarya (1984 a,b). The present findings are also in confirmity with these recorded by

Sharma and Lopez (1989). They were of the opinion that head bug density at half anthesis, complete anthesis, milk and dough stage is very much crucial for population build-up of earhead bugs. It also confirms the observations made by Sharma (1985a) and Sharma *et al.* (1992 a,b).

Studies on extent of damage *Kharif*, 2001

In this experiment, the panicles were exposed for a different periods to head bugs and then damage was recorded as under:

The sorghum earheads were exposed for a period of 7, 14, 21 and 28 days to earhead bugs and data presented in Table 4 reveal that irrespective of the exposure periods, there were significant differences for mean per cent grain weight loss in four varieties. It was significantly lower (11.55%) in variety HC 260, followed by HC 171 (14.54%) and HC 308(18.69%) and was maximum in HC 136 (20.90%). Also there were significant differences in mean per cent grain weight loss when exposed for different periods. The maximum (24.77%) damage was observed at 28 days of exposure period and it was minimum (6.18%) at exposure period of 7 days. The mean per cent loss in grain weight was 14.46 and 20.27 per cent at exposure period of 14 and 21 days, respectively. It is evident from these findings that as the exposure period increased there was a corresponding increase in the extent of damage caused by the head bugs. Minimum (4.04%) grain weight loss was observed in

Table 4. Extent of damage in forage sorghum genotypes after different exposure periods to earhead bugs.

***Kharif*, 2001**

Varieties (A)	Mean per cent loss in grain weight days after exposure period (days)				
	(B) 7	14	21	28	Mean(A)
HC 308	7.13_a (15.48)	16.42_b (24.04)	22.24_c (28.12)	28.68 (32.36)	18.69 (25.00)
HC 171	5.67_d (13.76)	13.04 (21.16)	17.08_b (24.39)	22.36_c (28.20)	14.54 (21.88)
HC 136	7.90_a (16.31)	17.18_b (24.47)	26.89 (31.22)	31.64 (34.21)	20.90 (26.55)
HC 260	4.04_d (11.58)	10.89 (19.21)	14.87 (22.63)	16.39_b (23.86)	11.55 (19.32)
Mean (B)	6.18 (14.28)	14.46 (22.22)	20.27 (26.59)	24.77 (29.66)	16.42 (23.18)

Figures in parenthesis are angular transformed values.
Figures with same letter are at par.

Tables of S.Em. and C.D.

Factors	S.Em.	C.D. (P=0.05)
Varieties (A)	0.32	0.92
Exposure period (B)	0.32	0.92
Interaction (AxB)	0.64	1.84

variety HC 260 at 7 days of exposure period and it was due to early flowering and loose type of panicles which hinder early pest build-up. Mean per cent grain weight loss was significantly more (31.64%) in variety HC 136 as compared to that observed in other three varieties when exposed for period of 28 days. This may be due to the presence of compact type of earheads facilitating establishment and protection against abiotic and biotic factors. Among varieties loss in per cent grain weight was 7.13, 5.67, 7.9 and 4.04 per cent in variety HC 308, HC 171, HC 136 and HC 260, respectively at 7 days of exposure period. It varied from 10.89 to 17.18 per cent in different varieties of sorghum at 14 days of exposure period. At exposure period of 21 and 28 days, the mean per cent grain weight loss were 14.87 and 16.39, 26.89 and 31.64, 17.08 and 22.36, 22.24 and 28.38 per cent in variety HC 260, HC136, HC 171 and HC308, respectively.

It is evident from the data given in Table 4 that as exposure periods of panicles increases to earhead bugs, there is a corresponding increase in grain weight loss indicating a direct correlation between exposure periods of panicles to head bug infestation and loss in grain weight.

Studies on extent of damage *kharif*, 2002

The data presented in Table 5 on grain weight loss in different sorghum varieties exposed for different period exhibited same trend as observed during 2001 as exposure periods to earhead bugs increases, the loss in

Table 5. Extent of damage in forage sorghum genotypes at different exposure periods to earhead bugs

***Kharif*, 2002**

Varieties (A)	Mean per cent loss in grain weight days after exposure period				
	(B) 7	14	21	28	Mean(A)
HC 308	4.99_{a} (12.89)	10.34_{f} (18.73)	12.69_{b} (20.84)	20.14_{g} (26.65)	12.04 (19.78)
HC 171	4.93_{a} (12.82)	13.28_{bc} (21.35)	14.28_{c} (22.19)	19.76_{g} (26.37)	13.06 (20.68)
HC 136	6.28_{e} (14.50)	13.25_{bc} (21.33)	19.50_{g} (26.19)	25.19 (30.10)	16.06 (23.03)
HC 260	2.59 (9.20)	7.35_{ed} (15.70)	7.91_{d} (16.31)	10.60_{f} (18.90)	7.11 (15.03)
Mean (B)	4.70 (12.35)	11.06 (19.28)	13.59 (21.38)	18.92 (25.51)	12.96 (19.63)

Figures in parenthesis are angular transformed values.
Figures with same letter are at par.

Tables of S.Em. and C.D.

Factors	S.Em.	C.D. (P=0.05)
Varieties (A)	0.26	0.76
Treatments (B)	0.26	0.76
Interaction (AxB)	0.53	1.53

grain weight also increases. Irrespective of the varieties, the minimum (4.70%) grain weight loss was observed at 7 days of exposure period and it was maximum (18.92%) at exposure period of 28 days being 11.06 and 13.59 per cent at an exposure periods of 14 and 21 days, respectively. Irrespective of the exposure period, mean per cent grain weight loss was significantly lesser (7.11%) in variety HC 260 and was maximum (16.06%) in variety HC 136 and differed significantly from other two varieties. The mean per cent grain weight loss in variety HC 171 and HC 308 was 13.06 and 12.04 per cent, respectively and the differences between these two were non-significant (Table 5).

At exposure period of 7 days, the per cent grain weight loss varied from 2.59 to 6.28 per cent in different varieties of sorghum and it was significantly lesser (2.59%) in variety HC 260 and was significantly more (6.28%) in variety HC 136. The mean per cent grain weight loss was on par in other two varieties being 4.93 and 4.99 per cent in variety HC 171 and HC 308, respectively. The mean per cent grain weight loss was always lesser in variety HC 260 and it was 7.35, 7.91 and 10.60 per cent at exposure periods of 14, 21 and 28 days, respectively. At exposure period of 14 days, the mean per cent loss was maximum (13.28%) in variety HC 171, however, it was on par with variety HC 136 (13.25%). The mean per cent grain weight loss was maximum in variety

HC 136, being 19.50 and 25.19 per cent at exposure period of 21 and 28 days, respectively.

It is evident from the present findings that exposure to head bugs in initial days is very much responsible for maximum yield losses and these are in confirmity with those reported by Natarajan *et al.* (1988b). Steck *et al.* (1989) also observed that with increase in pest numbers within a variety, there was an increase in damage in case of *Eurystylus marginatus,* due to enhanced oviposition and feeding. Damage to earhead by bugs was responsible for reduction in yield and germination of sorghum seeds depend on the bug species and infestation period during development and number of bugs per panicle (Hall and Teetes, 1982a) and they concluded that maximum reduction in yield occurred when panicles were infested from milk stage to maturity (28 days) in case of panicle feeding bugs in sorghum. Similar results were reported by Hall and Teetes (1982 b,c), they observed that loss in grain weight was due to small and lighter weight grain earheads resulting from excessive feeding by earhead bugs.

Studies on avoidable losses *kharif*, 2001

To find out the avoidable losses caused by sorghum earhead bugs, four sorghum varieties viz. HC 136, HC 171, HC 260 and HC 308 were sown during July, 2001 in randomized block design with three replications. In one set of varieties protections from earhead bugs was provided by spraying 0.07 per cent endosulfan 35 EC,

Table 6. Grain weight of sorghum genotypes under protected and unprotected conditions in relation to earhead bug incidence

***Kharif*, 2001**

Varieties(A)	Mean grain weight (g)/ panicle under		Mean(A)	Per cent avoidable loss	Mean number of earhead bugs/20 panicles under		Mean	Per cent reduction in bug population
	Sprayed condition	Unsprayed condition			Sprayed* condition	Unsprayed** condition		
HC 308	73.53	47.61	60.57	35.25	7.9	397.5	202.7	98.01
HC 171	62.63	45.89	54.26	26.73	5.3	235.0	120.2	97.70
HC 136	67.53	46.66	57.09	30.89	9.8	467.5	238.7	97.90
HC 260	31.99	29.43	30.71	8.01	3.2	38.5	20.9	91.68
Mean (B)	58.92	42.40	50.65	25.22	6.6	284.6	145.62	96.33

* Mean no. of earhead bugs/ 20 panicles observed after 3rd day of 2nd spraying, first spray of endosulfan given on 64-68 days after sowing.

**Mean no. of earhead bugs/20 panicles observed before spraying.

Tables of S.Em. and C.D.

Factors	S.Em.	C.D. (P=0.05)
Varieties (A)	.17	.51
Treatments (B)	.12	.36
Interaction (AxB)	.24	.72

whenever the bug population approached at economic threshold levels. If need be second spraying was also given 15 days after the first spraying or as soon as the bug population reached economic threshold. Another set of varieties was kept unprotected and avoidable losses were determined at harvest. The data presented in Table 6 reveal that irrespective of varieties, mean grain weight/earhead was always more (58.92 g/earhead) under sprayed conditions as compared to unsprayed (42.40 g/earhead) ones. Irrespective of the protection provided, the mean grain weight/earhead was significantly more (60.57g) in variety HC 308 and was least (30.71g) in variety HC 260. In remaining two varieties i.e. HC 171 and HC 136, it was 54.26 and 57.09g, respectively. The mean grain weight (g) per earhead under protected condition was significantly more (73.53g) in variety HC 308 and was followed in variety HC 136 (67.53g) and was least (31.99g) in variety HC 260. Similar trend was observed under unprotected conditions.

The mean per cent avoidable loss was significantly more (35.25%) in variety HC 308 and was least (8.01%) in variety HC 260. In other two varieties, the mean per cent avoidable losses were 26.73 and 30.89 per cent in variety HC 171 and HC 136, respectively.

Irrespective of the variety, the mean number of bugs/20 panicles were significantly more (284.6 bugs) under unsprayed condition as compared to those

observed under sprayed condition (6.6 bugs). The mean number of earhead bugs/20 panicles were 467.5, 397.5, 235.0 and 38.5 in variety HC 136, HC 308, HC 171 and HC 260 under unsprayed condition and under sprayed condition the mean number of bugs were 9.8, 7.9, 5.3 and 3.2, respectively (Table 6).

Studies on avoidable losses *kharif*, 2002

To confirm the earlier results achieved during 2001, the experiment was repeated during *kharif*, 2002 and the results recorded are presented as below:

The data presented in Table 7 clearly indicated that irrespective of varieties, the mean grain weight (g) per earhead was significantly more (60.43g) under sprayed condition as compared to that observed under unsprayed conditions (46.92g). Irrespective of protection provided, mean grain weight was significantly more (68.90g) in variety HC 136 and was least (30.94g) in variety HC 260. In other two sorghum varieties, i.e. HC 171 and HC 308 the mean grain weight/earhead was 60.67 and 54.18g, respectively. The mean grain weight (g)/earhead was always more under sprayed condition than observed under unsprayed condition in all the tested varieties. Under protected conditions, it was significantly more (81.69g) in variety HC 136, followed by variety HC 171 (68.89g), and was minimum (31.28g) in HC 260. Same trend was observed under unprotected conditions in different varieties. The mean per cent avoidable loss was significantly more (31.31%) in variety HC 136 and was

Table 7. Grain weight of sorghum genotypes under protected and unprotected conditions in relation to earhead bug incidence.

***Kharif*, 2002**

Varieties (A)	Mean grain weight (g)/ panicle under		Mean(A)	Per cent avoidable loss	Mean number of earhead bugs/20 panicles under		Mean	Per cent reduction in bug population
	Sprayed condition	Unsprayed condition			Sprayed* condition	Unsprayed** condition		
HC 308	59.85	48.50	54.18	18.96	3.3	263.5	133.4	98.7
HC 171	68.89	52.45	60.67	23.86	3.7	188.0	95.8	98.03
HC 136	81.69	56.11	68.90	31.31	5.1	422.5	213.8	98.79
HC 260	31.28	30.60	30.94	2.17	1.2	32.5	16.85	96.30
Mean (B)	60.43	46.92	53.67	19.07	4.0	226.62	114.96	97.96

* Mean no. of earhead bugs/ 20 panicles observed after 3rd day of protection, endosulfan sprayed on 64-68 days after sowing.
**Mean no. of earhead bugs/20 panicles observed before spraying.

Tables of S.Em. and C.D.

Factors	S.Em.	C.D. (P=0.05)
Varieties (A)	.15	.45
Treatments (B)	.10	.32
Interaction (AxB)	.22	.64

least (2.17%) in variety HC 260. In other two varieties, the mean per cent avoidable losses were 23.86 and 18.96 per cent in variety HC 171 and HC 308, respectively. Irrespective of the varieties, the mean number of earhead bugs per 20 earheads were always lesser (4.0 bugs) under sprayed condition as compared to those observed in unsprayed condition (226.62).

The mean number of bugs/20 earheads under sprayed condition were 422.5, 263.5, 188.0 and 32.5 in variety HC 136, HC 308, HC 171 and HC 260, respectively and corresponding number under unsprayed conditions in these varieties was 5.1, 3.3, 3.7 and 1.2, respectively. It is evident from the data that mean grain weight/earhead was always more under sprayed conditions as compared to unsprayed conditions. Mean grain weight was more in variety with compact or semi-compact type of earheads and was lesser in variety with loose type of earheads. Varieties with compact or semi-compact type of earheds also supported more population of bugs while varieties with loose type of earhead had lower populations of bugs. It becomes essential to check the population build-up of these bugs, hence insecticidal interventions become necessary as soon as the pest approaches economic threshold levels. Many workers have advocated the use of insecticidal sprays for the management of bugs infesting sorghum (Bhanot *et al.*, 1982; Galvan *et al.*, 1995; Sharma and Lopez, 1989, 1993b). However, Rao and Azam (1987) had shown the

effectiveness of simple tapping of earheads in water kerosene mixture (10:1) to control bugs population upto 58 per cent. Whereas Ramamurthy and Rajaram (2001) and Sharma *et al.* (1999) utilized extract of plant origin to control, *C. angustatus* effectively to avoid losses in grain sorghum. It was well documented by Puttarudriah (1947) that midge and earhead bugs could cause damage amounting to more than 75 per cent. Several workers had earlier observed that earhead bugs were responsible for causing grain damage in sorghum earheads (Taley *et al.,* 1971; Gowda, 1975 and Rao, 1975. Similar results had earlier been reported by Leuschner and Sharma (1983), Sharma and Lopez (1994a, 1993b), Bhanot *et al.* (1982), Mote and Jadhav (1990) and Hall & Teetes (1982 a,b,c) had observed that these losses in grain weight were due to shrivelled, lighter and smaller grains due to seed feeders.

Studies on population dynamics

Based on preliminary screening during *kharif*, 2001, ten sorghum genotypes were selected on the basis of earhead bug infestation and grain damage rating (GDR). Five genotypes were from resistant group while other five were from susceptible group. These genotypes were sown during July, 2002 and observations on earhead bugs were recorded at weekly interval and results are presented below:

The data presented in Table 8 reveal that the mean number of head bugs per 5 panicles during *kharif,* 2002

Table 8. Population dynamics of earhead bug complex in resistant and susceptible sorghum genotype during *kharif*, 2002

Date of observations	Mean number of earhead bugs/5 panicles in Resistant sorghum genotypes: ICSV 714	AKENT 7-1	ICSV 711	SPH 1352	DJ 6514	Mean	Susceptible sorghum genotypes: IS 2312	IS 112	SR 1048-1	SRF 2102	SFCR 1111	Mean
D_1	3.67	4.33	2.01	3.66	2.02	3.1	11.35	9.67	9.03	6.01	4.32	10.0
D_2	3.67	4.02	3.01	3.01	4.67	3.6	13.65	11.01	9.67	7.67	17.33	11.8
D_3	4.67	6.00	5.01	6.33	7.01	5.8	22.26	14.00	12.65	12.00	31.33	18.4
D_4	3.32	3.33	4.01	4.33	4.00	3.8	14.65	16.00	11.32	10.33	20.66	14.5
D_5	2.66	2.00	3.32	3.00	2.33	2.6	12.64	11.33	7.65	6.67	19.33	11.5
Total	17.99	19.68	17.36	20.33	20.03	18.90	74.55	62.01	50.32	42.68	92.97	66.20
Mean	3.54	3.93	3.47	4.06	4.00		14.91	12.40	10.06	8.53	18.59	
S.Em. ±	0.045	0.004	0.005	0.003	0.003	-	0.031	0.003	0.008	0.009	0.004	-
CD(P=0.05)	0.150	0.014	0.018	0.010	0.011	-	0.103	0.009	0.027	0.030	0.012	-

Date of observations	Week	Temperature range (°C) Max.	Min.	Relative humidity range (%) Mor.	Even.	Sunshine (Hrs.)
D_1 20 September, 2002	13-19 Sept., 02	28.2-35.5	20.3-24.0	79-100	40-76	3.0-10.5
D_2 27 September, 2002	20-26 Sept.,02	33.6-36.4	17.6-22.5	69-95	29-40	8.7-10.5
D_3 4 October, 2002	27 Sept.-10 Oct.,02	35.5-36.6	16.1-20.4	80-92	22-38	9.6-10.1
D_4 11 October, 2002	4-10 Oct., 02	34.2-39.1	16.0-21.7	69-90	13-45	9.6-10.2
D_5 18 October, 2002	11-17 Oct.,02	31.2-34.4	16.7-21.7	75-96	29-45	8.2-9.5

Department of Agricultural Meteorology, CCSHAU, Hisar
Daily Meteorological Data of Hisar

0727 LMT
1427 LMT

Location: LAT : 29°10', LONG: 75°46', ALT: 215.2,

September, 2002

Day	Temperature °C		Relative humidity (%)		Sunshine (Hrs.)
	Max.	Min.	Morn.	Even.	
13	28.2	21.6	98	76	4.2
14	30.5	22.7	96	45	3.0
15	35.5	21.9	100	60	3.6
16	32.2	23.3	90	56	5.8
17	33.4	24.0	79	46	10.5
18	34.6	24.0	87	49	8.7
19	34.3	20.3	86	40	6.3
20	35.0	21.1	90	40	8.9
21	34.1	19.7	89	37	10.2
22	35.0	20.6	91	39	10.2
23	34.6	20.6	90	39	9.9
24	35.0	21.0	95	32	10.5
25	36.4	22.5	69	38	9.5
26	33.6	17.6	87	29	8.7
27	36.0	18.0	85	31	10.0
28	35.6	20.0	86	32	9.6
29	36.6	20.4	91	31	9.6
30	35.5	18.2	84	38	9.7

October, 2002

Day	Temperature °C		Relative humidity (%)		Sunshine (Hrs.)
	Max.	Min.	Morn.	Even.	
1	35.5	16.1	80	28	10.0
2	35.6	16.1	81	28	10.1
3	35.6	16.2	92	22	10.0
4	37.8	16.0	90	13	10.2
5	39.1	18.6	69	18	10.1
6	38.1	19.0	74	25	10.1
7	35.9	20.0	72	23	9.8
8	38.0	20.5	86	42	9.6
9	34.2	19.7	83	38	9.8
10	34.5	21.7	80	45	9.6
11	34.2	21.4	83	44	9.4
12	34.4	21.7	75	42	9.1
13	34.4	17.5	83	41	9.2
14	31.2	17.5	96	45	9.5
15	32.0	18.1	92	37	9.2
16	32.7	16.7	92	42	9.1
17	33.0	17.5	90	29	8.2
18	34.1	17.5	90	35	7.9

