STUDIES ON MULTIPLE RESISTANCE AND MANAGEMENT OF SORGHUM PESTS IN *RABI*

Thesis submitted to the
University of Agricultural Sciences, Dharwda
in partial fulfillment of the requirements for the
Degree of

MASTER OF SCIENCE (AGRICULTURE)

In

AGRICULTURAL ENTOMOLOGY

By

NAGESH CHIKKARUGI

DEPARTMENT OF AGRICULTURAL ENTOMOLOGY
COLLEGE OF AGRICULTURE, DHARWAD
UNIVERSITY OF AGRICULTURAL SCIENCES,
DHARWAD – 580 005

AUGUST – 2007

ADVISORY COMMITTEE

DHARWAD **(R.A. BALIKAI)**
AUGUST, 2007 **MAJOR ADVISOR**

Approved by :

Chairman : ______________________________
(R.A. BALIKAI)

Members : **1.** ______________________________
(J.S. AWAKNAVAR)

2. ______________________________
(H.B. BABALAD)

3. ______________________________
(Y.K. KOTIKAL)

4. ______________________________
(SHEKHARAPPA)

CONTENTS

Contd….

LIST OF TABLES

Contd…

LIST OF FIGURES

LIST OF PLATES

LIST OF APPENDICES

1. INTRODUCTION

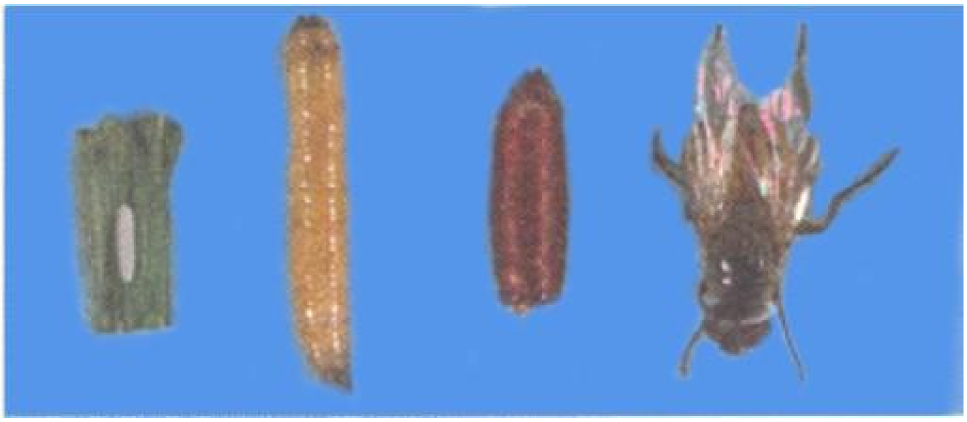
Sorghum (*Sorghum bicolor* (L.) Moench) is a staple food for more than 300 million people and feed for cattle in Asia, Africa, the Americas and Australia. Among cereals, sorghum ranks fifth in the world's production next only to wheat, maize, rice and barley. India has the largest share (32.3 %) in world's sorghum area but ranks seventh in production. World's sorghum production of 58.80 million tonnes comes from an area of 42.07 million hectares with productivity of 1394 kg per ha (Anon., 2004).

In India, sorghum is cultivated during three seasons *viz*., *kharif, rabi* and summer producing around 7.00 million tonnes from an area of 9.69 million ha with productivity of 733 kg per ha, which is much lower than world's average (Anon., 2004). In Karnataka, sorghum is grown during *kharif* and *rabi* seasons covering an area of 2.3 million ha with productivity of 1122 and 570 kg per ha, respectively. Karnataka ranks second in area and production after Maharashtra. It is an important cereal crop of northern Karnataka.