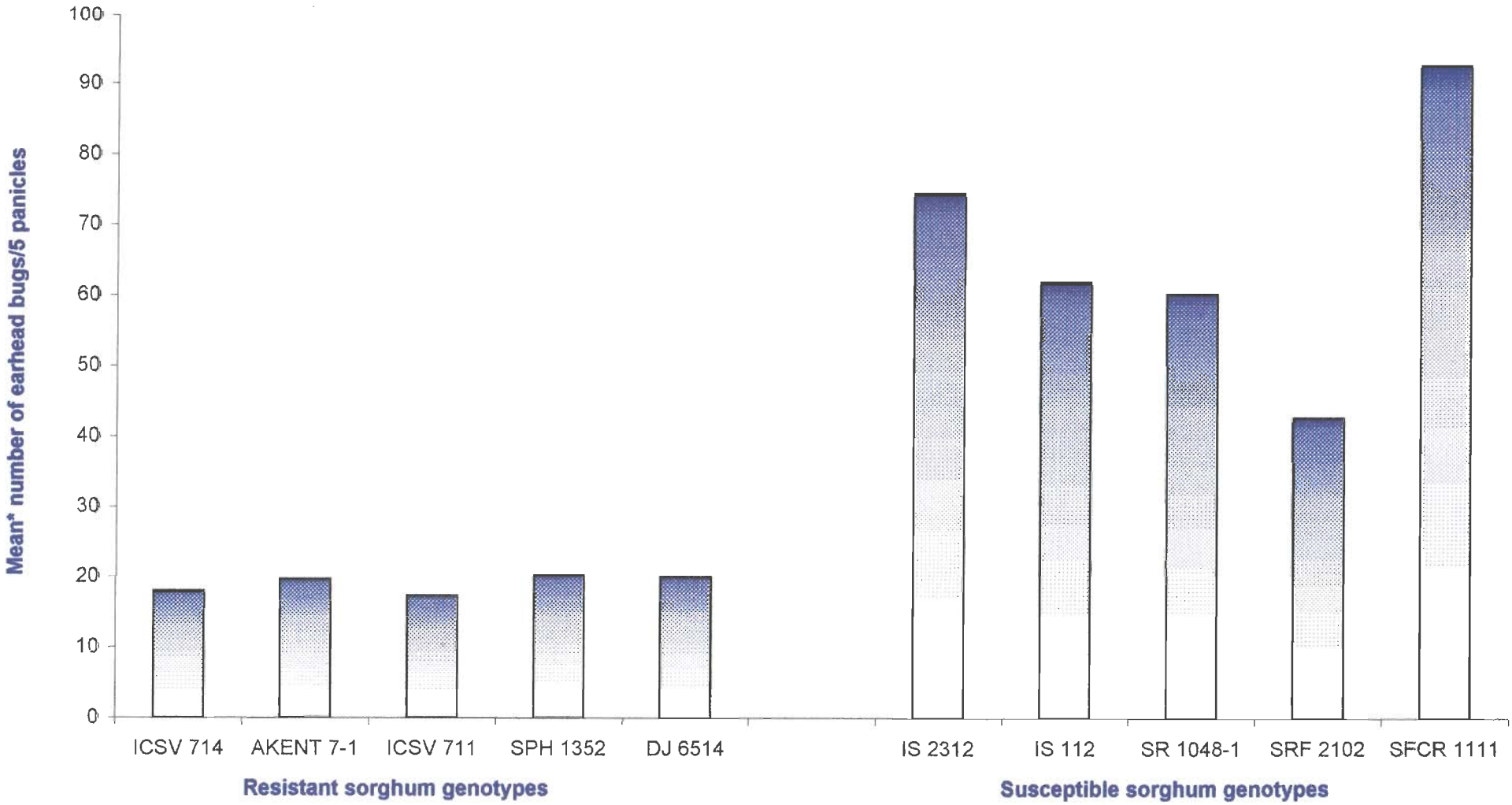

Fig. 3: Mean* population of earhead bugs complex per 5 panicles in resistant and susceptible sorghum gentoypes during *kharif*, 2002 (*total of 5 observations)

in different resistant sorghum genotypes ranged from 17.36 to 20.33. The mean number of head bugs per 5 earhead were minimum (17.36) in genotype ICSV 711 and were maximum (20.33) in genotype SPH 1352. Irrespective of the genotypes, the mean number of bugs varied between 2.6 to 5.8 on different dates of observation, being maximum (5.8) when observed on 4th October, 2002 (D_3) and was least (2.6) on 18th October, 2002 (D_5). All the differences amongst different genotypes for different dates were significant.

In case of susceptible genotypes, irrespective of date of observation, mean number of bugs/5 earheads (cumulative total) ranged from 42.68 to 92.97 in different genotypes, being maximum (92.97 bugs) in genotype SFCR 1111 and least (42.68) in genotype SRF 2102. Irrespective of genotypes, the mean number of bugs/5 earheads ranged from 10.0 to 18.4 in different genotypes, being maximum (18.4) when observed on 4th October, 2002 and were least (10.0) on 20th September, 2002 (Fig. 3). The mean number of bugs/5 panicles ranged from 8.53 to 18.59 in different genotypes, irrespective of date of observation. It can be concluded that mean number of bugs/5 earheads were more on susceptible genotypes in comparison to resistant ones. Amongst the resistant genotypes, ICSV 711 was the most resistant genotype and amongst the susceptible ones SFCR 1111 was the most susceptible ones.

From the above observations, the inference can be drawn that low initial population (lesser number of bugs) included largely adults and nymphs were scantly, because at this time of flowering, adult females showed their preference to oviposit eggs inside the glumes, of developing ovary/grain. Eggs hatch and develop into nymphs and at the times of recording third observation, population of head bugs included more number of nymphs and less adults. Such type of observations had already been recorded by different workers (Hall and Teetes, 1982a, b; Sharma and Lopez, 1990a; Raja Sekhar, 1997; Malgwi *et al.*, 2000).

Correlation with temperature (°C)

The correlation between bug population and various abiotic factors like temperature, relative humidity and sunshine hours were worked out and results are presented in Table 9.

The population build-up of sorghum earhead bugs on resistant and susceptible genotypes showed a positive correlation with maximum mean temperature (°C) whereas the correlation was negative with minimum mean temperature (°C) (Fig. 4). The correlation coefficient (r) of resistant sorghum genotypes (ICSV 714, AKENT 7-1, ICSV 711, SPH 1352 and DJ 6514) with mean maximum temperature was 0.376, 0.314, 0.759, 0.557 and 0.710, respectively and with minimum temperature (mean) was -0.109, -0.031, -0.901, -0.503 and -0.606, respectively (Table 9). The correlation between bug population and

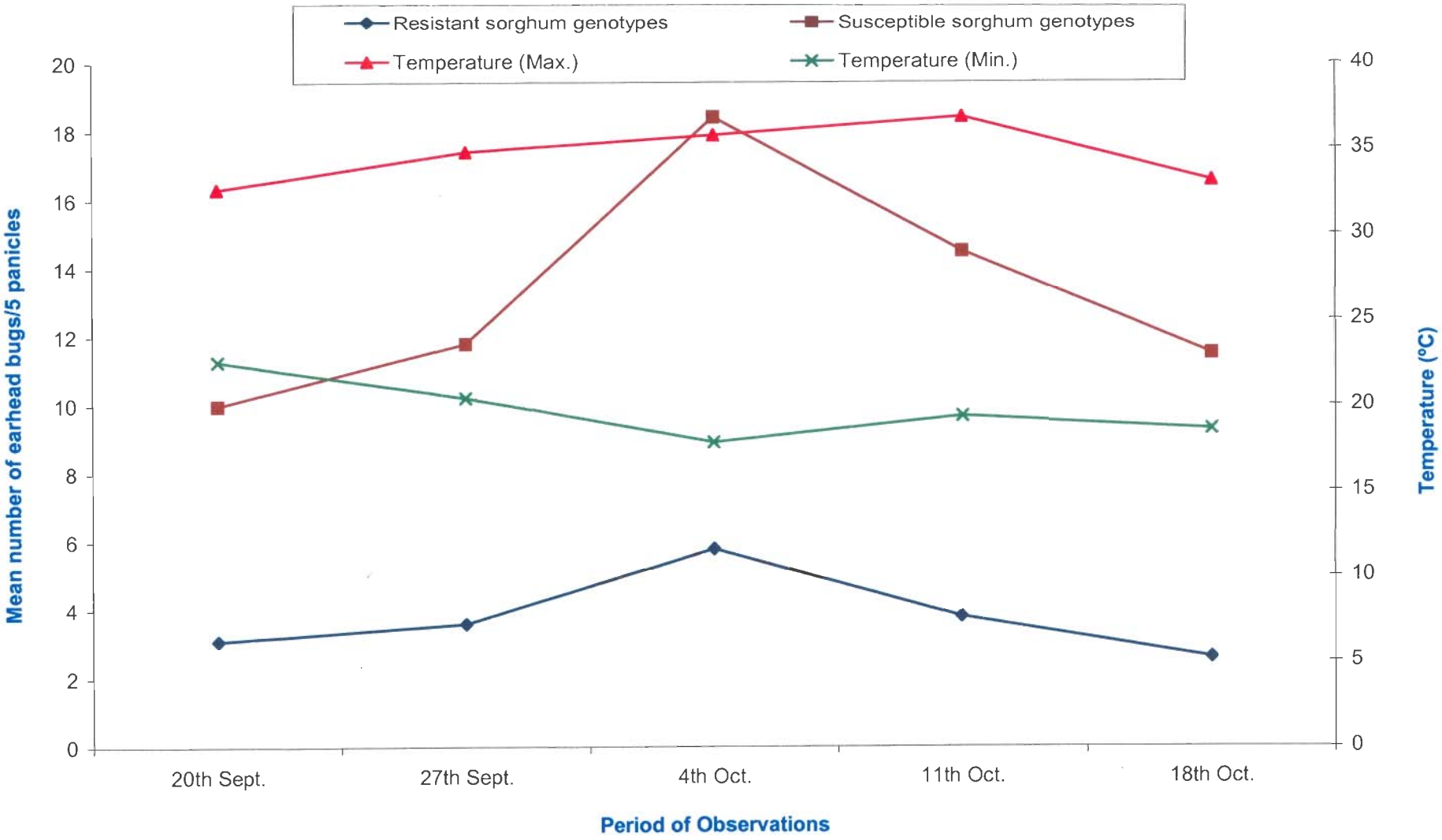

Fig. 4: Relationship between mean population of earhead bugs on resistant and susceptible sorghum genotypes with temperature (°C) during *kharif*, 2002

Table 9. Correlation coefficients between sorghum genotypes and weather parameters.

	ICSV 714	AKENT 7-1	ICSV 711	SPH 1352	DJ 6514	IS 2312	IS 112	SR 1048-1	SRF 2102	SFCR 1111	Temp.(°C)		R.H. (%)		S.S. (hrs.)
											Max.	Min.	Mor.	Even.	
1.	1.000	.994**	.453	.794	.806	.774	.182	.800	.632	.628	.376	-.109	.081	-.259	.058
2.		1.000	.386	.785	.741	.727	.134	.770	.581	.578	.314	-.031	.129	-.162	-.045
3.			1.000	.787	.828	.900*	.803	.765	.936*	.947*	.759	-.901*	-.594	-.787	.774
4.				1.000	.783	.920*	.589	.889*	.874	.888*	.557	-.503	-.292	-.372	.250
5.					1.000	.931*	.540	.864	.879*	.859	.710	-.606	-.311	-.755	.636
6.						1.000	.565	.845	.903*	.977**	.602	-.706	-.273	-.603	.530
7.							1.000	.732	.851	.613	.919*	-.639	-.941*	-.747	.669
8.								1.000	.939*	.765	.825	-.411	-.527	-.617	.416
9.									1.000	.889*	.871	-.694	-.646	-.761	.645
10.										1.000	.577	-.822	-.328	-.606	.587
11.											1.000	-.528	-.872	-.874	.729
12.												-1.000	.484	.722	-.836
13.													1.000	.709	-.643
14.														1.000	-.955*
15.															1.000

*Significant at P= 0.05

**Significant at P= 0.01

maximum temperature was significantly positive in resistant genotypes ICSV 711, SPH 1352 and DJ 6514 and the relationship between bug population and minimum temperature was significantly negative in these three varieties.

The correlation coefficient (r) of susceptible genotypes *viz.*, IS 2312, IS 112, SR 1048-1, SRF 2102 and SFCR 1111 with maximum mean temperature (°C) was 0.602, 0.919, 0.825, 0.871 and 0.577, respectively and with minimum mean temperature (°C) was -0.706, -0.639, -0.411, -0.694 and -0.822, respectively (Table 8) under Hisar condition, head bug population showed a positive correlation with maximum temperature and negative correlation with minimum temperature. Similar results have earlier been reported where population of earhead bugs had shown a positive correlation with maximum temperature (Sharma and Lopez, 1990a; Ramamurthy and Gopalan, 1993). Average minimum temperature was highly correlated with population of *C. angustatus* (Prabhakar *et al.*, 1986). The results reported in these studies are contradictory to those reported by Hiremath and Thontadarya (1984b), they observed a significant negative correlation between bug population and maximum temperature.

Correlation with relative humidity (%)

In case of relative humidity (%), all the entries had shown negative correlation with morning and evening relative humidity (%) except resistant genotypes ICSV 714

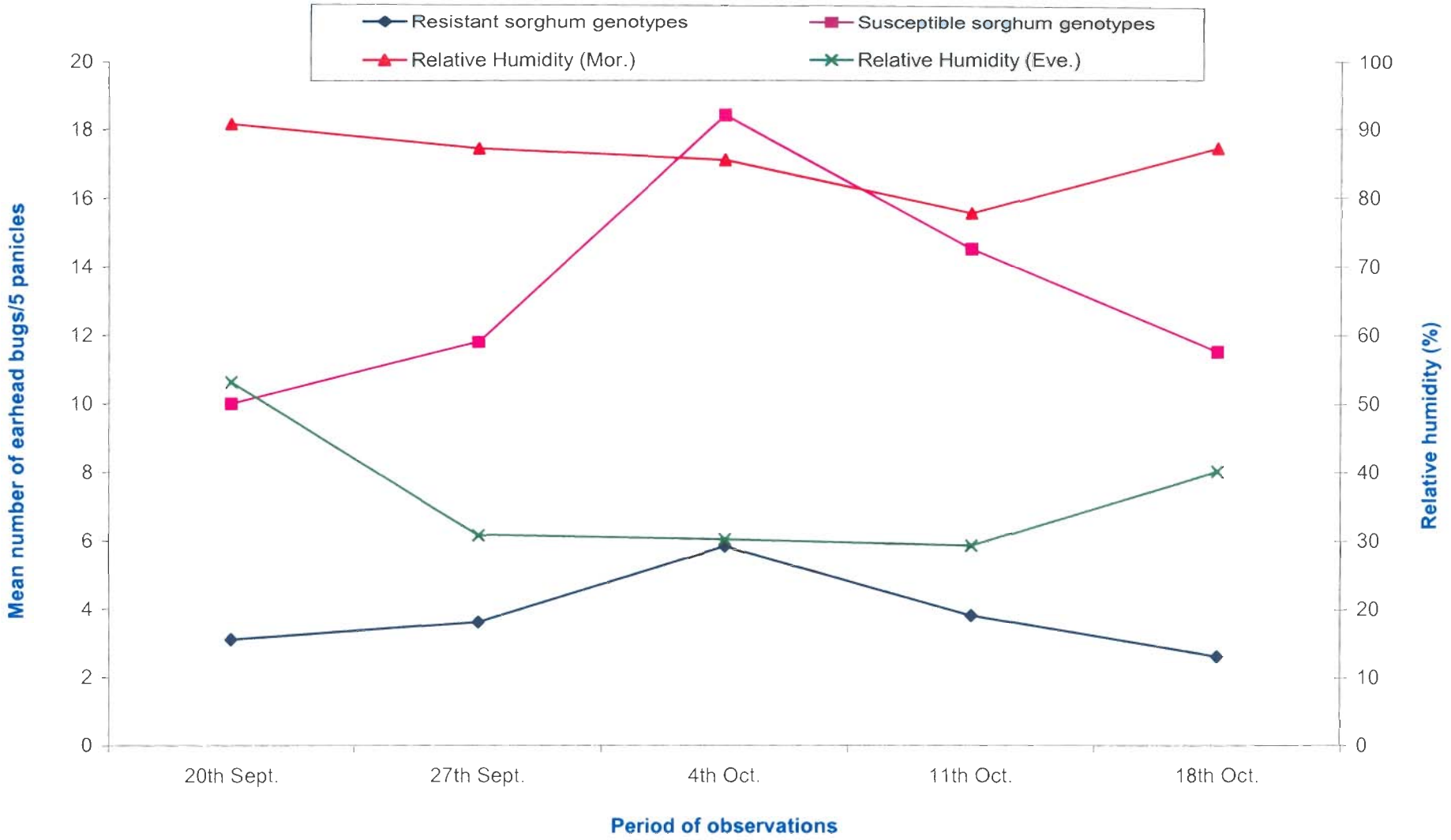

Fig. 5: Relationship between mean population of earhead bugs on resistant and susceptible sorghum genotypes with Relative humidity (%) during *kharif*, 2002

and AKENT 7-1 which exhibited positive correlation i.e. 0.081 and 0.129 that too only with relative humidity (%)morning (Fig. 5). The correlation between bug population and resistant and susceptible sorghum genotypes was negative. The correlationship between bug population and mean relative humidity morning was significantly negative in resistant sorghum genotype ICSV 711. In susceptible sorghum genotypes, this correlation was significantly negative in genotypes IS 112, SR 1048-1 and SRF 2102. The correlation coefficient (r) for bug population and morning relative humidity (%) for entries ICSV 711, SPH 1352 and DJ 6514 (resistant group) were -0.594, -0.292 and -0.311 respectively and the values for enteries in susceptible genotypes viz. IS 2312, IS 112, SR 1048-1, SRF 2102 and SFCR 1111 were -0.273, -0.941, -0.527, -0.646 and -0.328, respectively (Table 9).

The relative humidity (%) evening was negatively correlated with bug populations both in resistant and susceptible group. In resistant entries ICSV 714, AKENT 7-1, ICSV 711, SPH 1352 and DJ 6514, the coefficients of correlation (r) was -0.259, -0.162, -0.787, -0.372 and -0.755, respectively, while in susceptible genotypes the value of 'r' was -0.603, -0.747, -0.617, -0.761 and -0.606 for IS 2312, IS 112, SR 1048-1, SRF 2102 and SFCR 1111 genotypes, respectively (Table 9).

It can be concluded from the data obtained during both the year that bug population in most of genotypes studied (both resistant and susceptible) had negative

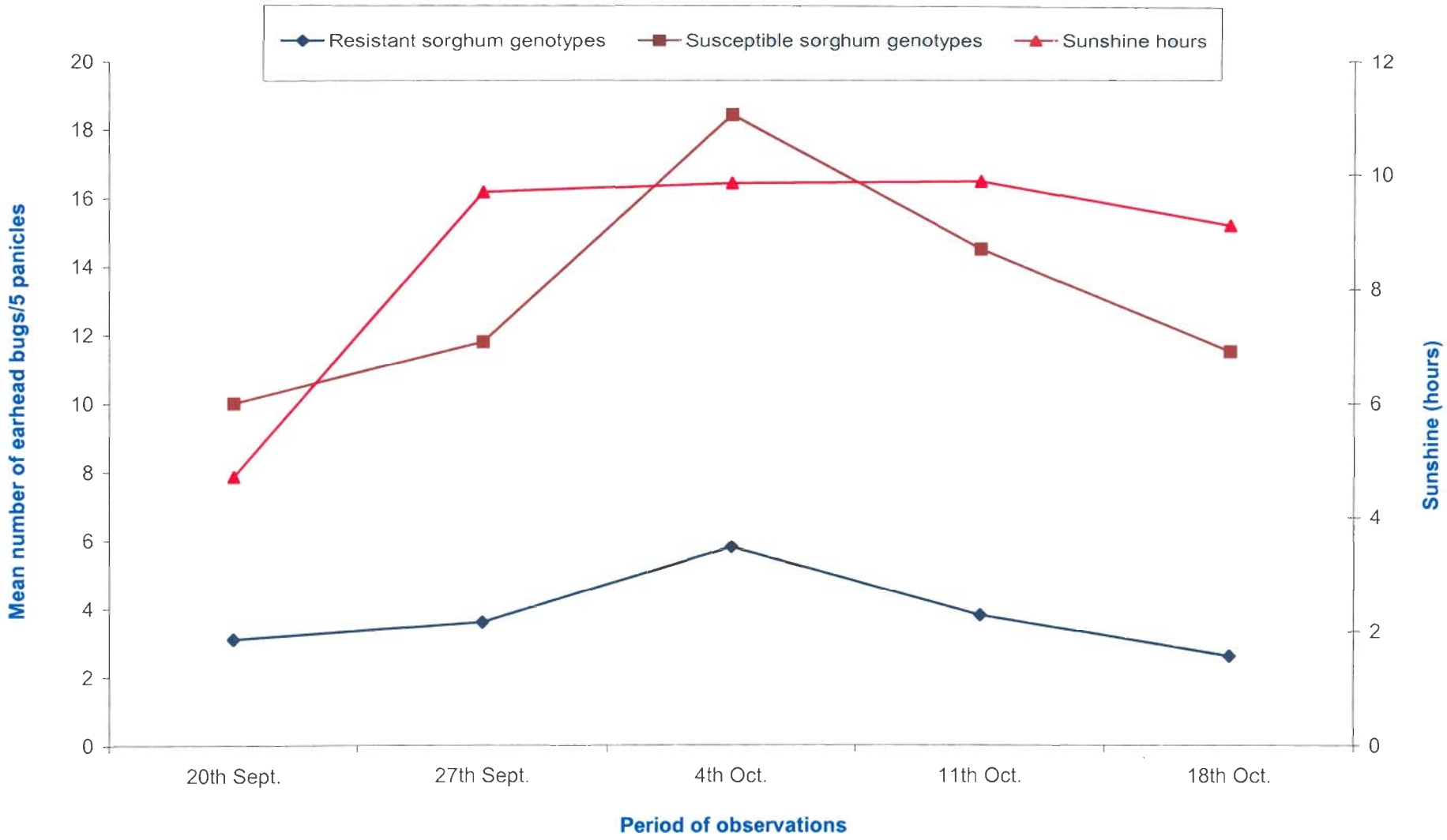

Fig. 6: Relationship between mean population of earhead bugs on resistant and susceptible sorghum genotypes with Sunshine (hours) during *kharif*, 2002

correlation with morning and evening relative humidity. These results are in contradiction to those earlier report (Hiremath and Thontadarya, 1984b; Sharma and Lopez, 1990a). They observed a positive correlation between headbug population and relative humidity. This variation in results may be due to the difference in climatic conditions of two places and also there was rains before the recording of first observation on population and thereafter it was a complete dry spell during the season (*Kharif,* 2002).

Correlation with sunshine hours

The correlation between population dynamics of different sorghum entries and sun-shine showed a positive correlation (Fig. 6). The population of earhead bugs on resistant sorghum genotypes i.e. ICSV 714, ICSV 711, SPH 1352 and DJ 6514 elicited positive correlation with sun shine hours (r = 0.058, 0.045, 0.774, 0.250 and 0.636, respectively) alongwith these susceptible entries IS 2312, IS 112, SR 1048-1, SRF 2102 and SFCR 1111 also displayed their positive reaction with sunshine hours (r= 0.530, 0.669, 0.416, 0.645 and 0.587, respectively) (Table 9). No studies in relation with population build-up of earhead bugs and sun-shine hours had earlier been reported.

Grain mould

During the studies on population dynamics of earhead bugs complex on sorghum panicles, it was observed that the panicles which were heavily infested by

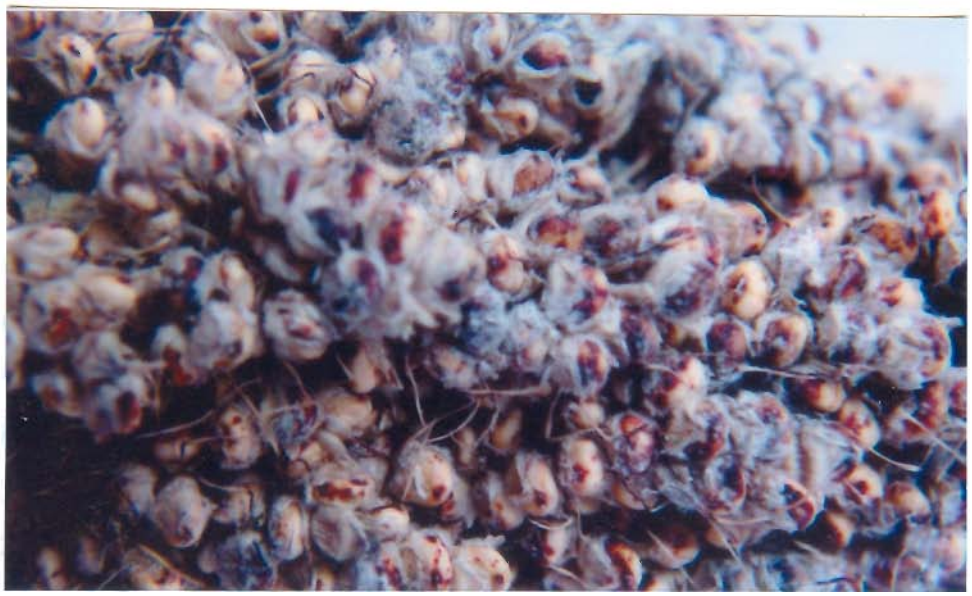

Fig. (A)

Fig. (B)

Fig. 7 (A&B) :Bug infested sorghum earheads (A & B) showing fungal (sooty mold) development.

bugs, developed fungus growth leading to development of mould on these panicles (Fig. 7 A to B). This finding in this experiment is in conformity with those reported by Sharma *et al.* (1992a, 1994a, 1995, 2000); Wood and Starks (1972) and Marley and Malgwi (1999) They had reported the presence of mould on sorghum grains in association with insect-pests particularly head bugs.

Studies on natural enemies

To study the parasitoids associated with earhead bugs under Hisar conditions, field collected earhead bugs were reared on sorghum panicles of varieties, HC 136 and HC 171.

Presence of parasitoids, if any was recorded at an interval of 3 days upto one month in each case. Most of the earhead bugs died within this period and no presence of any parasitoid was observed in this experiment.

However, presence of some species of spider, lady bird beetle and green lace wing bugs were frequently observed on sorghum panicles of different sorghum varieties under field conditions.

Different natural enemies associated with head bugs had been reported by several workers (Hiremath, 1989; Jackson *et al.,* 1970, 1971). They had reported different predators i.e. formicid, reduviid, lygaeid, mantid, different species of spider and entomogenous fungus. However, the available literature revealed that there is no report on parasitoids of earhead bugs infesting sorghum particularly in Northern India.

Gravena (1979) and Rice and Wilde (1989) reported predators and parasites of green bug namely, *Scymoces*

spp., *Cycloneda sanguinea, Chrysopa cincta, Diacretiella rapae* and *Hippondamia convergens.* Fernandes *et al.* (1997) observed presence of braconid, *Lysiphlebus testaceipes.*

Studies on morphological characters in relation to head bugs complex incidence on sorghum panicle

Some morphological characters *viz.*, 1000-grain weight (Test weight), length and breadth of panicles, colour and type of earheads, colour of the glume of 150 sorghum genotypes screened, were observed and recorded on the basis of these morphological characters, sorghum genotypes were categorized into different groups. The results on these parameters are presented as below :

1000-Grain weight (Test weight)

One hundred and fifty sorghum genotypes were categorized into 5 different groups on the basis of 1000-grain weight (Table 10a). Category-1 comprised of only 2 sorghum entries namely RSU 158 and AKENT 14 and in these two sorghum genotypes mean grain weight was 7.80 and 8.58g, respectively with average mean grain weight of 8.19g. These two genotypes supported 1.0 and 9.0 mean number of bugs/5 panicles. In second category, there were forty sorghum genotypes, in which the mean grain weight varied from 12.10 to 19.80g with an overall mean of 17.07g. The mean grain weight was maximum (19.80g) in genotype BT 623 and the minimum (12.10) in genotype SPV 1567 (Table 10b). Category third comprised of maximum (86) number of sorghum genotypes and

Table 10a. Sorghum genotypes categorized into different groups on the basis of 1000-grain weight.

Category	Grain weight (g) (Range)	Number of sorghum genotypes	Mean grain weight(g)	Mean no.of bugs/5 panicles	Sorghum genotypes
1	0.0 to 10.0	2	8.19	5.0	RSU 158, AKENT 14
2	10.1 to 20.0	40	17.07	10.42	SPV 1567, SU 699, DSFR-3, DJ 6514, DSFR 2, SRF 2102, SPV 1581, RSU 202, SPV 1576, ICSV 711, RSE 9728, SPV 1570, SPV 1579, ICSV 714, 168-II-112, GD 65174-1, ICSV-1, IS 18551, SPV 1577, SR 770-2, SPV 1568, AKENT 8-3, IS 2205, SPV 1580, CSH 7, SR 2460-1, GD 65195, GMSB 69, SRF 1665, SR 1048-1, CSH 5, SU 700, SPH 1355, SPH 1280, SPV 1574, 27B, CH 3, AKENT 10-1, SPH 1354, BT X 623.
3	20.1 to 30.0	86	23.96	12.24	SRF 203, CSV 457, AKMS 14-A, DSFR-5, SPV 1573, ICSV 708, CSH 14, SPV 1565, CSH 17, SFCR 1047, RSV 204, SR 2458, SPH 1374, GMSB 4, SPV 1571, SPH 1375, GMSB 76, CSH 16, CSV 15, SPV 1575, GMSB 5, 296 B, SPV 1578, SPH 1350, GMSB 15, CSH 9, GD 65019, ICSV 700, 168 UU 1006, SU 663, ICSV 112, SR 1436, SFCR 1143, IS 2312, 200-1011, SDSL 92131, SPV 1569, RSE 9715, SR 833-2-3, CSV 16, 200 IU 1005, SPH 1353, IS 22893, 200 UU 1011,ICSV 745, IS 2269, 168-II-108, SPH 1183, SFCR 1070, SPV 1562, Khwang Pahawang, IS 6566, GSSV 312, SPH 1334, IS 25596, ICSV 93046, 168-IU-1021, 168-II-122, SPV 1605, AKENT 10-2, SPV 1563, GMSB 131, IS 20016, IS 2123, IS 11119, RSU 283, IS 112, 168 UU 1022, IS 1044, IS 4663, IS 2122, AKENT 15, ICSV 705, GD 65055, RSE 9741, SFCR 1105, RSE 9745, 296-A, SFCR 1111, SPH 1335, 463-A, SU 45, SPH 1352, SRF 2549, SU 52, RSE 9744
4	30.1 to 40.0	18	34.01	12.46	RSE 9727, SPH 1372, SR 2460, GD 65040, SR 2704, AKENT 7-1-1, GD 65004, SR 2459, ICSV 717, GD 65022, ICSR 93034, SPH 1349, S-35, GD65006, SPH 1376, SPH 1341, SPH 1347, SPH 1329
5	40.1 to 50.0	4	41.90	14.47	Amarnath, NT 52, Swati, AKENT 16

Table 10b. Sorghum genotypes categorized on the basis of 1000-grain weight

Sr. No.	Sorghum genotype	Grain weight (gm)	Mean no. of earhead bugs/5 panicles
0.0-10.0 gm – Grain weight			
1.	RSU 158	7.80	1.0
2.	AKENT 14	8.58	9.0
	Average	**8.09**	**5.0**
10.1-20.0 gm – Grain weight			
3.	SPV 1567	12.10	12.3
4.	SU 699	12.92	1.2
5.	DSFR-3	13.16	8.5
6.	DJ 6514	13.36	6.0
7.	DSFR 2	13.62	11.6
8.	SRF 2102	14.00	12.8
9.	SPV 1581	14.04	16.3
10.	RSU 202	14.71	5.3
11.	SPV 1576	15.08	8.4
12.	ICSV 711	15.88	5.2
13.	RSE 9728	16.23	23.1
14.	SPV 1570	16.26	9.3
15.	SPV 1579	16.33	15.4
16.	ICSV 714	16.72	5.4
17.	168-II-112	16.86	4.0
18.	GD 65174-1	17.08	0.0
19.	ICSV-1	17.22	23.0
20.	IS 18551	17.30	3.7
21.	SPV 1577	17.34	11.1
22.	SR 770-2	17.68	23.2
23.	SPV 1568	17.72	19.1
24.	AKENT 8-3	17.80	3.8
25.	IS 2205	17.84	8.2
26.	SPV 1580	17.85	0.0
27.	CSH 7	17.89	26.9
28.	SR 2460-1	18.12	15.8
29.	GD 65195	18.26	7.6
30.	GMSB 69	18.43	8.1
31.	SRF 1665	18.68	15.5
32.	SR 1048-1	18.76	15.1
33.	CSH 5	18.83	23.7
34.	SU 700	19.02	11.4
35.	SPH 1355	19.18	19.8

Contd...

Sr. No.	Sorghum genotype	Grain weight (gm)	Mean no. of earhead bugs/5 panicles
36.	SPH 1280	19.20	8.4
37.	SPV 1574	19.44	6.7
38.	27 B	19.52	23.9
39.	CH 3	19.53	15.2
40.	AKENT 10-1	19.56	23.1
41.	SPH 1354	19.72	19.0
42.	BT X 623	19.80	11.8
	Average	**17.07**	**10.42**
20.1 – 30.0 gm – Grain weight			
43.	SRF 203	20.11	19.0
44.	CSV 457	20.12	11.6
45.	AKMS 14-A	20.34	12.5
46.	DSFR-5	20.52	25.6
47.	SPV 1573	20.56	0.0
48.	ICSV 708	20.76	17.2
49.	CSH 14	20.76	17.6
50.	SPV 1565	20.90	8.5
51.	CSH 17	20.94	19.5
52.	SFCR 1047	21.14	4.4
53.	RSV 204	21.16	15.1
54.	SR 2458	21.20	29.0
55.	SPH 1374	21.36	27.1
56.	GMSB 4	21.45	7.9
57.	SPV 1571	21.46	19.9
58.	SPH 1375	21.48	4.6
59.	GMSB 76	21.50	4.1
60.	CSH 16	21.57	15.9
61.	CSV 15	21.71	16.3
62.	SPV 1575	21.72	16.5
63.	GMSB 5	21.76	8.2
64.	296 B	21.77	15.8
65.	SPV 1578	21.86	21.8
66.	SPH 1350	21.88	8.6
67.	GMSB 15	22.06	8.5
68.	CSH 9	22.28	24.0
69.	GD 65019	22.3	15.4
70.	ICSV 700	22.42	3.9

Contd.....

Sr. No.	Sorghum genotype	Grain weight (gm)	Mean no. of earhead bugs/5 panicles
71.	168 UU 1006	22.44	4.4
72.	SU 663	22.47	15.6
73.	ICSV 112	22.48	8.2
74.	SR 1436	22.53	16.1
75.	SFCR 1143	22.64	22.8
76.	IS 2312	22.79	22.4
77.	200-1011	22.80	17.6
78.	SDSL 92131	22.84	0.0
79.	SPV 1569	22.92	12.3
80.	RSE 9715	22.92	3.8
81.	SR 833-2-3	22.96	19.2
82.	CSV 16	22.98	13.6
83.	200 IU 1005	22.98	19.1
84.	SPH 1353	23.03	18.0
85.	IS 22893	23.06	3.8
86.	200 UU 1011	23.26	15.4
87.	ICSV 745	23.44	9.1
88.	IS 2269	23.48	4.0
89.	168-II-108	23.66	7.9
90.	SPH 1183	23.78	4.1
91.	SFCR 1070	24.12	22.7
92.	SPV 1562	24.18	16.0
93.	Khwang Pahawang	24.24	0.0
94.	IS 6566	24.27	8.1
95.	GSSV 312	24.34	7.5
96.	SPH 1334	24.62	11.0
97.	IS 25596	24.82	0.0
98.	ICSV 93046	24.98	7.5
99.	168-IU-1021	25.02	13.9
100.	168-II-122	25.07	7.8
101.	SPV 1605	25.08	4.3
102.	AKENT 10-2	25.24	4.4
103.	SPV 1563	25.26	16.6
104.	GMSB 131	25.44	8.0
105.	IS 20016	25.66	0.0
106.	IS 2123	25.74	7.7

Contd.....

Sr. No.	Sorghum genotype	Grain weight (gm)	Mean no. of earhead bugs/5 panicles
107.	IS 11119	25.74	7.6
108.	RSU 283	25.82	3.8
109.	IS 112	25.82	18.6
110.	168 UU 1022	26.02	7.7
111.	IS 1044	26.46	11.5
112.	IS 4663	26.51	8.4
113.	IS 2122	26.52	9.9
114.	AKENT 15	26.56	3.8
115.	ICSV 705	27.05	4.0
116.	GD 65055	27.16	10.0
117.	RSE 9741	27.18	6.5
118.	SFCR 1105	27.48	23.1
119.	RSE 9745	27.58	9.2
120.	296-A	28.16	26.5
121.	SFCR 1111	28.28	30.9
122.	SPH 1335	28.30	16.0
123.	463-A	28.76	3.9
124.	SU 45	28.98	12.5
125.	SPH 1352	29.16	6.1
126.	SRF 2549	29.43	25.7
127.	SU 52	29.58	12.0
128.	RSE 9744	29.68	24.1
	Average	**23.96**	**12.24**
30.1-40.0 gm – Grain weight			
129.	RSE 9727	30.23	12.2
130.	SPH 1372	30.32	12.7
131.	SR 2460	30.34	12.1
132.	GD 65040	30.52	11.4
133.	SR 2704	32.38	12.4
134.	AKENT 7-1-1	32.48	5.9
135.	GD 65004	32.58	15.2
136.	SR 2459	32.90	26.7
137.	ICSV 717	33.62	17.7
138.	GD 65022	34.16	11.3
139.	ICSR 93034	34.58	17.5
140.	SPH 1349	35.40	8.6

Contd.....

Sr. No.	Sorghum genotype	Grain weight (gm)	Mean no. of earhead bugs/5 panicles
141.	S-35	35.48	15.5
142.	GD65006	36.64	15.3
143.	SPH 1376	37.16	11.8
144.	SPH 1341	37.18	20.1
145.	SPH 1347	37.64	20.1
146.	SPH 1329	38.70	13.8
	Average	**34.01**	**14.46**
40.1-50.0 gm – Grain weight			
147.	Amarnath	40.06	15.6
148.	NT 52	40.72	17.1
149.	Swati	43.26	17.0
150.	AKENT 16	43.58	8.2
	Average	**41.90**	**14.47**
	S.E.±	2.28	

these genotypes had average grain weight of 23.96g and the mean number of bugs/5 panicles was 12.24. In this category least (20.11g) test weight was recorded in genotype SRF 203, it was followed by CSV 457 (20.12g) and AKMS (20.34g) and maximum (29.68g) 1000-grain weight was recorded in sorghum genotype RSE 9744. In fourth category average 1000-grain weight was 34.01g, and least (30.23g) mean grain weight was observed in genotype RSE 9727 followed by SPH 1372 (30.32g) and SR 2460 (30.34g) and the maximum (38.70g) 1000-grain weight was recorded in genotype SPH 1329. The mean numbers of bugs per 5 earheads in this category were 12.46 bugs/5 panicle and it varied from 5.9 bugs in genotype AKENT 7-1 to 26.7 bugs/5 panicles (in genotype SR 2459) (Table 10b). Fifth category consisted of with only four genotypes i.e. Amarnath, NT 52. Swati and AKENT 16 with mean 1000-grain weight 40.06, 40.72, 43.23 and 43.58, respectively and the average mean grain weight of 41.90g and the mean number of bugs/5 panicles varied from 8.2 (AKENT 16) to 17.1 (NT 52). The correlation (r= 0.290) between mean number of bugs/5 panicles and 1000-grain weight was positive (Table 19).