Sorghum grain yields on farmer's fields in Asia and Africa are generally low (500-800 kg/ha) mainly due to insects, diseases, weeds and drought. Nearly 150 insect species have been reported as pests on sorghum (Reddy and Davies 1979; Jotwani *et al*., 1980). Shoot fly (*Atherigona soccata* Rondani), stem borer (*Chilo partellus* Swinhoe), army worm (*Mythimna separat*a (Walker)), shoot bug (*Peregrinus maidis* Ashmead), aphids *(Rhopalosiphum maidis* (Fitch.) and *Melanaphis sacchari* Zehntner), spider mites (*Oligonychus* spp.), grasshoppers and locusts (*Heiroglyphus* sp., *Oedaleus* sp*., Aiolopus* sp*., Schistocerca* sp. and *Locusta* sp.), sorghum midge (*Stenodiplosis sorghicola* Coquillett), mirid bug (*Calocoris angustatus* Lethiery) and panicle-feeding caterpillars (*Helicoverpa armigera* Hubner*, Eublemma* sp*., Cryptoblabes* sp*., Pyroderces* sp*.,* and *Nola* sp.) are the major pests of sorghum world wide. However, among them shoot fly, shoot bug and aphids are important ones in northern Karnataka (Plate 1). In case of sorghum shoot fly, maximum yield losses of 75.6 per cent in grain and 68.6 per cent in fodder have been reported by Pawar *et al.* (1984). The loss in grain and fodder yield due to aphid infestation varied from 11.74 to 26.13 per cent and 9.83 to 31.43 per cent with an overall average loss of 16.09 and 14.99 per cent, respectively (Balikai and Lingappa, 2003 & 2004). An over all loss of 11.16 and 21.11 per cent in grain and fodder yield, respectively was recorded due to shoot bug (Anaji, 2005).

Peterschmitt *et al.* (1991) observed a disease characterized by chlorotic stripes and bands, named it as sorghum stripe disease (SStD) on sorghum in India with an incidence of less than 0.5 per cent to nearly 10 per cent. The affected plants were dwarfed and had poor or no panicle formation (Plate 2). This disease could be transmitted by the delphacid plant hopper *P. maidis* to sorghum. Singh *et al.* (2004a) reported that, sugarcane aphid, *M. sacchari* is a vector of three persistent viruses (millet red leaf, sugarcane yellow leaf and sugarcane mosaic viruses). Schenck and Lehrer (2000) reported that, sugarcane, *Saccharum spp*. hybrid was widely infected in the United States and many other countries with a yellowing and stunting disease called sugarcane yellow leaf syndrome. The causal agent Sugarcane yellow leaf virus (ScYLV) was a Polerovirus of the Luteoviridae family transmitted by the sugarcane aphid, *M. sacchari*.

Recommendations for the integrated management of insect pests in sorghum involve cultural practices, natural enemies, insecticides and host plant resistance (HPR). In rainfed agriculture, the sowing date cannot be manipulated to avoid pest damage. Insecticides are expensive, uneconomical and beyond the reach of resource–poor farmers in the semi-arid tropics. HPR is the most important component of integrated pest management in sorghum; it does not involve any extra cost or require application skills in pest control techniques and is compatible with other methods of pest control. The negative effect of resistant genotypes on insect populations is continuous and cumulative over time. Reduction in pest populations through HPR can also enhance the effectiveness of natural enemies and reduce the need to use pesticides (Sharma, 1993). This will help to preserve the environment and avoid the risks associated with the use of pesticides. However, HPR is not a panacea for all pest problems but it is most useful when carefully combined with other components of pest management.