Length of panicle (cm)

On the basis of panicle length (cm), one hundred and fifty sorghum genotypes were categorized into 5 groups with length ranging from 0.0 to 10.0, 10.1 to 15.0, 15.1 to 20.0, 20.1 to 25.0 and 25.1 to 30.0 cm into group 1,2,3,4 and 5, respectively (Table 11a). In

Table 11a. Sorghum genotypes categorized into different groups on the basis of length of panicle.

Category	Length of sorghum panicle (cm)	Number of sorghum genotypes	Mean length of sorghum panicle (cm)	Mean no.of bugs/5 panicles	Sorghum genotypes
1	0.0 to 10.0	Nil	--	--	Nil
2	10.1 to 15.0	20	13.63	10.26	SRF 2102, SRF 1665, SU 45, BT X 623, GSSV 312, ICSV 717, RSE 9715, DSFR-2, AKENT 8-3, ICSV 708, RSU 158, AKMS 14-A, IS 2205, SR 2460-1, SPV 1605, SPV 1579, ICSV 714, RSU 202, IS 2269, SPV 1568
3	15.1 to 20.0	62	17.96	12.69	AKENT 15, 200 IU 1005, SRF 2549, IS 2122, RSE 9727, AKENT 10-1, DSFR 5, SPV 1562, ICSV 705, IS 112, SU 700, SR 2458, GMSB 69, SRF 203, SPH 1183, SR 2460, SPV 1563, SPH 1352, DSFR-3, SR 770-2, SU 699, IS 18551, RSV 204, 463-A, GMSB 76, CSV 457, SPH 1280, AKENT 10-2, ICSV 93046, SFCR 1047, SPV 1576, RSE 9744, GMSB5, IS 22893, ICSV 700, IS 6566, CSH 9, SPH 1349, 27B, DJ 6514, CSV 16, SPH 1350, SR 1048-1, ICSV 745, SFCR 1143, CSH 14, ICSV 711, IS 2312, SR 1436, IS 11119, 168 UU 1006, SPV 1571, CSH 17, GD 65055, 200 UU 1011, CSV 15, RSE 9728, ICSV 112, CSH 7, AKENT 14, GMSB 15, 168-II-108
4	20.1 to25.0	53	22.11	13.21	SPV 1580, GD 65019, SR 833-2-3, SU 663, 168-II-112, SPV 1569, GMSB4, GD 65195, SPH 1375, SPH 1334, SFCR 1070, SPH 1329, 168 IU 1021, RSE 9745, SPV 1574, SR 2704, GMSR 131, SPV 1567, SFCR 1105, SPV 1565, IS 4663, SU 52, SPH 1374, SFCR 1111, SPV 1581, SPH 1335, RSU 283, 200-1011, SPV 1570, 168 UU 1022, IS 2123, GD 65174-1, SPV 1575, IS 1044, 168II 122, SPV 1577, CH 3, SPH 1354, CSH 16, GD 65040, 296-B, SPH 1355, SPH 1376, ICSR 93034, SPH 1353, SPV 1578, S 35, CSH 5, SPV 1573, SR 2459, GD 65006, AKENT 7-1-1, GD 65004,
5	25.1 to 30.0	15	27.06	11.87	296-A, SPH 1347, GD 65022, Swati, SPH 1341, Amarnath, SPH 1372, NT 52, ICSV-1, AKENT 16, RSE 9741, IS 25596, Khawang Pahwang, IS 20016, SDSL 92131

Table 11b . Sorghum genotypes categorized on the basis of length of panicle

Sr. No.	Sorghum genotype	Panicle length (cm)	Mean no. of earhead bugs/5 panicles
0.0-10.0 cm – Panicle length		NIL	
10.1 -15.0 cm - Panicle length			
1	SRF 2102	10.34	12.8
2	SRF 1665	12.00	15.5
3	SU 45	12.29	12.5
4	BT X 623	12.47	11.8
5	GSSV 312	12.56	7.5
6	ICSV 717	13.39	17.7
7	RSE 9715	13.67	3.8
8	DSFR-2	13.72	11.6
9	AKENT 8-3	13.78	3.8
10	ICSV 708	13.85	17.2
11	RSU 158	13.92	1.0
12	AKMS 14-A	14.16	12.5
13	IS 2205	14.30	8.2
14	SR 2460-1	14.35	15.8
15	SPV 1605	14.36	4.3
16	SPV 1579	14.50	15.4
17	ICSV 714	14.50	5.4
18	RSU 202	14.77	5.3
19	IS 2269	14.84	4.0
20	SPV 1568	14.90	19.1
	Average	**13.63**	**10.26**
15.1-20.0 cm – Panicle length			
21	AKENT 15	15.11	3.8
22	200 IU 1005	15.33	19.1
23	SRF 2549	15.34	25.7
24	IS 2122	15.51	9.9
25	RSE 9727	15.53	12.2
26	AKENT 10-1	15.79	23.1
27	DSFR 5	15.83	25.6
28	SPV 1562	16.20	16.0
29	ICSV 705	16.33	4.0
30	IS 112	16.40	18.6

Contd.....

Sr. No.	Sorghum genotype	Panicle length (cm)	Mean no. of earhead bugs/5 panicles
31	SU 700	16.67	11.4
32	SR 2458	16.76	29.0
33	GMSB 69	16.81	8.1
34	SRF 203	16.83	19.0
35	SPH 1183	16.70	4.1
36	SR 2460	17.11	12.1
37	SPV 1563	17.20	16.6
38	SPH 1352	17.33	6.1
39	DSFR-3	17.35	8.5
40	SR 770-2	17.36	23.2
41	SU 699	17.43	1.2
42	IS 18551	17.52	3.7
43	RSV 204	17.66	15.1
44	463-A	17.67	3.9
45	GMSB 76	17.69	4.1
46	CSV 457	17.77	11.6
47	SPH 1280	17.90	8.4
48	AKENT 10-2	18.00	4.4
49	ICSV 93046	18.10	7.5
50	SFCR 1047	18.24	4.4
51	SPV 1576	18.30	8.4
52	RSE 9744	18.33	24.1
53	GMSB 5	18.33	8.2
54	IS 22893	18.36	3.8
55	ICSV 700	18.39	3.9
56	IS 6566	18.48	8.1
57	CSH 9	18.50	24.0
58	SPH 1349	18.52	8.6
59	27 B	18.55	23.9
60	DJ 6514	18.60	6.0
61	CSV 16	18.65	13.6
62	SPH 1350	18.66	8.6
63	SR 1048-1	18.66	15.1
64	ICSV 745	18.70	9.1
65	SFCR 1143	18.72	22.8
66	CSH 14	18.73	17.6
67	ICSV 711	19.17	5.2
68	IS 2312	19.20	22.4

Contd.....

Sr. No.	Sorghum genotype	Panicle length (cm)	Mean no. of earhead bugs/5 panicles
69	SR 1436	19.23	16.1
70	IS 11119	19.28	7.6
71	168 UU 1006	19.31	4.4
72	SPV 1571	19.40	19.9
73	CSH 17	19.47	19.5
74	GD 65055	19.47	10.0
75	200 UU 1011	19.47	15.4
76	CSV 15	19.60	16.3
77	RSE 9728	19.62	23.1
78	ICSV 112	19.63	8.2
79	CSH 7	19.66	26.9
80	AKENT 14	19.77	9.0
81	GMSB 15	19.80	8.5
82	168-II-108	19.91	7.9
	Average	17.96	12.69
20.1-25.0 cm – Panicle length			
83	SPV 1580	20.10	0.0
84	GD 65019	20.23	15.4
85	SR 833-2-3	20.33	19.2
86	SU 663	20.37	15.6
87	168-II-112	20.38	4.0
88	SPV 1569	20.40	12.3
89	GMSB 4	20.45	7.9
90	GD 65195	20.49	7.6
91	SPH 1375	20.50	4.6
92	SPH 1334	20.50	11.0
93	SFCR 1070	20.53	22.7
94	SPH 1329	20.66	13.8
95	168 IU 1021	20.69	13.9
96	RSE 9745	20.73	9.2
97	SPV 1574	20.80	6.7
98	SR 2704	20.81	12.4
99	GMSB 131	20.83	8.0
100	SPV 1567	20.90	12.3
101	SFCR 1105	20.93	23.1
102	SPV 1565	21.10	8.5
103	IS 4663	21.36	8.4

Contd.....

Sr. No.	Sorghum genotype	Panicle length (cm)	Mean no. of earhead bugs/5 panicles
104	SU 52	21.47	12.0
105	SPH 1374	21.50	27.1
106	SFCR 1111	21.63	30.9
107	SPV 1581	21.66	16.3
108	SPH 1335	21.83	16.0
109	RSU 283	21.84	3.8
110	200-1011	21.90	17.6
111	SPV 1570	22.30	9.3
112	168 UU 1022	22.53	7.7
113	IS 2123	22.54	7.7
114	GD 65174-1	22.54	0.0
115	SPV 1575	22.60	16.5
116	IS 1044	22.70	11.5
117	168 II 122	22.73	7.8
118	SPV 1577	22.90	11.1
119	CH 3	23.12	15.2
120	SPH 1354	23.33	19.0
121	CSH 16	23.35	15.9
122	GD 65040	23.40	11.4
123	296-B	23.48	15.8
124	SPH 1355	23.50	19.8
125	SPH 1376	23.66	11.8
126	ICSR 93034	23.78	17.5
127	SPH 1353	23.83	18.0
128	SPV 1578	24.00	21.8
129.	S 35	24.13	15.5
130.	CSH 5	24.16	23.7
131.	SPV 1573	24.20	0.0
132.	SR 2459	24.32	26.7
133.	GD 65006	24.57	15.3
134.	AKENT 7-1-1	24.88	5.9
135.	GD 65004	24.88	15.2
	Average	**22.11**	**13.21**
25.1-30.0 cm – Panicle length			
136.	296-A	25.22	26.5
137.	SPH 1347	25.50	20.1
138.	GD 65022	25.51	11.3
139.	Swati	25.91	17.0
140.	SPH 1341	26.5	20.1

Contd.....

Sr. No.	Sorghum genotype	Panicle length (cm)	Mean no. of earhead bugs/5 panicles
141.	Amarnath	26.52	15.6
142.	SPH 1372	26.66	12.7
143.	NT 52	26.82	17.1
144.	ICSV-1	27.16	23.0
145.	AKENT 16	27.55	8.2
146.	RSE 9741	28.13	6.5
147.	IS 25596	28.24	0.0
148.	Khawang Pahwang	28.39	0.0
149.	IS 20016	28.91	0.0
150.	SDSL 92131	28.96	0.0
	Average	**27.06**	**11.87**
	S.E. ±	1.42	

Category-I i.e. (0.0 to 10.0 cm length), no sorghum entry was included. While Category-II included twenty, Category-III included sixty two, Category-IV included fifty three and Category-V included fifteen sorghum genotypes (Table 11a). In Category-II, the least (10.34 cm) panicle length was observed in genotype SRF 2102, followed by SRF 1665 (12.00 cm) and SU45 (12.29 cm), it was maximum (14.90 cm) in entry SPV 1568. Average panicle length in this category was 13.63 cm and the mean number of bugs/5 panicles were 10.26 (Table 11b).

In Category-III, genotypes AKENT 15, had the least (15.11 cm) panicle length and it was maximum (19.91 cm) in entry 168-II-108. In this category, the mean number of bugs/5 panicles were maximum (29.0) in genotype SR 2458 and were least (1.2) in genotype SU 699. In Category-IV, entry SPV 1580 had the least (20.10 cm) panicle length and it was followed by GD 65019 (20.23 cm) and SR 833-2-3 (20.33 cm) and it was maximum (24.88 cm) in genotype GD 65004. The mean number of bugs per 5 panicles varied from 0.0 in genotype SPV 1580 to 30.9 in genotype SFCR 1111 (Table 11b). In Category-V, genotype 296-A had the smallest panicle length (25.22 cm) and entry SDSL 92131 had the maximum (28.96 cm). The mean number of bugs/5 panicles were least (0.0) in genotypes Khawang Pahwang, IS 20016 and SDSL 92131. The average panicle length (in cm) in Category-I, II, III, IV and V was 13.63, 17.21, 22.11 and 27.06 cm with mean number of bugs/5

panicles were 10.26, 12.69, 13.21 and 11.87, respectively. Length of panicles showed a positive correlation (r=0.123) with pest incidence (Table-19).

Breadth of panicle (cm)

One hundred and fifty sorghum genotypes were categorized on the basis of breadth of panicle (cm) into 5 different categories (Table 12a). Category one included seventy six entries and the average breadth of these genotypes was 4.17 cm and mean number of bugs/5 panicles were 7.23 bugs. Least (2.5 cm) panicle breadth was observed in genotype ICSV 708 followed by ICSV 714 (2.6 cm) and AKENT 8-3 (2.8 cm) and maximum (5.0 cm) panicle breadth was observed in genotype SFCR 1047. In second category, a total of seventy sorghum genotypes were included and the least (5.1 cm) panicle breadth was observed in genotypes IS 2123, SPV 1578, CSH 17 and SFCR 1070 and maximum (9.6 cm) panicle breadth was observed in entry SPH 1329, having mean panicle breadth of 6.42 cm and the mean number of bugs/5 panicles were 13.85 bugs (Table 12b). In category-III, only 2 genotypes SPV 1573 and GD 65174-1 were included with panicle breadth of 11.4 and 14.7 cm, respectively. In this category the mean panicle breadth was 13.05 cm and with no bugs/population. Category five also included two entries, Khawang Pahawang and SDSL 92131 with panicle breadth of 20.1 and 22.5 cm respectively having mean panicle breadth of 21.3 cm with no bugs presence. No sorghum genotype was included in

Table 12a. Sorghum genotypes categorized into different groups on the basis of breadth of panicle.

Category	Breadth of sorghum panicle (cm) (Range)	Number of sorghum genotypes	Mean breadth of sorghum panicle (cm)	Mean no.of bugs/5 panicles	Sorghum genotypes
1	0.0 to 5.0	76	4.17	7.27	ICSV 708, ICSV 714, AKENT 8-3, SRF 2102, SPV 1605, DSFR-2, AKMS 14-A, IS 22893, SPV 1576, IS 6566, IS 112, 27-B, RSU 202,ICSV 112, 296-B, SR 2458, IS 11119, SPV 1579, SU 700, RSE 9727, ICSV 745, ICSV 93046, GMSB 5, SPV 1562, SR 1436, GD 65019, AKENT 10-1, SRF 1665, RSU 283, 168-UU-1006, GMSB 131, SU 52, AKENT 15, 463-A, 168-II-112, GMSB 76, IS 4663, GD 65195, SU 663, CSV 457, SR 770-2, CSH 7, SDH 1352, SU 699, RSE 9745, SR 2460-1, CSH 3, 168-IU-1021, SR 2460, IS 1044, RSE 9715, 168-II-108, RSU 158, ICSV 700, SPH 1280, SR 1048-1, CSH 14, SPV 1567, SPV 1571, GSSV 312, GD 65055, GMSB 4, SPV 1575, SPV 1577, CSV 16, SPV 1568, SRF 203, 168-II-122, CSH 16, SR 2704, 296-A, RSE 9728, ICSR 93034, 168-UU-1022, GMSB 69, SFCR 1047
2	5.1 to 10.0	70	6.42	13.85	IS 2123, SPV 1578, CSH 17, SFCR 1070, SPV 1574, SPH 1375, ICSV 705, SU 45, AKENT 10-2, ICSV 711, DSFR-3, 200-UU-1011, SPH 1183, AKENT 14, GD 65006, SPV 1570, CSV 15, GD 65004, SR 2459, DJ 6514, SPH 1334, GD 65040, AKENT 7-1-1, SPV 1565, SPV 1569, 200-1011, GD 65022, SR 833-2-3, AKENT 16, GMSB 15, IS 18551, IS 2269, SPH 1349, S-35, SPH 1350, SPV 1563, SPH 1335, SPH 1376, SPH 1341, SRF 2549, SPH 1374, NT 52, SFCR 1143, Amarnath, SPH 1354, SPH 1347, Swati, SPH 1355, SFCR 1105, RSE 9741, SFCR 1111, 200-IU-1005, CSH 9, SPH 1353, SPH 1372, RSE 9744, SPV 1580, RSV 204, ICSV 717, CSH 5, IS 2205, DSFR 5, ICSV-1, BT X 623, IS 2312, IS 2122, SPV 1581, IS 20016, IS 25596, SPH 1329
3	10.1 to 15.0	2	13.05	--	SPV 1573, GD 65174-1
4	15.1 to 20.0	0	--	--	Nil
5	20.1 to 25.0	2	21.3	--	Khawang Pahawang, SDSL 92131

Table 12b. Sorghum genotypes categorized on the basis of breadth of panicle

Sr. No.	Sorghum genotype	Breadth (cm)	Mean no. of earhead bugs/5 panicles
0.0 – 5.0 cm – Panicle breadth			
1	ICSV 708	2.5	17.2
2	ICSV 714	2.6	5.4
3	AKENT 8-3	2.8	3.8
4	SRF 2102	2.9	12.8
5	SPV 1605	3.2	4.3
6	DSFR-2	3.3	11.6
7	AKMS 14-A	3.4	12.5
8	IS 22893	3.5	3.8
9	SPV 1576	3.5	8.4
10	IS 6566	3.5	8.1
11	IS 112	3.5	18.6
12	27-B	3.5	23.9
13	RSU 202	3.6	5.3
14	ICSV 112	3.6	8.2
15	296-B	3.6	15.8
16	SR 2458	3.6	29.0
17	IS 11119	3.8	7.6
18	SPV 1579	3.8	15.4
19	SU 700	3.8	11.4
20	RSE 9727	3.8	12.2
21	ICSV 745	3.9	9.1
22	ICSV 93046	3.9	7.5
23	GMSB 5	3.9	8.2
24	SPV 1562	3.9	16.0
25	SR 1436	3.9	16.1
26	GD 65019	4.0	15.4
27	AKENT 10-1	4.0	23.1
28	SRF 1665	4.0	15.5
29	RSU 283	4.1	3.8
30	168-UU-1006	4.1	4.4
31	GMSB 131	4.1	8.0
32	SU 52	4.1	12.0

Contd.....

Sr. No.	Sorghum genotype	Breadth (cm)	Mean no. of earhead bugs/5 panicles
33	AKENT 15	4.2	3.8
34	463-A	4.2	3.9
35	168-II-112	4.2	4.0
36	GMSB 76	4.2	4.1
37	IS 4663	4.2	8.4
38	GD 65195	4.2	7.6
39	SU 663	4.2	15.6
40	CSV 457	4.2	11.6
41	SR 770-2	4.2	23.2
42	CSH 7	4.2	26.9
43	SDH 1352	4.3	6.1
44	SU 699	4.3	1.2
45	RSE 9745	4.3	9.2
46	SR 2460-1	4.3	15.8
47	CSH 3	4.3	15.2
48	168-IU-1021	4.3	13.9
49	SR 2460	4.4	12.1
50	IS 1044	4.4	11.5
51	RSE 9715	4.5	3.8
52	168-II-108	4.6	7.9
53	RSU 158	4.7	1.0
54	ICSV 700	4.9	3.9
55	SPH 1280	4.7	8.4
56	SR 1048-1	4.7	15.1
57	CSH 14	4.7	17.6
58	SPV 1567	4.7	12.3
59	SPV 1571	4.7	19.9
60	GSSV 312	4.8	7.5
61	GD 65055	4.8	10.0
62	GMSB 4	4.8	7.9
63	SPV 1575	4.8	16.5
64	SPV 1577	4.8	11.1
65	CSV 16	4.8	13.6
66	SPV 1568	4.8	19.1
67	SRF 203	4.8	19.0
68	168-II-122	4.9	7.8

Contd.....

Sr. No.	Sorghum genotype	Breadth (cm)	Mean no. of earhead bugs/5 panicles
69	CSH 16	4.9	15.9
70	SR 2704	4.9	12.4
71	296-A	4.9	26.5
72	RSE 9728	5.0	23.1
73	ICSR 93034	5.0	17.5
74	168-UU-1022	5.0	7.7
75	GMSB 69	5.0	8.1
76	SFCR 1047	5.0	4.4
	Average	**4.17**	**7.23**
5.1 – 10.0 cm – Panicle breadth			
77	IS 2123	5.1	7.7
78	SPV 1578	5.1	21.8
79	CSH 17	5.1	19.5
80	SFCR 1070	5.1	22.7
81	SPV 1574	5.2	6.7
82	SPH 1375	5.2	4.6
83	ICSV 705	5.2	4.0
84	SU 45	5.2	12.5
85	AKENT 10-2	5.3	4.4
86	ICSV 711	5.3	5.2
87	DSFR-3	5.3	8.5
88	200-UU-1011	5.3	15.4
89	SPH 1183	5.4	4.1
90	AKENT 14	5.4	9.0
91	GD 65006	5.4	15.3
92	SPV 1570	5.6	9.3
93	CSV 15	5.6	16.3
94	GD 65004	5.6	15.2
95	SR 2459	5.6	26.7
96	DJ 6514	5.7	6.0
97	SPH 1334	5.7	11.0
98	GD 65040	5.7	11.4
99	AKENT 7-1-1	5.8	5.9
100	SPV 1565	5.8	8.5
101	SPV 1569	6.0	12.3

Contd.....

Sr. No.	Sorghum genotype	Breadth (cm)	Mean no. of earhead bugs/5 panicles
102	200-1011	6.0	17.6
103	GD 65022	6.0	11.3
104	SR 833-2-3	6.0	19.2
105	AKENT 16	6.1	8.2
106	GMSB 15	6.1	8.5
107	IS 18551	6.2	3.7
108	IS 2269	6.2	4.0
109	SPH 1349	6.2	8.6
110	S-35	6.2	15.5
111	SPH 1350	6.3	8.6
112	SPV 1563	6.3	16.6
113	SPH 1335	6.3	16.0
114	SPH 1376	6.3	11.8
115	SPH 1341	6.3	20.1
116	SRF 2549	6.4	25.7
117	SPH 1374	6.4	27.1
118	NT 52	6.5	17.1
119	SFCR 1143	6.6	22.8
120	Amarnath	6.7	15.6
121	SPH 1354	6.7	19.0
122	SPH 1347	6.7	20.1
123	Swati	6.8	17.0
124	SPH 1355	6.8	19.8
125	SFCR 1105	6.8	23.1
126	RSE 9741	6.9	6.5
127	SFCR 1111	6.9	30.9
128	200-IU-1005	7.0	19.1
129	CSH 9	7.0	24.0
130	SPH 1353	7.1	18.0
131	SPH 1372	7.2	12.7
132	RSE 9744	7.2	24.1
133	SPV 1580	7.2	0.0
134	RSV 204	7.3	15.1
135	ICSV 717	7.3	17.7
136	CSH 5	7.3	23.7
137	IS 2205	7.6	8.2

Contd.....

Sr. No.	Sorghum genotype	Breadth (cm)	Mean no. of earhead bugs/5 panicles
138	DSFR 5	7.7	25.6
139	ICSV-1	7.8	23.0
140	BT X 623	7.9	11.8
141	IS 2312	8.0	22.4
142	IS 2122	8.2	9.9
143	SPV 1581	8.7	16.3
144	IS 20016	8.7	0.0
145	IS 25596	8.7	0.0
146	SPH 1329	9.6	13.8
	Average	**6.42**	**13.85**
10.1 – 15.0 cm – Panicle breadth			
147	SPV 1573	11.4	0.0
148	GD 65174-1	14.7	0.0
	Average	**13.05**	**--**
15.1 – 20.0 cm – Panicle breadth		NIL	
20.1 – 25.0 cm – Panicle breadth			
149	Khawang Pahawang	20.1	0.0
150	SDSL 92131	22.5	0.0
	Average	**21.30**	**--**
	S.E. ±	.937	

Category IV. It is concluded that as the breadth of panicle increases from a certain level, either there was a reduction in bug population or it was negligible. Breadth of panicle (cm) and the mean number of bugs/5 panicles exhibited a positive correlation (r= 0.465) (Table 19).

The grain weight, length and breadth of panicle and mean number of bugs present on panicle seems to be inter-related with each other. Similar results have earlier been reported by Sharma (1985a), who observed that small grains covered by hairy glumes hindered oviposition by females in comparison to those which had bigger size grain. He also observed that lesser the 1000-grain weight, smaller will be the grain size and lesser will be the population of earhead bugs. As for length and breadth of panicle are concerned, it is already well established by many worker that size of panicle matters in case of deciding the number of head bugs as in case of *C. angustatus,* Sharma and Lopez (1994) recorded that the number of *C. angustatus* increased with increase in size of panicle in susceptible cultivars. They also observed more panicle breadth in loose type of earheads resulting in lesser population of bugs.

Colour of grain

On the basis of grain colour, the one hundred and fifty sorghum genotypes were categorized into different nine categories (Table 13a). Category-I i.e. straw colour, it included 99 sorghum genotypes and the mean number of bug/5 panicles varied from 0.0 to 30.9 with an average

Table 13a. Sorghum genotypes categorized into different groups on the basis of colour of grain.

Category	Colour of sorghum grain	Number of sorghum genotypes	Mean no.of bugs/5 panicles	Sorghum genotypes
1	Straw	99	13.66	SPV 1573, SPV 1580, RSU 158, IS 18551, RSE 9715, RSU 283, AKENT 15, ICSV 705, IS 2269, 168-II-112, SPV 1605, SFCR 1047,SPH 1375, ICSV 711, RSU 202, ICSV 714, AKENT 7-1-1, DJ 6514,SPH 1352, RSE 9741, GSSV 312, IS 2123, GMSB-4, GMSB 131, IS 6566, GMSB 69, AKENT 16, GMSB 5, SPV 1576, IS 4663, SPH 1280, SPV 1565, GMSB 15, AKENT 14, ICSV 745, SPV 1570, IS 2122, SPH 1334, SPV 1577, SU 700, SPH 1376, SU 52, SR 2460, RSE 9727, SPV 1567, SPV 1569, SR 2704, AKMS 14-A, SPH 1372,CSV 16, 168IU 1021, SR 1048-1, RSV 204, CH 3, SPV 1579, 200UU 1011, SRF 1665, SU 663, 296-B, CSH 16, SR 1436, CSV 15, SPV 1581, SPV 1575, SPV 1563, Swati, ICSV 708, ICSR 93034, CSH 14, 200-1011, SPH 1353, IS112, SPH 1354, SRF 203, SPV 1568, 200IU 1005, SR 833-2-3, CSH 17, SPH 1355, SPV 1571, SPH 1347, SSPH 1341, SPV 1578, IS 2312, SFCR 1070, SFCR 1143, ICSV-1, RSE 9728, SFCR 1105, SR 770-2, CSH 5, 27B, CSH 9, RSE 9744, DSFR-5, CSH 7, SPH 1374, SR 2458, SFCR-1111,
2	Milky white	2	12.65	SU 45, SRF 2102
3	White	24	11.41	IS 20016, SU 699, AKENT 8-3, ICSV 700, GMSB 76, SPH 1183, AKENT 10-2, ICSV 93046, ICSV 112, DSFR-3, SPH 1349, IS 1044, DSFR-2, CSV 457, BT X 623, S 35, Amarnath, SR 2460-1, SPH 335, NT 52, ICSV 717, AKENT 10-1, SRF 2549, SR 2459
4	Reddish brown	9	10.42	IS 25596, GD 65195, IS 11119, GD 65055, GD 65022, GD 65040, GD 65004, GD 65006, GD 65019
5	Light Red	11	10.23	463-A, 168UU 1006, SPV 1574, 168 UU 1022, 16811 122, 168 II-108, SPH 1350, RSE 9745, SPH 1329, SPV 1562, 296-A
6	Reddish white	1	8.02	IS 2205
7	Grey	1	3.8	IS 22893
8	Brown	2	0.0	SDSL 92131, GD 65174-1
9	Blackish grey	1	0.0	Khawang Pahawang

Table 13b. Sorghum genotypes categorized on the basis of grain colour.

Straw - Grain colour

Sr. No.	Sorghum genotype	Mean no. of earhead bugs/5 panicles
1.	SPV 1573	0.0
2.	SPV 1580	0.0
3.	RSU 158	1.0
4.	IS 18551	3.7
5.	RSE 9715	3.8
6.	RSU 283	3.8
7.	AKENT 15	3.8
8.	ICSV 705	4.0
9.	IS 2269	4.0
10.	168-II-112	4.0
11.	SPV 1605	4.3
12.	SFCR 1047	4.4
13.	SPH 1375	4.6
14.	ICSV 711	5.2
15.	RSU 202	5.3
16.	ICSV 714	5.4
17.	AKENT 7-1-1	5.9
18.	DJ 6514	6.0
19.	SPH 1352	6.1
20.	RSE 9741	6.5
21.	GSSV 312	7.5
22.	IS 2123	7.7
23.	GMSB-4	7.9
24.	GMSB 131	8.0
25.	IS 6566	8.1
26.	GMSB 69	8.1
27.	AKENT 16	8.2
28.	GMSB 5	8.2
29.	SPV 1576	8.4
30.	IS 4663	8.4
31.	SPH 1280	8.4

Contd.....

Sr. No.	Sorghum genotype	Mean no. of earhead bugs/5 panicles
32.	SPV 1565	8.5
33.	GMSB 15	8.5
34.	AKENT 14	9.0
35.	ICSV 745	9.1
36.	SPV 1570	9.3
37.	IS 2122	9.9
38.	SPH 1334	11.0
39.	SPV 1577	11.1
40.	SU 700	11.4
41.	SPH 1376	11.8
42.	SU 52	12.0
43.	SR 2460	12.1
44.	RSE 9727	12.2
45.	SPV 1567	12.3
46.	SPV 1569	12.3
47.	SR 2704	12.4
48.	AKMS 14-A	12.5
49.	SPH 1372	12.7
50.	CSV 16	13.6
51.	168 IU 1021	13.9
52.	SR 1048-1	15.1
53.	RSV 204	15.1
54.	CH 3	15.2
55.	SPV 1579	15.4
56.	200 UU 1011	15.4
57.	SRF 1665	15.5
58.	SU 663	15.6
59.	296-B	15.8
60.	CSH 16	15.9
61.	SR 1436	16.1
62.	CSV 15	16.3

Contd.....

Sr. No.	Sorghum genotype	Mean no. of earhead bugs/5 panicles
63.	SPV 1581	16.3
64.	SPV 1575	16.5
65.	SPV 1563	16.6
66.	Swati	17.0
67.	ICSV 708	17.2
68.	ICSR 93034	17.5
69.	CSH 14	17.6
70.	200-1011	17.6
71.	SPH 1353	18.0
72.	IS112	18.6
73.	SPH 1354	19.0
74.	SRF 203	19.0
75.	SPV 1568	19.1
76.	200 IU 1005	19.1
77.	SR 833-2-3	19.2
78.	CSH 17	19.5
79.	SPH 1355	19.8
80.	SPV 1571	19.9
81.	SPH 1347	20.1
82.	SSPH 1341	20.1
83.	SPV 1578	21.8
84.	IS 2312	22.4
85.	SFCR 1070	22.7
86.	SFCR 1143	22.8
87.	ICSV-1	23.0
88.	RSE 9728	23.1
89.	SFCR 1105	23.1
90.	SR 770-2	23.2
91.	CSH 5	23.7
92.	27B	23.9
93.	CSH 9	24.0
94.	RSE 9744	24.1
95.	DSFR-5	25.6
96.	CSH 7	26.9

Contd.....

Sr. No.	Sorghum genotype	Mean no. of earhead bugs/5 panicles
97.	SPH 1374	27.1
98.	SR 2458	29.0
99.	SFCR-1111	30.9
	Average	**13.66**
Light Red – Grain colour		
1.	463-A	3.9
2.	168 UU 1006	4.4
3.	SPV 1574	6.7
4.	168 UU 1022	7.7
5.	168 II 122	7.8
6.	168 II-108	7.9
7.	SPH 1350	8.6
8.	RSE 9745	9.2
9.	SPH 1329	13.8
10.	SPV 1562	16.0
11.	296-A	26.5
	Average	**10.23**
Reddish white – Grain colour		
1.	IS 2205	8.2
	Average	**8.2**
White – Grain colour		
1.	IS 20016	0.0
2.	SU 699	1.2
3.	AKENT 8-3	3.8
4.	ICSV 700	3.9
5.	GMSB 76	4.1
6.	SPH 1183	4.1
7.	AKENT 10-2	4.4
8.	ICSV 93046	7.5
9.	ICSV 112	8.2
10.	DSFR-3	8.5
11.	SPH 1349	8.6
12.	IS 1044	11.5

Contd.....

Sr. No.	Sorghum genotype	Mean no. of earhead bugs/5 panicles
13.	DSFR-2	11.6
14.	CSV 457	11.6
15.	BT X 623	11.8
16.	S 35	15.5
17.	Amarnath	15.6
18.	SR 2460-1	15.8
19.	SPH 1335	16.0
20.	NT 52	17.1
21.	ICSV 717	17.7
22.	AKENT 10-1	23.1
23.	SRF 2549	25.7
24.	SR 2459	26.7
	Average	**11.41**
Milky white– Grain colour		
1.	SU 45	12.5
2.	SRF 2102	12.8
	Average	**12.65**
Reddish brown– Grain colour		
1	IS 25596	0.0
2	GD 65195	7.6
3	IS 11119	7.6
4	GD 65055	10.0
5	GD 65022	11.3
6	GD 65040	11.4
7	GD 65004	15.2
8	GD 65006	15.3
9	GD 65019	15.4
	Average	**10.42**
Brown– Grain colour		
1.	SDSL 92131	0.0
2.	GD 65174-1	0.0
Blackish Grey– Grain colour		
1.	Khawang Pahawang	0.0
Grey– Grain colour		
1.	IS 22893	3.8
	Average	**3.8**

of 13.66 bugs. The mean number of bugs/5 panicles were minimum (0.0) in genotype SPV 1573 and SPV 1580 and it was followed by genotype RSU 158 (1.0 bug) and the maximum (30.9 bugs) were observed in genotype SFCR 1111 (Table 13b). Milky white grain colour i.e. category-II, had only 2 sorghum genotypes and the mean number of bugs/5 panicles present were 12.5 and 12.8 in genotypes SU 45 and SRF 2102, respectively. Category-III had white grain colour, and it included 24 sorghum genotypes with mean number of bugs varying from 0.0 to 26.7 with an average mean number of 11.41 bugs. Category IV had reddish brown grain coloured nine genotypes and the mean number of bugs/5 panicles varied from 0 (IS 25596) to 15.4 (GD 65019). Category V: light red grain colour, it had 11 sorghum entries and in this category the number of bugs/5 panicles varied from 3.9 to 26.5 bugs with an overall average of 10.23 bugs/5 panicles. The maximum (26.5 bugs) number of bugs were observed in genotype 296-A and the least (3.9 bugs) in genotype 463-A. Category-VI had reddish white grain colour, this category had only one genotype i.e. IS 2205 and it supported 8.2 bugs/5 panicles (Table 13b).

Category VIII with brown grain colour included two genotypes (GD 65174-1 and SDSL 92131) without having any bug infestation. Two categories i.e. Category IX and Category VII with blackish grey and grey grain colour, each represented by one sorghum genotype i.e. Khawang Pahawang and IS 22893 with 0.0 and 3.8 mean number

of bugs/5 panicles. The mean number of bug/5 panicles observed in all the 9 categories in ascending order were : brown and blackish grey (0.0), grey (3.8), reddish white (8.02), light red (10.23), reddish brown (10.42), white (11.41), milky white (12.65) and straw (13.66) (Table 13b).

It can be concluded from the above results that light coloured i.e. straw, white and milky white coloured grain are more preferred by head bugs, whereas, coloured grains showed less preference. These results draw the support from work done by Sharma and Lopez (1990b, 1991, 1992a, b). They observed that resistant sorghum genotypes i.e. IS 17610, IS 17645, IS 21443 and IS 17618 had dark colour grain while panicle having light coloured grain had increased number of *C. angustatus* in CSH 1 and CSH 5. Similar results were reported by Graham (1916). Colour in grain is largely due to the presence of tannin which act as antifeedant biochemical constituent to pest and its preference for food.

Type of earhead

One hundred and fifty sorghum genotypes were grouped into different categories on the basis of type of earhead present (Table 14a). There were three categories. Category-I comprised of those genotype which had loose type earheads and there were seven such sorghum genotypes, which had no bug infestation (0.0 number of bugs) (Table 14b). Category-II comprised of 133 sorghum genotypes, which had semi-compact type of earheads and

Table 14a. Sorghum genotypes categorized into different groups on the basis of type of earhead.

Category	Type of sorghum earhead	Number of sorghum genotypes	Mean no.of bugs/5 panicles	Sorghum genotypes
1	Loose	7	0.0	SPV 1573, SPV 1580, SDSL 92131, GD 65174-1, IS 25596, IS 20016, Khawang Pahawang
2	Semi-compact	133	12.89	RSU 158, SU 699, IS 18551, RSE 9715, RSU 283, AKENT 15, AKENT 8-3, IS 22893, 1CSV 700, 463-A, ICSV 705, 168-II-112,GMSB 76, SPH 1183, SPV 1605, AKENT 10-2, 168 UU 1006, SFCR 1047, SPH 1375, ICSV 711, RSU 202, ICSV 714, AKENT 7-1-1, DJ 6514, SPH 1352, RSE 9741, SPV 1574, GSSV 312, ICSV 93046, GD 65196, IS 11119, IS 2123, 168UU 1022, 168 II 122, GMSB 4, 168 II 108, GMSB 131, IS 6566, GMSB 69, AKENT 16, ICSV 112, GMSB 5, SPV 1576, IS 4663, SPH 1280, SPV 1565, DSFR-3, GMSB 15, SPH 1349, SPH 1350, AKENT 14, ICSV 745, RSE 9745, SPV 1570, GD 65055, SPH 1334, SPV 1577, GD 65022, SU 700, GD 65040, IS 1044, DSFR 2, CSV 457, SPH 1376, SU 52, SR 2460, RSE 9727, SPV 1567, SPV 1569, SR 2704, AKMS 14-A, SPH 1372, SRF 2102, CSV 16, SPH 1329, 168 IU 1021, SR 1048-1, RSV 204, CH 3, GD 65004, GD 65006, SPV 1579, GD 65019, 200 UU 1011, SRF 1665, S 35, SU 663, Amarnath, SR 2460-1, 296 B, CSH 16, SPV 1562, SPH 1335, SR 1436, CSV 15, SPV 1581, SPV 1575, SPV 1563, Swati, NT 52, ICSV 708, ICSR 93034, CSH 14, 200-1011, SPH 1353, IS112, SPH 1354, SRF 203, SPV 1568, SR 833-2-3, CSH 17, SPH 1355, SPV 1571, SPH 1347, SPH 1341, SPV 1578, SFCR 1070, SFCR 1143, ICSV-1, AKENT 10-1, RSE 9728, SFCR 1105, SR 770-2, CSH 5, 27 B, RSE 9744, SRF 2549, 296-A, SR 2459, CSH 7, SPH 1374, SR 2458, SFCR 1111
3	Compact	10	15.52	IS 2269, IS 2205, IS 2122, BT X 623, SUU 5, ICSV 717, 200 IU 1005, IS 2312, CSH 9, DSFR 5

Table 14b. Sorghum genotypes categorized on the basis of type of ear head

Sr.No.	Sorghum genotype	Mean no. of earhead bugs/5 panicles
Loose-Type of ear head		
1.	SPV 1573	0.0
2.	SPV 1580	0.0
3.	SDSL 92131	0.0
4.	GD 65174-1	0.0
5.	IS 25596	0.0
6.	IS 20016	0.0
7.	Khawang Pahawang	0.0
	Average	**0.0**
Semi-compact -Type of ear head		
1	RSU 158	1.0
2	SU 699	1.2
3	IS 18551	3.7
4	RSE 9715	3.8
5	RSU 283	3.8
6	AKENT 15	3.8
7	AKENT 8-3	3.8
8	IS 22893	3.8
9	1CSV 700	3.9
10	463-A	3.9
11	ICSV 705	4.0
12	168-II-112	4.0
13	GMSB 76	4.1
14	SPH 1183	4.1
15	SPV 1605	4.3
16	AKENT 10-2	4.4
17	168 UU 1006	4.4
18	SFCR 1047	4.4
19	SPH 1375	4.6
20	ICSV 711	5.2
21	RSU 202	5.3
22	ICSV 714	5.4

Contd.....