A. Sorghum shoot fly, Atherigona soccata : Egg, maggot, pupa and adult fly

B. Sorghum aphid, Melanaphis sacchari on the under suface of leaf

C. Shoot bug, peregrinus maidis

Plate 1: Major insect pests of rabi sorghum

A. Deadhearts caused by sorghum shoot fly

B. Sorghum stripe disease

C. Severe plant damage due to shoot bug

Plate 2: Damage symptoms of sorghum shoot fly and shoot bug

To develop insect resistant cultivars, it is important to ensure adequate and uniform insect infestation over seasons. Hot spots can serve as useful locations to screen and breed for resistance to insects. Major emphasis has been placed on developing cultivars resistant to shoot fly, stem borers, midge, shoot bug, aphid and head bugs. Considerable progress has been made in developing techniques to screen for resistance to these insects, identifying the source of resistance and transferring resistance to high-yielding sorghum cultivars (Sharma *et al*., 1992). Screening for resistance to insects under green house/field conditions is the most effective method of developing insect resistant cultivars. However, it is not possible to rear all insect species at all locations and the occurrence and abundance of insect populations under natural conditions are sporadic and highly influenced by the environment. Therefore, in order to continue the process of selecting for resistance to insects, it is important to under stand the mechanism of resistance and the factors contributing to/associated with insect resistance. In view of the above facts the present study was undertaken with the following objectives.

1. Reaction of different *rabi* sorghum genotypes to shoot fly, shoot bug and aphid.
2. Correlation of morphological characters of *rabi* sorghum genotypes with shoot fly, shoot bug and aphid incidence.
3. Correlation of bio-chemical parameters of *rabi* sorghum genotypes with shoot fly, shoot bug and aphid incidence.
4. Management of sorghum pests by eco-friendly tactics.

2. REVIEW OF LITERATURE

The literature pertaining to the reaction of different *rabi* sorghum genotypes to shoot fly, shoot bug and aphid, biophysical and biochemical parameters responsible for resistance and management of shoot fly, shoot bug and aphid through IPM practices are presented under this chapter.

2.1 Reaction of sorghum genotypes to shoot fly, shoot bug and aphid

2.1.1 Shoot fly, *A. soccata*

Singh and Narayana (1978) studied the influence of highly susceptible Swarna and CSH 1, susceptible M 35-1 and IS 2269 and moderately resistant IS 2123 and IS 5604 varieties of sorghum on the biology of the sorghum shoot fly. Oviposition was more on highly susceptible varieties than on resistant and moderately resistant groups.

Eighteen selected varieties of sorghum were evaluated for their resistance to the sorghum shoot fly. Four observations were recorded for the sorghum deadheart counts at one week to four weeks at 7 days intervals after sowing. For the second reading, the line SFIS 5622 was considered as the best variety for resistance with only 4.00 per cent deadhearts followed by SF 5566, SFIS 3962 (2-1), SFIS 5604, SF Blum 221, SFIS 8315 (12-1) and SF 3. For the third and fourth readings, the line SFIS 3962 (2-1) was the best variety with only 12.00 and 14.00 per cent deadhearts followed by SFIS 5622 and differed significantly from IS 5604 and SF 5566, respectively (Sawang *et al.,* 1988).

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

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

Balikai *et al.* (1999) developed sorghum lines resistant to the shoot fly. M 35-1, a popular local variety in Karnataka, India was crossed with the resistant check IS 2312 during 1989-90. An F_2 population consisting of 400 plants was grown during 1990-91 and 50 promising plants were selected. Of these, 11 were retained and tested over the next 4 years; these showed a resistance level of 9.0-12.8 per cent, which was on par with IS 2312 and higher than M 35-1 (28.1%).

Balikai and Kullaiswamy (1999) tested 14 F_2 populations of sorghum for resistance *to A. soccata* in India during the *rabi* season of 1990-91 and reported that, M 35-1 x SPV 488, M 35-1 x 19B, M 35-1 x Afzalpur local, M 35-1 x Selection 3 and M 35-1 x IS 2315 were promising on the basis of percentage of deadhearts. Narkhede *et al.* (2002) screened 1150 *rabi* sorghum cultivars for resistance to shoot fly and reported that, stability analysis of the 19 cultivars over three seasons showed the resistance of cultivars RSV 175, RSV 176, RSV 182 and RSV 290 to shoot fly and were stable across several locations.