Sr. No.	Sorghum genotype	Mean no. of earhead bugs/5 panicles
23	AKENT 7-1-1	5.9
24	DJ 6514	6.0
25	SPH 1352	6.1
26	RSE 9741	6.5
27	SPV 1574	6.7
28	GSSV 312	7.5
29	ICSV 93046	7.5
30	GD 65196	7.6
31	IS 11119	7.6
32	IS 2123	7.7
33	168UU 1022	7.7
34	168 II 122	7.8
35	GMSB 4	7.9
36	168 II 108	7.9
37	GMSB 131	8.0
38	IS 6566	8.1
39	GMSB 69	8.1
40	AKENT 16	8.2
41	ICSV 112	8.2
42	GMSB 5	8.2
43	SPV 1576	8.4
44	IS 4663	8.4
45	SPH 1280	8.4
46	SPV 1565	8.5
47	DSFR-3	8.5
48	GMSB 15	8.5
49	SPH 1349	8.6
50	SPH 1350	8.6
51	AKENT 14	9.0
52	ICSV 745	9.1
53	RSE 9745	9.2
54	SPV 1570	9.3
55	GD 65055	10.0
56	SPH 1334	11.0
57	SPV 1577	11.1
58	GD 65022	11.3
59	SU 700	11.4

Contd.....

Sr. No.	Sorghum genotype	Mean no. of earhead bugs/5 panicles
60	GD 65040	11.4
61	IS 1044	11.5
62	DSFR 2	11.6
63	CSV 457	11.6
64	SPH 1376	118
65	SU 52	12.0
66	SR 2460	12.1
67	RSE 9727	12.2
68	SPV 1567	12.3
69	SPV 1569	12.3
70	SR 2704	12.4
71	AKMS 14-A	12.5
72	SPH 1372	12.7
73	SRF 2102	12.8
74	CSV 16	13.6
75	SPH 1329	13.8
76	168 IU 1021	13.9
77	SR 1048-1	15.1
78	RSV 204	15.1
79	CH 3	15.2
80	GD 65004	15.2
81	GD 65006	15.3
82	SPV 1579	15.4
83	GD 65019	15.4
84	200 UU 1011	15.4
85	SRF 1665	15.5
86	S 35	15.5
87	SU 663	15.6
88	Amarnath	15.6
89	SR 2460-1	15.8
90	296 B	15.8
91	CSH 16	15.9
92	SPV 1562	16.0
93	SPH 1335	16.0
94	SR 1436	16.1

Contd.....

Sr. No.	Sorghum genotype	Mean no. of earhead bugs/5 panicles
95	CSV 15	16.3
96	SPV 1581	16.3
97	SPV 1575	16.5
98	SPV 1563	16.6
99	Swati	17.0
100	NT 52	17.1
101	ICSV 708	17.2
102	ICSR 93034	175
103	CSH 14	17.6
104	200-1011	17.6
105	SPH 1353	18.0
106	IS112	18.6
107	SPH 1354	19.0
108	SRF 203	19.0
109	SPV 1568	19.1
110	SR 833-2-3	19.2
111	CSH 17	19.5
112	SPH 1355	19.8
113	SPV 1571	19.9
114	SPH 1347	20.1
115	SPH 1341	20.1
116	SPV 1578	21.8
117	SFCR 1070	22.7
118	SFCR 1143	22.8
119	ICSV-1	23.0
120	AKENT 10-1	23.1
121	RSE 9728	23.1
122	SFCR 1105	23.1
123	SR 770-2	23.2
124	CSH 5	23.7
125	27 B	23.9
126	RSE 9744	24.1
127	SRF 2549	25.7
128	296-A	26.5
129	SR 2459	26.7

Contd.....

Sr. No.	Sorghum genotype	Mean no. of earhead bugs/5 panicles
130	CSH 7	26.9
131	SPH 1374	27.1
132	SR 2458	29.0
133	SFCR 1111	30.9
	Average	**12.89**
Compact-Type of ear head		
1	IS 2269	4.0
2	IS 2205	8.2
3	IS 2122	9.9
4	BT X 623	11.8
5	SUU 5	12.5
6	ICSV 717	17.7
7	200 IU 1005	19.1
8	IS 2312	22.4
9	CSH 9	24.0
10	DSFR 5	25.6
	Average	**15.52**

the mean number of bugs/5 panicles varied from 1.0 to 30.9 with an average of 12.89 bugs/5 panicles. The mean number of bugs/5 panicles were least (1.0) in genotype RSU 158 and the maximum (30.9) in genotype SFCR 1111. In III Category, the sorghum genotypes had compact type of earheads and there were ten entries in this category. Mean number of bugs/5 panicles in these genotypes varied from 4.0 to 25.6 bugs, being least (4.0) in genotype IS 2269 and was maximum (25.6) in genotype DSFR 5 with an average population of 15.52 bugs/5 panicles (Table 14b).

It can be concluded from the data that loose type of earheads were least preferred and semi-compact and compact type of earheads were most preferred; because compact type of earhead provide good environmental conditions to get establish the headbugs and also protect them from abiotic parameters. Compact and semi-compact type of earheads support more number of earheads bugs as compared to loose type of earheads. Similar results had earlier been reported by Sharma *et al.* (1994a). They had observed low population of *C. angustatus* in genotype with loose type of panicle, compactness attract more number of head bugs, because it protects and shield them from natural parameters i.e. abiotic and biotic factors (Sharma, 1985a; Sharma *et al.*, 1994b).

Table 15a. Sorghum genotypes categorized into different groups on the basis of colour of the glume.

Category	Colour of glume	Number of sorghum genotypes	Mean no.of bugs/5 panicles	Sorghum genotypes
1	Tan	57	7.12	SDSL 92131, GD 65174-1, IS 25596, IS 20016, RSU 158, SU 699, IS 18551, RSE 9715, RSU 283, AKENT 15, IS 22893, ICSV 700, 463-A ICSV 705, IS 2269, 168-II-112, GMSB 76, SPH 1183, SPV 1605, AKENT 10-2, SPH 1375, RSU 202, ICSV 714, DJ 6514, SPH 1352, RSE 9741, GSSV 312, ICSV 93046, GD 65195, IS 11119, IS 2123, IS 2205, AKENT 16, ICSV 112, IS 4663, DSFR-3, SPH 1349, SPH 1350, AKENT 14, RSE 9745, GD 65055, GD 65022, SU 700, GD 65040, IS 1044, BT X 623, RSE 9727, SPH 1329, GD 65004, GD 65006, GD 65019, 296-B, ICSV 708, ICSV 717, IS 112, IS 2312, 296-A
2	Straw	93	15.12	SPV 1573, SPV 1580, Khawang Pahawang, AKENT 8-3, 168 UU 1006, SFCR 1047, ICSV 711, AKENT 7-1-1, SPV 1574, 168 UU 1022, 168 II 122, GMSB 4, 168 II 108, GMSB 131, IS 6566, GMSB 69, GMSB 5, SPV 1576, SPH 1280, SPV 1565, GMSB 15, ICSV 745, SPV 1570, IS 2122, SPH 1334, SPV 1577, DSFR-2, CSV 457, SPH 1376, SU 52, SR 2460, SPV 1567, SPV 1569, SR 2704, AKMS 14-A, SU 45, SPH 1372, SRF 2102, CSV 16, 168 IU 1021, SR 1048-1, RSV 204, CH 3, SPV 1579, 200 UU 1011, SRF 1665, S-35, SU 663, Amarnath, SR 2460-1, CSH 16, SPV 1562, SPH 1335, SR 1436, CSV 15, SPV 1581, SPV 1575, SPV 1563, Swati, NT 52, ICSR 93034, CSH 14, 200 – 1011, SPH 1353, SPH 1354, SRF 203, SPV 1568, 200 IU 1005, SR 833-2-3, CSH 17, SPH 1355, SPV 1571, SPH 1347, SPH 1341, SPV 1578, SFCR 1070, SFCR 1143, ICSV-1, AKENT 10-1, RSE 9728, SFCR 1105, SR770-2, CSH 5, 27B, CSH 9, RSE 9744, DSFR-5, SRF 2549, SR 2459, CSH 7, SPH 1374, SR 2458, SFCR 1111

Table 15b. Sorghum genotypes categorised on the basis of colour of glume

Sr. No.	Sorghum genotype	Mean no. of earhead bugs/5 panicles
Tan - Colour of Glume		
1	SDSL 92131	0.0
2	GD 65174-1	0.0
3	IS 25596	0.0
4	IS 20016	0.0
5	RSU 158	1.0
6	SU 699	1.2
7	IS 18551	3.7
8	RSE 9715	3.8
9	RSU 283	3.8
10	AKENT 15	3.8
11	IS 22893	3.8
12	ICSV 700	3.9
13	463-A	3.9
14	ICSV 705	4.0
15	IS 2269	4.0
16	168-II-112	4.0
17	GMSB 76	4.1
18	SPH 1183	4.1
19	SPV 1605	4.3
20	AKENT 10-2	4.4
21	SPH 1375	4.6
22	RSU 202	5.3
23	ICSV 714	5.4
24	DJ 6514	6.0
25	SPH 1352	6.1
26	RSE 9741	6.5
27	GSSV 312	7.5
28	ICSV 93046	7.5
29	GD 65195	7.6
30	IS 11119	7.6
31	IS 2123	7.7
32	IS 2205	8.2
33	AKENT 16	8.2
34	ICSV 112	8.2

Contd.....

Sr. No.	Sorghum genotype	Mean no. of earhead bugs/5 panicles
35	IS 4663	8.4
36	DSFR-3	8.5
37	SPH 1349	8.6
38	SPH 1350	8.6
39	AKENT 14	9.0
40	RSE 9745	9.2
41	GD 65055	10.0
42	GD 65022	11.3
43	SU 700	11.4
44	GD 65040	11.4
45	IS 1044	11.5
46	BT X 623	11.8
47	RSE 9727	12.2
48	SPH 1329	13.8
49	GD 65004	15.2
50	GD 65006	15.3
51	GD 65019	15.4
52	296-B	15.8
53	ICSV 708	17.2
54	ICSV 717	17.7
55	IS 112	18.6
56	IS 2312	22.4
57	296-A	26.5
	Average	**7.12**
Straw - Colour of Glume		
1	SPV 1573	0.0
2	SPV 1580	0.0
3	Khawang Pahawang	0.0
4	AKENT 8-3	3.8
5	168 UU 1006	4.4
6	SFCR 1047	4.4
7	ICSV 711	5.2
8	AKENT 7-1-1	5.9
9	SPV 1574	6.7
10	168 UU 1022	7.7
11	168 II 122	7.8

Contd.....

Sr. No.	Sorghum genotype	Mean no. of earhead bugs/5 panicles
12	GMSB 4	7.9
13	168 II 108	7.9
14	GMSB 131	8.0
15	IS 6566	8.1
16	GMSB 69	8.1
17	GMSB 5	8.2
18	SPV 1576	8.4
19	SPH 1280	8.4
20	SPV 1565	8.5
21	GMSB 15	8.5
22	ICSV 745	9.1
23	SPV 1570	9.3
24	IS 2122	9.9
25	SPH 1334	11.0
26	SPV 1577	11.1
27	DSFR-2	11.6
28	CSV 457	11.6
29	SPH 1376	11.8
30	SU 52	12.0
31	SR 2460	12.1
32	SPV 1567	12.3
33	SPV 1569	12.3
34	SR 2704	12.4
35	AKMS 14-A	12.5
36	SU 45	12.5
37	SPH 1372	12.7
38	SRF 2102	12.8
39	CSV 16	13.6
40	168 IU 1021	13.9
41	SR 1048-I	15.1
42	RSV 204	15.1
43	CH 3	15.2
44	SPV 1579	15.4
45	200 UU 1011	15.4
46	SRF 1665	15.5
47	S-35	15.5
48	SU 663	15.6
49	Amarnath	15.6
50	SR 2460-1	15.8

Contd.....

Sr. No.	Sorghum genotype	Mean no. of earhead bugs/5 panicles
51	CSH 16	15.9
52	SPV 1562	16.0
53	SPH 1335	16.0
54	SR 1436	16.1
55	CSV 15	16.3
56	SPV 1581	16.3
57	SPV 1575	16.5
58	SPV 1563	16.6
59	Swati	17.0
60	NT 52	17.1
61	ICSR 93034	17.5
62	CSH 14	17.6
63	200 - 1011	17.6
64	SPH 1353	18.0
65	SPH 1354	19.0
66	SRF 203	19.0
67	SPV 1568	19.1
68	200 IU 1005	19.1
69	SR 833-2-3	19.2
70	CSH 17	19.5
71	SPH 1355	19.8
72	SPV 1571	19.9
73	SPH 1347	20.1
74	SPH 1341	20.1
75	SPV 1578	21.8
76	SFCR 1070	22.7
77	SFCR 1143	22.8
78	ICSV-1	23.0
79	AKENT 10-1	23.1
80	RSE 9728	23.1
81	SFCR 1105	23.1
82	SR770-2	23.2
83	CSH 5	23.7
84	27B	23.9
85	CSH 9	24.0
86	RSE 9744	24.1
87	DSFR-5	25.6
88	SRF 2549	25.7
89	SR 2459	26.7
90	CSH 7	26.9

Contd.....

Sr. No.	Sorghum genotype	Mean no. of earhead bugs/5 panicles
91	SPH 1374	27.1
92	SR 2458	29.0
93	SFCR 1111	30.9
	Average	**15.12**

Colour of glume

One hundred and fifty sorghum genotypes were categorized into two categories on the basis of colour of glume (Table 15a). Category-I, tan colour glume, included a total of 57 sorghum genotypes and the number of bugs/5 panicles varied from 0.0 to 26.5 bugs with an average of 7.12 bugs/5 panicles. Mean number of bugs/5 panicles were maximum (26.5 bugs) in genotype 296-A and were least (0.0) in genotype SDSL 92131 (Table 15b).

Straw colour glume category, included 93 sorghum genotypes and the mean number of bugs/5 panicles varied from 0.0 to 30.9 bugs being minimum (0.0) in genotypes SPV 1573, SPV 1580 and Khawang Pahawang and maximum (30.9) in genotype SFCR 1111 with an average mean population of 15.12 bugs (Table 15b) showing preference of earheads with straw coloured glume as compared to earheads with tan coloured glumes. It can be concluded from the present studies that head bugs were attracted by those genotypes which had straw coloured glume. Graham (1916) reported similar results that incidence of head bugs was lesser on sorghum genotypes with dark coloured glume..

Studies on biochemical constituents in relation to head bug incidence on sorghum panicle

Biochemical constituents of ten sorghum genotypes, five each from resistant and susceptible groups were analysed and were correlated with mean number of earhead bugs/5 panicles on these genotypes. The

following biochemical constituents of mature and immature grains were analysed and results are presented in Table 16, 17 and 18.

Carbohydrates (mg/g)

Total sugar – The data presented in Table 16 showed that the amount of total sugar in immature grains ranged from 27.78 mg/g (SPH 1352) to 32.28 mg/g (AKENT 7-1) with a mean of 29.10 mg/g of total sugar in resistant genotypes while the susceptible genotypes had a mean of 39.32 mg/g of total sugar, ranging from 24.38 mg/g in genotype (SRF 2102 to 48.53 mg/g in genotype SFCR 1111). All the differences for total sugar in immature grains amongst the different genotypes were significant and showed a positive correlation (r= 0.884) with pest incidence (Table 19).

It is evident from Table 16 that there was a reduction in total sugar content in mature grains, but the total sugar was low in resistant genotypes as compared to susceptible ones. In resistant genotypes, ICSV 711 had the minimum (12.02 mg/g) total sugar and it was maximum (14.98 mg/g) in genotype DJ 6514 with an average mean total sugar of 13.86 mg/g. In susceptible entries total sugar in mature grains ranged from 11.75 to 18.24 mg/g and it was minimum (11.75 mg/g) in SRF 2102 and it was maximum (18.24 mg/g) in genotype IS 112 with an average mean total sugar of 16.13 mg/g (Fig. 8).

Table 16. Biochemical constituents of mature and immature grains of sorghum genotypes in relation to earhead bugs incidence.

Carbohydrates (mg/g)

Varieties	Bugs population+	Total sugar		Reducing sugar		Non-reducing sugar	
		Immature* grains	Mature** grains	Immature* grains	Mature** grains	Immature* grains	Mature** grains
Resistant group							
ICSV 714	16.2	27.85	14.90	18.64	9.21	9.21	5.69
AKENT 7-1	17.7	32.28	12.48	14.21	7.18	18.07	5.30
ICSV 711	15.6	28.30	12.02	17.24	7.17	11.06	4.85
SPH 1352	18.3	27.78	14.94	18.36	8.57	9.42	6.37
DJ 6514	18.0	29.30	14.98	13.65	8.97	15.65	6.01
Mean	17.2	29.10	13.86	16.42	8.22	12.68	5.64
Susceptible group							
IS 2312	67.2	47.33	17.45	22.17	10.94	25.26	6.51
IS 112	55.8	39.15	18.24	20.97	9.93	18.18	8.31
SR 1048-1	45.3	37.19	17.04	19.74	10.23	17.45	6.81
SRF 2102	38.4	24.38	11.75	18.75	6.45	5.63	5.30
SFCR 1111	92.7	48.53	16.15	17.49	8.72	31.04	7.43
Mean	59.9	39.32	16.13	19.82	9.25	19.51	6.87
S.Em.±		0.027	0.040	0.038	0.053	0.039	0.049
CD(P=0.05)		0.079	0.119	0.114	0.158	0.118	0.146

+Mean number of earhead bugs/5 panicles

*Immature grains : 85 to 95 days after sowing.

**Mature grains: At harvest.

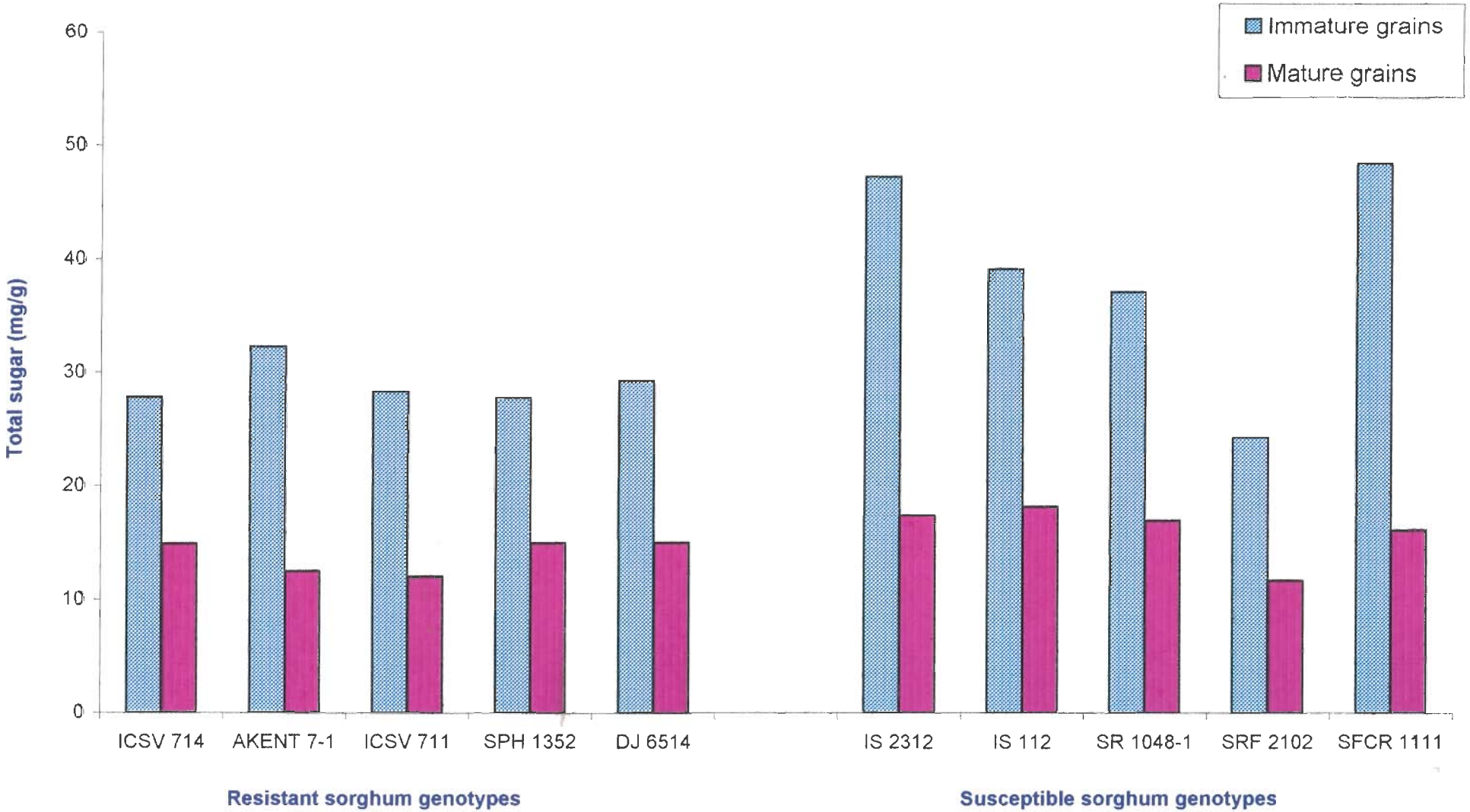

Fig. 8: Amount of total sugar (mg/g) in grains of different sorghum genotypes

Total sugar in immature grain and mature grain showed a positive correlation with head bug population (r = .884 and .360, respectively).

Reducing sugar - The data presented in Table 16 showed the amount of reducing sugar present in different genotypes of sorghum. In resistant genotypes, the amount of reducing sugar in immature grains was maximum (18.64 mg/g) in genotype ICSV 714 and was minimum (13.65 mg/g) in genotype DJ 6514 with an average mean of 16.42 mg/g. In susceptible group, the reducing sugar was minimum (17.49 mg/g) in genotype SFCR 1111 and was maximum (22.17 mg/g) in genotype IS 2312 with an average mean of 19.82 mg/g. In mature grains, the amount of reducing sugar decreased and it was lowest (6.45 mg/g) in genotype SRF 2102 and was maximum (10.94 mg/g) in genotype IS 2312 with an average mean of 9.25 mg/g). In resistant genotypes reducing sugar varied from 7.17 to 9.21 mg/g being least (7.17) in genotype ICSV 711 and maximum (9.21 mg/g) in genotype ICSV 714. Reducing sugar also showed a positive correlation with head bug incidence in immature and mature grains (r= 0.497, 0.211) (Table 19).

Non reducing sugar - The data pertaining to non-reducing sugars in immature and mature grains of susceptible and resistant sorghum genotypes is given in Table 16. In resistant genotypes, the amount of non-reducing sugars varied from 9.21 to 18.07 mg/g, being minimum (9.21 mg/g) in resistant genotype ISCV 714 and

was maximum (18.07 mg/g) in genotype AKENT 7-1 with an average mean of 12.68 mg/g, while in susceptible genotypes, the amount of non-reducing sugar ranged from 5.63 mg/g in SRF 2102 to 31.04 mg/g in SFCR 1111 with mean amount 19.51 mg/g. In case of mature grains, in resistant genotypes, the non-reducing sugar ranged from 4.85 mg/g in ICSV 714 to 6.37 mg/g in SPH 1352 with mean amount 5.64 mg/g while in susceptible group, mean amount was 6.87 of mg/g of non-reducing sugar and it ranged from 5.30 mg/g in SRF 2102 to 8.31 mg/g in IS 2312 (Table 19).

The correlation coefficient (r= 0.799 and 0.472) between non-reducing sugar in immature and mature grains and head bug population exhibited positive relationship.

Total sugar and reducing sugar varied greatly in grains of sorghum genotypes alongwith non-reducing sugar and showed a significant positive relationship with pest incidence at immature stages of panicle development. As sugar is an important vital nutrient in grain and differences in relative amounts of sugars between different genotypes with differential level of pest susceptibilities (because of level of incidence of pest indicate) these compound might act as phagostimulants to head bugs feeding on sorghum grains particularly at initial stages of panicle development. Sharma *et al.* (1993b) also detected lower amount of soluble sugars in midge resistant lines as a part of resistance.

Phenolic constituents (mg/g)

Total phenol - The data presented in Table 17 reveal that the amount of phenolic constituents present in different sorghum genotypes. In resistant sorghum genotypes, the amount of phenol in immature grains varied from 1.780 to 2.620 mg/g it was minimum (1.787 mg/g) in resistant sorghum genotype DJ 6514 and was maximum (2.620 mg/g) in resistant sorghum genotypes ICSV 714 and with an average mean of 2.121 mg/g. In susceptible genotypes the mean total phenol varied between 1.045 mg/g (sorghum genotype IS 2312) to 1.432 mg/g (susceptible genotypes SRF 2102) with an average mean of 1.292 mg/g. The total phenol in immature grain was negatively correlated with pest incidence (r = -0.775) (Table 19).

The total phenol in mature grain was maximum (2.065 mg/g) in genotype ICSV 714 was minimum (1.402 mg/g) in sorghum genotype DJ 6514 with an average mean of 1.676 mg/g in resistant genotypes of sorghum (Fig. 9).

In mature grain, the amount of total phenol in susceptible genotypes was maximum (1.083 mg/g) in sorghum genotype SR 1048-1 and was minimum (.968 mg/g) in genotype IS 2312 with an average mean of 1.028 mg/g in susceptible genotypes of sorghum. The amount of total phenol present in mature grains of susceptible sorghum genotypes exhibited a negative correlation (r= -0.716) with the population of head bugs in sorghum.

Table 17. Biochemical constituents of mature and immature grains of sorghum genotypes in relation to earhead bugs incidence.

Phenolic constituents (mg/g)

Varieties	Bugs population+	Total phenol		O-Dihydroxy phenol		Flavanol	
		Immature* grains	Mature** grains	Immature* grains	Mature** grains	Immature* grains	Mature** grains
Resistant group							
ICSV 714	16.2	2.620	2.065	0.584	0.550	0.485	0.405
AKENT 7-1	17.7	2.503	1.937	0.362	0.339	0.778	0.724
ICSV 711	15.6	1.873	1.499	0.060	0.043	0.658	0.594
SPH 1352	18.3	1.827	1.476	0.584	0.546	0.655	0.586
DJ 6514	18.0	1.780	1.402	0.650	0.589	0.503	0.463
Mean	17.2	2.121	1.676	0.556	0.534	0.616	0.554
Susceptible group							
IS 2312	67.2	1.045	0.968	0.433	0.377	0.437	0.398
IS 112	55.8	1.327	1.043	0.488	0.443	0.485	0.448
SR 1048-1	45.3	1.423	1.083	0.302	0.262	0.420	0.352
SRF 2102	38.4	1.432	1.057	0.504	0.476	0.426	0.371
SFCR 1111	92.7	1.245	0.991	0.524	0.488	0.350	0.276
Mean	59.9	1.292	1.028	0.450	0.409	0.424	0.369
S.Em. ±		0.002	0.003	0.004	0.009	0.003	0.001
CD(P=0.05)		0.006	0.010	0.013	0.028	0.010	0.005

+Mean number of earhead bugs/5 panicles

*Immature grains : 85 to 95 days after sowing.

**Mature grains: At harvest.

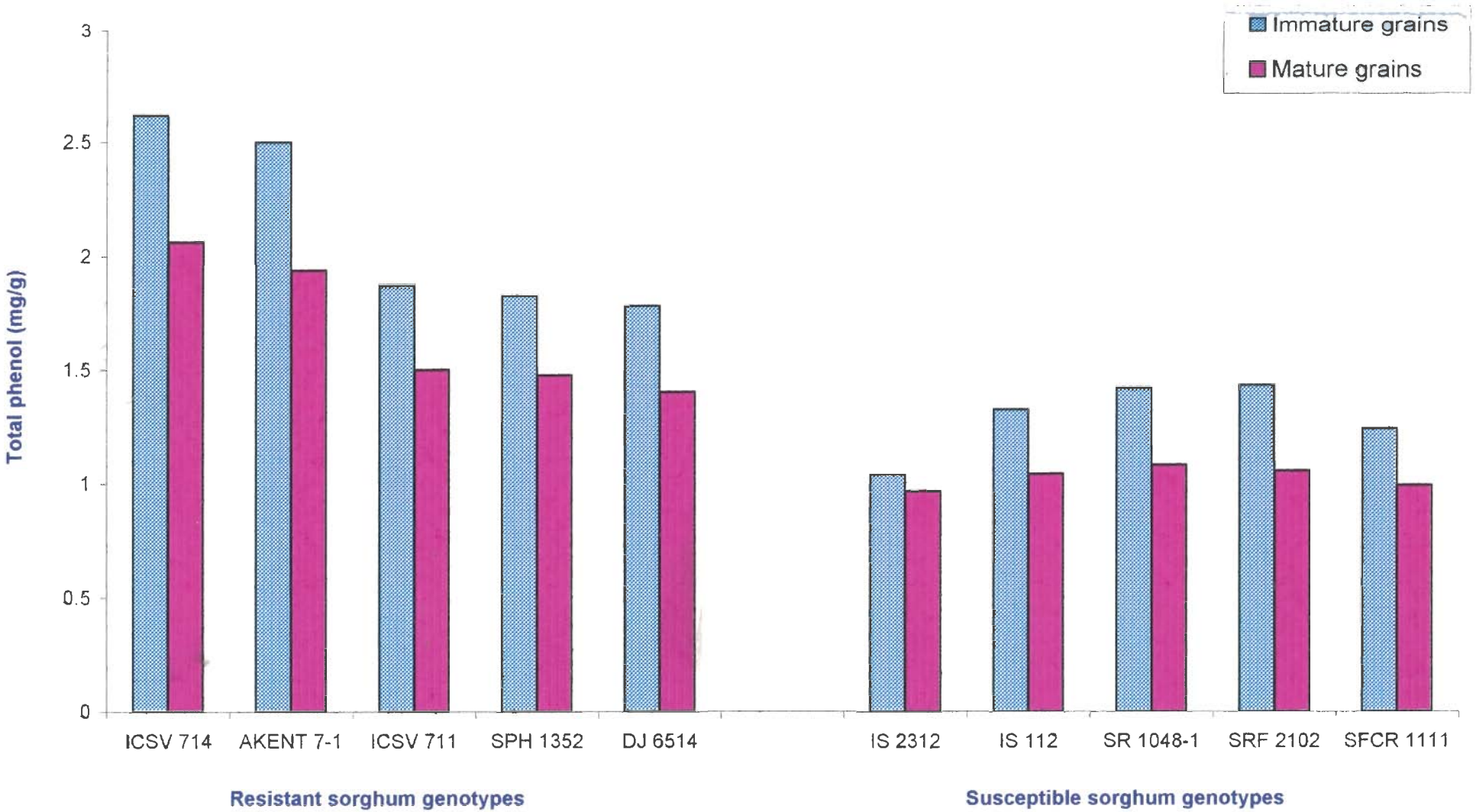

Fig. 9: Amount of total phenol (mg/g) in grains of different sorghum genotypes

Ortho-Dihydroxyphenol- The amount of O-dihydroxy-phenol in immature grain of resistant sorghum genotypes varied from 0.362 mg/g in genotype AKENT 7-1 to 0.650 mg/g in genotype DJ 6514 and resistant group of genotypes had an average mean of 0.556 mg/g of O-dihydroxy phenol (Table 17). In susceptible genotypes, the maximum (0.52 mg/g) amount of O-dihydroxyphenol was present in genotype SFCR 1111 and it was minimum (0.302 mg/g) in susceptible genotype SR 1048-1 with an average mean of 0.450 mg/g of dihydroxyphenol in immature grains of susceptible sorghum genotypes.

The correlation between the amount of O-dihydroxyphenol in immature grains of sorghum genotypes and the pest incidence in sorghum genotypes was positive (r = 0.099) (Table 19).

In mature grain, the mean amount of O-dihydroxyphenol in resistant group was 0.534 mg/g and it was maximum (0.589 mg/g) in genotype DJ 6514 and minimum (0.043 mg/g) in resistant genotype ICSV 711 (Table 17). The amount of O-dihydroxyphenol in susceptible genotypes varied from 0.262 mg/g in entry SR 1048-1 to 0.448 mg/g in SFCR 1111 with mean amount 0.409 mg/g and O-dihydroxyphenol amounts in mature grains of sorghum exhibited a positive correlation (r= 0.080) with pest incidence.

Flavanol- The mean amount of flavanol in resistant group of sorghum genotypes was 0.616 mg/g in immature

grain and varied from 0.485 mg/g in genotype ICSV 714 to 0.778 mg/g in resistant genotype AKENT 7-1 (Table 17). While in susceptible genotype the mean amount of flavanol in immature grain was 0.424 mg/g, being lowest (0.350 mg/g) in sorghum genotype SFCR 1111 and was maximum (0.485 mg/g) in IS 112. The flavanol amount in mature grain in resistant group had mean of 0.554 mg/g with maximum amount 0.724 mg/g observed in genotype AKENT-1 and it was minimum (0.405 mg/g) in genotype ICSV 714. In susceptible group, the mean flavanol amount was 0.369 mg/g and it was minimum (0.276 mg/g) in genotype SFCR 1111 and was maximum (0.448 mg/g) in genotype IS 112. The flavanol amount had exhibited negative correlation with head bug incidence (r= -0.716, -0.699) in immature and mature grains (Table 19).

The amount of phenolic constituents was lesser in mature grains than observed in immature grains. The phenolic constituents in susceptible sorghum genotypes decreased while the mean number of head bugs/5 panicles increased in such genotypes. In resistant group of genotypes, the amount of flavanol was more in comparison to that observed in susceptible genotypes. The presence of higher amount of phenolic compounds in plant species make it a resistant plant species to various insect-pests. The effect of presence of total phenols on the infestation of earhead bugs in sorghum panicles have not been so far been investigated, however, some work on

the role of polyphenol in relation to aphid feeding in sorghum have been conducted. Phenol being important group of plant defence chemicals and have antibiotic effect on insect pests. Phenolic compounds act as antifeedant/antibiotic towards insects in sorghum grains (Sharma *et al.*, 1993b), in soybean (Sharma and Norris, 1991) and cotton (Sharma and Agarwal, 1982 a,b). Flavan-4-ol was reported as deterrent to aphid feeding (Dreyer *et al.*, 1981). In resistant rice variety, total phenol constituents were higher than susceptible ones (Vishwanathan and Kalode, 1990). Butter *et al.* (1992) also reported negative correlation between whitefly population and phenolic constituents in cotton. Sachan and Sachan (1991) also investigated direct relationship between aphid population and phenols.

Tannin (mg/g)

The amount of tannin content estimated in immature and mature grains of sorghum genotypes presented in Table 18 revealed that the mean amount of tannin content in immature grains of resistant genotype was 0.992 mg/g, and it was maximum (1.144 mg/g) in resistant sorghum genotype AKENT 7-1 and was minimum (0.872 mg/g) in genotype DJ 6514. In susceptible genotypes, the tannin content ranged from 0.490 mg/g to 0.817 mg/g, being maximum (0.817 mg/g) in genotype IS 2312 and was minimum (0.490 mg/g) in genotype IS 112 with an average amount mean of 0.637 mg/g, while in mature grains of resistant group mean

Table 18. Biochemical constituents of mature and immature grains of sorghum genotypes in relation to earhead bugs incidence.

Tannin (mg/g) and protein (%)

Varieties	Bugs population+	Tannin		Protein	
		Immature* grain	Mature** grain	Immature* grain	Mature** grain
Resistant group					
ICSV 714	16.2	0.926	0.708	14.00 (21.96)	12.68(20.85)
AKENT 7-1	17.7	1.144	0.872	13.70(21.72)	12.25(20.48)
ICSV 711	15.6	1.035	0.790	13.56(21.60)	11.81(20.09)
SPH 1352	18.3	0.981	0.763	13.13(21.24)	12.39(20.60)
DJ 6514	18.0	0.872	0.681	10.26(18.67)	9.18(17.63)
Mean	17.2	0.992	0.763	12.93	11.66
Susceptible group					
IS 2312	67.2	0.817	0.654	10.28(18.69)	9.63(18.06)
IS 112	55.8	0.490	0.408	11.24(19.58)	10.30(18.71)
SR 1048-1	45.3	0.626	0.449	11.09(19.44)	10.13(18.55)
SRF 2102	38.4	0.654	0.497	13.05(21.17)	11.65(19.95)
SFCR 1111	92.7	0.599	0.431	10.06(18.48)	8.75(17.20)
Mean	59.9	0.637	0.489	11.14	10.09
S.Em. ±		0.013	0.011	0.023	0.002
CD(P=0.05)		0.041	0.034	0.069	0.007

Figures in parentheses are angular transformed values.

+Mean number of earhead bugs/5 panicles

*Immature grains : 85 to 95 days after sowing.

**Mature grains: At harvest.

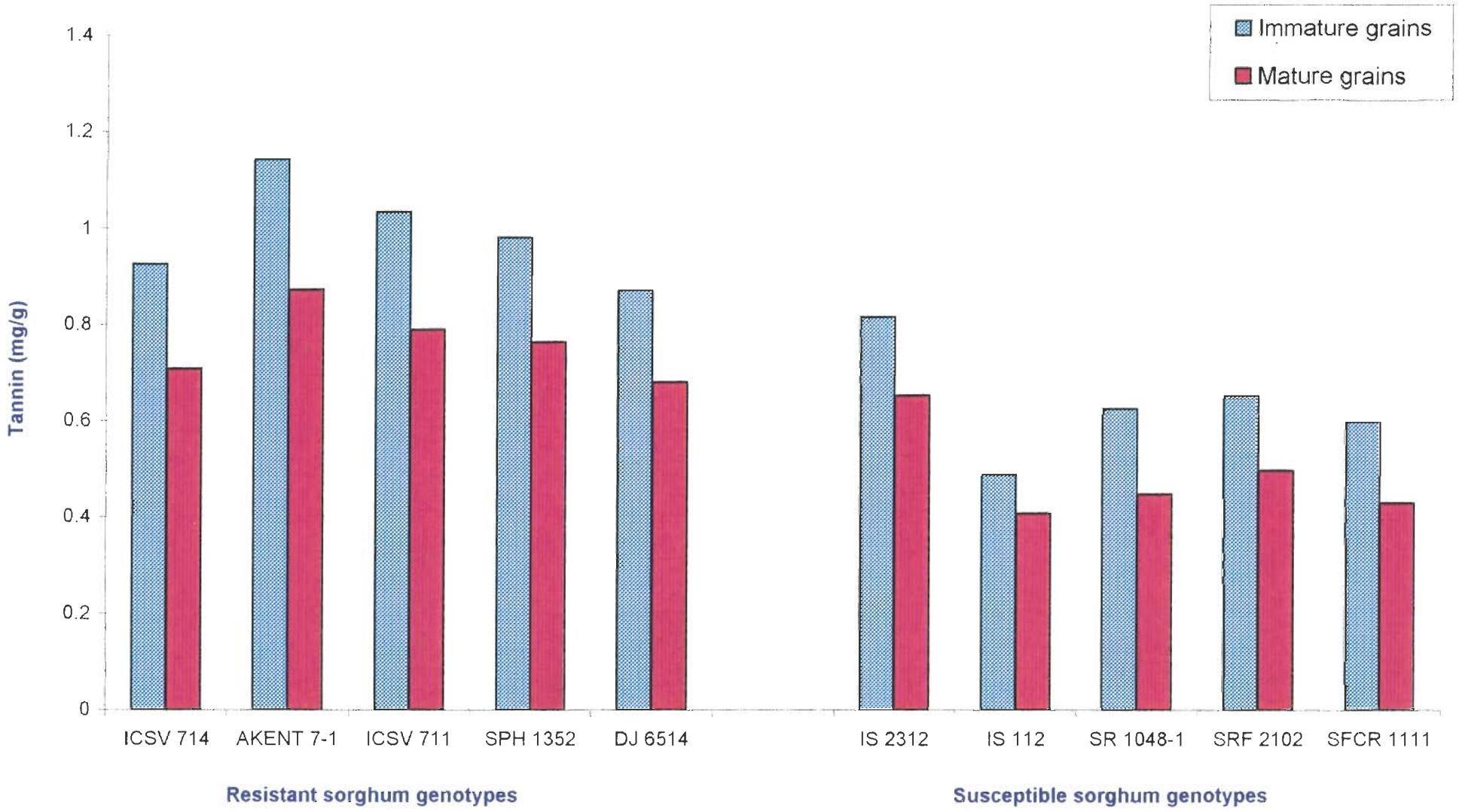

Fig. 10: Amount of tannin (mg/g) in grains of different sorghum genotypes

tannin content was 0.763 mg/g and it ranged from 0.872 mg/g (in genotype AKENT 7-1) to 0.681 mg/g (DJ 6514) whereas in susceptible group the mean amount of tannin content was 0.48 mg/g and maximum (0.654 mg/g) amount of tannin was observed in genotype IS 2312 and it was minimum (0.408 mg/g) in genotype IS 112 (Fig. 10). The tannin content in immature and mature grain showed a negative correlation (r= -0.728, -0.99) with pest incidence in sorghum genotypes (Table 19).