Thawari *et al.* (2003) screened nine sorghum hybrids (AKSH 42R, AKSH 43R, AKSH 46R, AKSH 48R, AKSH 49R, AKSH 50R, AKSH 52R, AKSV 0012R and AKSV 0013R) for their resistance to shoot fly during *rabi* 2001-02 in Akola, Maharashtra, India. The hybrids CSH 15R, CSH 19R, M 35-1 and SPV 1359 were used as controls. The percentage of deadhearts was lowest in AKSV 0013R (12.50%) and highest in AKSH 46R (66.66%). No shoot fly eggs were observed on AKSV 0013R, whereas only 2 eggs per plant were observed on AKSH 52R and AKSV 0012R.

Deshpande *et al.* (2003) screened new stabilized 230 sorghum genotypes against shoot fly to assess their level of tolerance. The per cent deadhearts, per cent oviposited plants and number of eggs per plant were positively correlated with each other. New genotypes SP 15050, SP 15003 and SP 15047 being glossy recorded 26, 27 and 27 per cent deadhearts with 1.2, 0.7 and 1.4 eggs per plant, respectively were tolerant to shoot fly during the *rabi* season.

Kumar *et al.* (2003) evaluated twenty nine genotypes belonging to seven different groups of sorghum for their resistance to sorghum shoot fly. Ovipositional non-preference or antixenosis was expressed by the resistant controls (IS 2312 and IS 18551) and elite resistant lines (ICSV 700, ICSV 705, ICSV 708, ICSV 93088, ICSV 93089, ICSV 93090, ICSV 93091 and PB 14390-4) as these recorded less number of eggs compared to other genotypes. In contrast, the susceptible controls (CSV 1 and DJ 6514) and forage sorghum genotypes (GSSV 148, SR 350-1-16 and SSG 59-3) were the most preferred groups for shoot fly oviposition. Among the genotypes, ICSV 708 and ICSV 705 recorded the lowest number of deadhearts, while CSV 1 and DJ 6514 recorded the highest deadheart formation.

The results on the field evaluation of restorer lines of sorghum over three years revealed that, among 28 lines tested in one set, thirteen of them (ICSR 170, SPV 1156, M 148-138, SPV 1173, IS 33742, A 1, SPV 462, IS 33859, SPV 570, SPV 489, KSV 18R, IS 33843 and 5-4-1 (Muguti) were found to be promising against shoot fly. While in another set, out of 27 lines, fifteen entries (IS 18366, IS 12611, SPV 655, SPV 1155, Afzalpur local, SPV 839, IS 4657, IS 33751, DRC 1000, BRJ 17, Selection-3, DRV 20, IS 188758, M 35-1 and 5-4-1 (Muguti)) were found to be promising against shoot fly in *rabi* season. These entries were statistically at par with the resistant check, IS 2312 (Balikai and Biradar, 2003b).

Gite *et al.* (2003) evaluated forty five sorghum hybrids and their 10 parents (IS 18551, IS 2205, IS 1122, AKENT 1, AKENT 2, AKENT 3, HK 90012, GJ 40, SPV 1023 and ICS 70B) in Akola, Maharashtra, India, during *kharif* 1998 for heterobeltiosis for resistance to shoot fly (*A. soccata*) and related characters. Significant heterobeltiosis in the desired direction was recorded for deadheart percentage, number of eggs per plant, plant height, number of trichomes, chlorophyll content and grain yield per plant. AKENT 3 x IS 1122, AKENT 3 x GJ 40, ICS 70B x GJ 40, ICS 70B x HR 90012 and HR 90012 x AKENT 1 showed significant heterobeltiosis in the desired direction for low deadheart percentage. Five hybrids exhibited positive and significant heterobeltiosis in the desired direction for number of trichomes on the leaf surface (HR 90012 x SPV 1023, ICS 70B x HR 90012, ICS 70B x GJ 40, HR 90012 x GJ 40 and AKENT 3 x GJ 40). HR 90012 x AKENT 1 recorded negative and significant heterobeltiosis in the desired direction for low chlorophyll content. Nineteen hybrids showed positive and significant heterobeltiosis for grain yield per plant. In general, GJ 40 x IS 18551, AKENT 3 x GJ 40, AKENT 1 x AKENT 2, HR 90012 x AKENT 3 and ICS 70B x GJ 40 appeared promising for grain yield per plant and characters associated with resistance to shoot fly. Heterotic effects exhibited by resistant x susceptible parental crosses would be useful for the development of resistant and high yielding genotypes in segregating generations.