As all tannins are phenols, tannins also act as semio-chemicals in plant defence chemical, being secondary metabolites known to act as antifeedant and or antibiotic agents against many insect pests (Sharma *et al.*, 1993b). Sharma and Lopez (1990b, 1991, 1992 a,b) detected higher amount of tannin in grains of resistant sorghum panicle against *Calcoris angustatus*. Higher amount of tannin content was observed to be associated in (resistant sorghum genotypes) imparting resistance to plant against midge (Sharma *et al.*, 1990, 1993b). Santos and Carmo (1974) and Sharma *et al.* (1990) viewed that low population in resistant grain sorghum genotypes appeared due to consequences of feeding deterrence and due to occurrence of relatively higher level of tannin in midge resistant lines as compared with susceptible ones.

Protein (%)

The data on the protein content, estimated in immature and mature grains of resistant and susceptible genotypes presented in Table 18 revealed that in

resistant group of genotypes the per cent protein content was maximum (14.00%) in genotype ICSV 711 and was least (10.26%) in DJ 6514 with an average mean protein content of 12.93 per cent. In case of susceptible group of genotypes, the average mean protein was 11.14 per cent and it ranged from 10.06 per cent (genotypes SFCR 1111) to 13.05 per cent (genotype SRF 2102).

The percent protein content in mature grains of resistant genotypes varied from 9.18 per cent in genotype DJ 6514 to 12.68 per cent in genotype ICSV 714 with an average mean per cent protein of 11.66 per cent. While mean per cent protein content was 10.09 per cent in susceptible group, being maximum (11.65%) in genotype SRF 2102 and minimum (8.75%) in genotype SFCR 1111. The correlation between protein content in mature grains of sorghum and earhead bugs incidence was negative (r= -0.730) (Table 19).

Protein contents differed significantly in grains of all selected sorghum genotypes at immature and mature stage (Fig. 11). Protein content showed a significant negative correlation with pest incidence of sorghum grains. Sharma *et al.* (1993b) felt difficulty to link greater amounts of proteins in midge resistant lines, with midge development. As polyphenols have an affinity for binding with protein, although tannins in sorghum do not interact equally with all proteins, but after linkage make strong bonding with hydrophobic proteins (Hagermann and Butler, 1981). Thus, high tannin in sorghums are

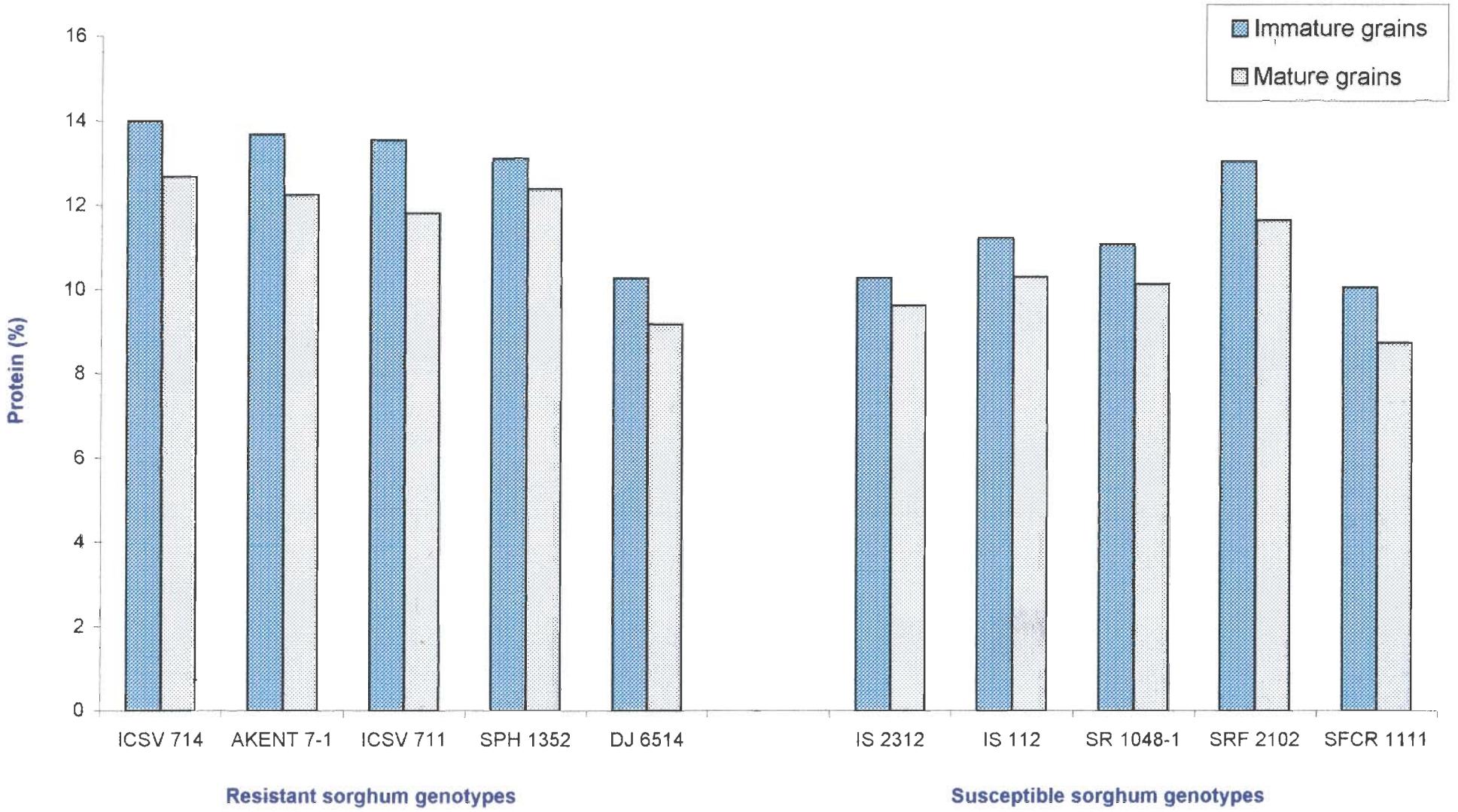

Fig. 11: Amount of protein (%) in grains of different sorghum genotypes

Table 19. Correlation coefficients between biochemical constituents and head bug population.

	Total sugar (mg/g)		Reducing sugar (mg/g)		Non-reducing sugar (mg/g)		Total Phenol (mg/g)		O-dihydroxy phenol (mg/g)		Flavanol (mg/g)		Tannin (mg/g)		Protein (%)		Mean no.of bugs/5 panicles	Grain weight (g)	Length of panicle (cm)	Breadth of panicle (cm)
	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2				
1.	1.000	-.280	.420	-.136	.951**	-.399	-.618	-.584	-.014	-.046	-.480	-.457	-.464	.007	-.749*	-.730*	.884**	.443	.469	.691*
2.		1.000	-.201	.939**	-.237	.889**	.645*	.576	-.256	-.208	.601	.541	.720*	-.093	.767**	.729*	.360	.314	.192	-.065
3.			1.000	.005	.118	-.426	-.573	-.327	-.077	-.096	-.493	-.482	-.549	.175	-.191	-.088	.497	.010	-.409	-.080
4.				1.000	-.150	.677*	.539	.416	-.305	-.265	.362	.299	.577	-.148	.663*	.618	.211	.154	.098	-.051
5.					1.000	-.291	-.483	-.530	.010	-.018	-.358	-.337	-.320	-.054	-.754*	-.769**	.799**	.481	.652*	.784**
6.						1.000	.647*	.663*	-.137	-.089	.800**	.759*	.768**	.007	.744*	.724*	.472	.477	.285	-.053
7.							1.000	.747*	.012	.049	.653*	.602	.734*	.057	.758*	.724*	-.775**	.029	.135	-.414
8.								1.000	.195	.225	.652*	.595	.708*	.045	.672*	7.31*	-.716*	.211	.023	-.355
9.									1.000	.998**	-.334	-.320	-.225	-.002	-.260	-.180	.099	.058	-.304	-.197
10.										1.000	-.311	-.302	-.207	-.009	-.209	-.134	.080	.072	-.315	-.231
11.											1.000	.993**	.832**	.305	.656*	.657*	-.716*	.357	.415	-.027
12.												1.000	.805**	.359	.602	.608	-.699*	.348	.413	.007
13.													1.000	-.117	.605	.595	-.890*	.114	.385	.126
14.														1.000	.096	.138	-.728*	.291	.004	-.260
15.															1.000	.980**	-.726*	-.011	-.215	-.603*
16.																1.000	-.730*	.044	-.250	-.614
17.																	1.000	.290	.123	.465
18.																		1.000	.615	.326
19.																			1.000	.719*
20.																			.	1.000

1-Immature grain
2-Mature grain
*Significant at P= 0.05
**Significant at P= 0.01

reported to suppress growth and increase the level of faecal nitrogen by affecting digestion, possibly by interacting with bone development and liver enzymes in higher animals after the digestion (Butler *et al.*, 1986). In this regard present findings are in accordance with report of Sharma *et al.* (1993b) that generally a greater amount of proteins have been detected in midge resistant lines compared with susceptible ones.

CHAPTER-V

SUMMARY AND CONCLUSION

The studies on earhead bugs in sorghum were carried out at Research Area, Forage Section, Department of Plant Breeding and the laboratory work was done in the Departments of Entomology, Plant Breeding, Zoology and Aquaculture, CCS Haryana Agricultural University, Hisar during the years 2001-03. For carrying out these investigations, four different experiments *viz.*, screening of different dual purpose sorghum genotypes against earhead bugs, to study the nature and extent of damage caused by earhead bugs in dual purpose sorghum under protected and unprotected conditions, population dynamics of earhead bugs and natural enemies, and role of morphological and physio-chemical characters in imparting resistance in susceptible and resistant sorghum genotypes were conducted.

For the experiment on screening of different dual purpose sorghum genotypes against earhead bugs, one

hundred and fifty sorghum genotypes were sown in the first fortnight of July, 2001 and these were accessed for earhead bug infestation on the basis of number of earhead bugs/5 panicles and also on the basis of grain damage rating at harvest.

Preliminary screening data for the year 2001 revealed that out of a total of 150 sorghum genotypes belonging to different maturity periods and plant types screened against earhead bugs, none was found completely free from the earhead bug damage except those genotypes which were having loose type of earheads and the mean number of earhead bugs/5 panicles ranged from 0.0 to 30.9 with a overall mean of 12.46 bugs/5 panicles. Out of these, 81 sorghum entries were above the overall mean of 12.46 bugs/5 panicles. All these, 150 sorghum entries were also categorized on the basis of grain damage rating (GDR) at maturity (Sharma *et al.*, 1992b) and were assigned grade from 1 to 8. Based on earhead bug infestation and GDR, 114 sorghum genotypes (having GDR<6) were resown during *kharif* 2002 to know their reaction against earhead bugs infestation. The mean number of bugs/5 panicles varied from 0.0 to 18.1 and GDR ranged from 1 to 5 and overall mean for these genotypes was 8.00 earhead bugs/5 panicles.

In the pooled data for *kharif*, 2001 and 2002, revealed that in different sorghum genotypes, the mean infestation ranged from 0.6 to 20.90 earhead bugs/

5 panicles with overall mean infestation of 9.27 earhead bugs/5 panicles and GDR ranged from 1 to 6.

To record the extent of damage caused by earhead bugs, the four sorghum genotypes i.e. HC 308, HC 136, HC 171 and H260 were selected on the basis of maturity, panicle type and susceptibility and earheads were exposed for periods of 7, 14, 21 and 28 days, respectively. After each exposure period, these exposed panicles were protected from being damaged further by earhead bugs and other insect pests by covering it with muslin cloth bags and ensured that no insect-pests were present in the panicle. At the exposure period of 7, 14, 21 and 28 days of sorghum panicle against head bugs, there was a corresponding increase in loss of grain weight. As the period of exposure of sorghum panicles to earhead bugs increases, there was an increase in grain weight loss.

The four sorghum varieties *viz.,* HC260, HC171, HC308 and HC136 were selected on the basis of maturity, panicle type and susceptibility. The crop of each variety was divided into two set of conditions i.e. protected and unprotected. The crop was protected by spraying 0.07 per cent endosulfan 35 EC, when the pest population reached at economic threshold. After harvesting, the earheads were thrashed separately of each variety from protected as well as unprotected plots and avoidable losses in grain yield were then computed in each variety.

Per cent avoidable loss to the tune of 35.25, 30.89, 26.74 and 8.01 in *kharif,* 2001 and 18.96, 31.31, 23.86

and 2.17 in *kharif*, 2002 can be avoided in varieties, HC308, HC136, HC171 and HC260, respectively by adapting proper control measures.

Based on preliminary screening, ten sorghum genotypes i.e. ICSV 714, AKENT 7-1, ICSV 711, SPH 1352 and DJ 6514 from resistant group and IS 2312, IS 112, SR 1048-1, SRF 2102 & SFCR 1111 from susceptible group were selected on the basis of head bugs infestation and grain damage rating (GDR) by visual observation method given by Sharma *et al.* (1992b) for observations on population dynamics. The total number of earhead bugs per plant were recorded at interval of one week on 5 randomly selected plants in each replication of each variety. Correlation of abiotic factors with head bug incidence was worked out.

The population build-up of sorghum earhead bugs was low (with mean of 18.9 bugs/5 panicles) in resistant sorghum genotypes as compared to susceptible ones (66.20 bugs/panicles) and minimum temperature, relative humidity of morning and evening hours were negatively correlated while maximum temperature and sunshine hours were positively correlated with head bug population build-up.

Morphological characters of 150 sorghum genotypes were observed and recorded at maturity in each genotype, 5 plants were selected randomly per repeat. Morphological plant characters i.e. 1000-grain weight, panicle size (length and breadth) of sorghum earhead showed a

positive correlation with earhead bug incidence. Loose panicle type earheads were less (0.0 bugs/5 panicles) preferred as compared to semi-compact (12.89 bugs/5 panicles) and compact (15.50 bugs/5 panicles) type of panicles by earhead bugs. Presence of coloured grains and tan coloured glumes in sorghum panicles were less preferred by earhead bugs.

Biochemical constituents of sorghum grains of 10 selected sorghum genotypes 5 from resistant genotypes and five from susceptible sorghum genotypes were analysed at milky stage and at maturity adapting standard method *viz.*, Protein contents (A.O.A.C., 1995); total soluble sugars (Dobois *et al.*, 1956); Reducing sugars (Walter, 1924); Non-reducing sugars (the difference between total sugars and reducing sugars); tannin content (Burns, 1971); Total phenols (Swain and Hills, 1959); Ortho dihydroxy phenols (Johnson and Schaal, 1952); Flavanols (Balba *et al.*, 1974).

The correlation between biochemical constituents of grains of ten selected genotypes were worked out with population dynamics of earhead bugs. Biochemical constituents of grains of sorghum like amount of carbohydrates (mg/g) was found to be positively correlated with head bugs number in sorghum panicles. Resistant sorghum genotypes had less (20.10 mg/g) of total sugar as compared to susceptible ones (39.32 mg/g). Total phenol and flavanol (mg/g) were negatively correlated while ortho-dihydroxy phenol (mg/g) found to

be non-significantly positively correlated with earhead bugs incidence. Amount of tannin in grains observed was lesser (0.63 mg/g) in susceptible and had more (0.99 mg/g) in resistant sorghum genotypes.

Protein (%) in grains was more in resistant genotypes as compared to susceptible ones. Amount of tannin (mg/g) and protein (%) were found to be negatively correlated with head bug numbers on sorghum panicles. Although, the results achieved on morphological and physio-chemical characteristics gives conspicuous indication of their role in imparting resistance and/or susceptibility in grains of sorghum panicles. Regarding populations build-up of head bugs, it need elaborated and detailed studies before drawing any conclusion on the above aspect.

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ABSTRACT

a)	Title of thesis	:	Studies on earhead bugs in sorghum.
b)	Full name of degree holder:	:	Dalip Kumar
c)	Title of degree	:	Doctor of Philosophy in Entomology
d)	Name and address of Major Advisor	:	Dr. J.P. Bhanot, Senior Entomologist Department of Entomology CCS Haryana Agricultural University Hisar-125 004, India.
e)	Degree awarding University/Institute	:	CCS Haryana Agricultural University, Hisar
f)	Year of award of degree:	:	2004
g)	Major Subject	:	Entomology
h)	Total number of pages in thesis	:	141 + xvii
i)	Number of words in the abstract	:	Approximately 390

The present investigations were carried out during the kharif seasons of 2001 and 2002 in the Research Area, Forage Section, Department of Plant Breeding and in the laboratory of the Departments of Entomology, Plant Breeding, Zoology and Aquaculture, CCSHAU, Hisar. The studies were carried out to know the reaction of dual purpose sorghum genotypes to earhead bugs, the nature and extent of damage caused by earhead bugs under protected and unprotected conditions, population dynamics of earhead bugs and natural enemies and role of morphological and physio-chemicals characters in imparting resistance in susceptible and resistant sorghum genotypes.

Screening of dual purpose sorghum genotypes of different maturity periods and plant types against earhead bugs revealed that out of 150 sorghum genotypes none was found to be completely resistant except those genotypes which were having loose type of panicles. However, thirty sorghum genotypes having range of 0.1 to 7.5 mean number of earhead bugs/5 panicles were considered suitable to be incorporated into breeding programme for earhead bug resistance.

At the exposure period of 7, 14, 21 and 28 days of sorghum panicle against earhead bugs, there were a corresponding increase in loss of grain weight. As the period of exposure of sorghum panicles to earhead bugs increases, there was an increase in grain weight loss. Per cent avoidable losses of 5.09, 25.30, 31.10 and 27.11 per cent (based on two year mean) can be avoided in varieties HC 260, HC 171, HC 136 and HC 308, respectively by adapting proper control measures under Haryana conditions.

Population build-up of sorghum earhead bug was low (18.9 bugs/5 panicles) in resistant sorghum genotypes as compared to susceptible ones (66.20 bugs/5 panicles) and minimum temperatures, relative humidity of morning and evening hours were negatively correlated while maximum temperature and sunshine hours were positively correlated with headbug incidence.

Morphological plant characters like 1000-grain weight, panicle size (length and breadth) of sorghum plant showed a positive correlation with earhead bug infestation. Plants having loose type of panicles were less preferred (0.0 bugs/5 panicles) as compared to semi-compact (12.89 bugs/5 panicles) and compact type (15.50 bugs/5 panicles) panicle by earhead bugs. Presence of coloured grains and tan coloured glumes in sorghum panicles were less preferred by earhead bugs.

Biochemical characteristics of sorghum grains like amount of carbohydrates was found to be positively correlated with head bug incidence. While amount of phenolic constituents, tannin and protein were found to be negatively correlated with earhead bug incidence.

25/8/04

Major Advisor

25 Oct, 2004

Signature of the Degree Holder

25/8/04

Head of the Department