Balikai and Biradar (2004) screened 200 sorghum germplasm for resistance to shoot fly in *rabi*. From this germplasm, 18 lines were selected based on their performance against shoot fly. During the next two consecutive years, the selected lines were again evaluated using fish meal technique. The results of the field screening over three consecutive years revealed that, the entries *viz*., IS 2191, IS 4481, IS 4516, IS 17596, IS 18366, IS 33714, IS 33717, IS 33722, IS 33740, IS 33742, IS 33756, IS 33761, IS 33764, IS 33810, IS 33820, IS 33839, IS 33843 and IS 33889 were identified as resistant to shoot fly by recording 17.6, 16.9, 12.0, 15.7, 13.8, 18.0, 18.6, 12.7, 10.9, 15.7, 10.7, 10.8, 9.2, 17.1, 9.0, 13.5, 9.9 and 18.7 per cent deadhearts, respectively. These entries were statistically at par with the resistant check, IS 2312 which recorded 13.0 per cent deadhearts due to shoot fly.

2.1.2 Shoot bug, *P. maidis*

Peterschmitt *et al.* (1991) observed a disease characterized by chlorotic stripes and bands, named sorghum stripe disease (SStD), on sorghum in India with an incidence of less than 0.5 per cent to nearly 10 per cent. The affected plants were dwarfed and had poor or no panicle formation. This disease could be transmitted by the delphacid plant hopper, *P. maidis* to sorghum but not to *Brachiaria eruciformis* (Sm.) Griseb, *Cenchrus ciliaris* (L.), *Chloris* *barbata* (L.), *Dichantium annulatum* (Forsk.), *Dichantium aristatum* (Poir), *Digitaria ciliaris* (Retz.) Koeler., *Dinebra retroflexa* (Vahl) Panz., *Echinochloa colonum* (L.) Link, *Eleusine coracana* (L.) Gaertn., *Pennisetum glaucum*(L.) R. Br., *Pennisetum violaceum* (Lam.) Rich., *Setaria pallida* fusca (Schum.) Stapf & Hubb., *Triticum aestivum* (L.) *and Zea mays*.(L.) Sorghum stripe disease was shown to be caused by a tenuivirus serologically related to maize stripe virus (MStV). Virus particles were filamentous and less than 10 nm in width. The purified virus preparation contained only one polypeptide of 34 500 D. Eight species of nucleic acids, 4 ssRNA of 1.21, 0.87, 0.73, 0.47 X 106D and 4 dsRNA of 2.43, 1.69, 1.40, 0.71 X 106D, were extracted from purified virus preparations. When the 4 dsRNA were denatured, they migrated along with the 4-ssRNA species indicating that dsRNA contained duplex RNA of same MW as the 4 ssRNA. In ELISA and in electro-blot immunoassay it was evident that MStV-Sorg was serologically more closely related to the MStV isolates from Florida, Reunion and Venezuela than to a RStV isolate from Japan. The virus was named MStV-Sorg to distinguish it from MStV, which readily infects maize. This was the first report of occurrence of a tenuivirus in the Indian subcontinent.

Shekhar *et al.* (1993b) carried out laboratory studies on resistance to the delphacid, *P. maidis* in ten sorghum genotypes and showed that IS 18676, IS 19677 and IS 19349 had stable levels of resistance for various components of pest resistance and could be used as potential donors in breeding programmes. Sekhar *et al.* (1995) screened thirty eight varieties/hybrids of sorghum against *P. maidis* during rainy/post-rainy seasons in India. SPV 736 and the hybrid MSH 65 were the most resistant to the delphacid by recording lowest pest populations. Hybrids PSYH 3 and SPH 430 also showed some resistance.

Jyothi *et al.* (1995) evaluated an isolate of maize mosaic nucleorhabdovirus on sorghum transmitted by the delphacid, *P. maidis* in a persistent manner. A single viruliferous plant hopper was able to cause 20 per cent infection and 100 per cent infection was obtained when a group of five plant hoppers per plant was used. The minimum acquisition and inoculation feeding periods were found to be 4 and 1 h, respectively. Nymphs were found to be more efficient in virus transmission (30%) than adults (13.3%). Similarly, macropterous *P. maidis* were more efficient vectors (33.3%) than brachypterous ones (23%) and in both cases the females showed higher rate of transmission.

Narayana and Muniyappa (1996a) surveyed for sorghum stripe disease caused by an isolate of maize stripe tenuivirus and observed the diseases on 0-13.5 per cent of crops in Karnataka, India. Continuous chlorotic stripe and bands on leaves characterized the disease and affected plants were dwarfed and produced poor panicles with few grains. Of the 276 field samples collected from 33 locations, 197 were positive in ELISA tests. The disease was transmitted by *P. maidis* and 1-6 insects/plant were observed during the survey. The minimum acquisition access period and inoculation access period were 4 and 1 h, respectively. The rate of transmission was 42 per cent, when single viruliferous *P. maidis* was used to inoculate seedlings. Of the several cultivated fodder and weed hosts tested under artificial inoculation, only wheat and *Sorghum halepense* (L.) showed characteristic symptoms similar to that on sorghum and reacted positively in ELISA tests.

Subbarayudu (2002) studied the incidence of shoot bugs (*P. maidis*) on 20 sorghum genotypes in a field trial during the rainy season (*kharif*) at the NRCS, Hyderabad, India. At 64 days after emergence (DAE), the maximum number of shoot bugs per plant were recorded on genotype, M 35-1 (25.8) and the fewest on genotype, DJ 6514 (3.5). Ten days later, there were fewer shoot bugs per plant on all genotypes except for ICSV 700. Genotype CSV 15 had the maximum number of damaged plants (50.5%) while CSH 6 had the least (9.5%) although differences were not significant.

Navi *et al.* (2004) monitored the maize stripe virus (MStV) prevalence on *S. bicolor* in the fields of Andhra Pradesh, Karnataka, Maharashtra and Tamil Nadu, India from August 1999 to March 2001. In a related experiment in Patancheru, Andhra Pradesh during 1999-2000 post-rainy seasons, the effect of MStV on grain and stover yields and digestibility under artificial inoculation was evaluated using sorghum genotypes M 35-1, ICSV 93046 and ICSV 745. Adult plant hoppers *(P. maidis*) previously fed on MStV infected plants were slowly transferred into whorls of each plant. Uninoculated plants served as the control. Among the 14 foliar diseases observed, MStV was the most destructive, recording a mean incidence and severity of 6 per cent and 85 per cent in Andhra Pradesh, 12 per cent and 83 per cent in Karnataka, 5 per cent and 67 per cent in Maharashtra and 12 per cent and 76 per cent in

Tamil Nadu across two years. MStV incidence and severity were higher in August 1999 to February 2000 than in August 2000 to March 2001. The mean MStV cumulative incidence in ICSV 93046, M 35-1 and ICSV 745 was 37.7, 25.8 and 17.6 per cent, respectively. The vegetative stage was more susceptible to MStV than the reproductive growth stage. The mean stover and grain yields of all cultivars were higher in the control than the inoculated treatments. The mean digestibility of leaves of inoculated plants was higher than that of control plants except in ICSV 93046. The mean digestibility of stems of inoculated plants was lower than that of control plants. Anaji (2005) reported that, CK 60B, Swati and RS 29 were promising against shoot bug by recording lower population.

2.1.3 Aphid, *M. sacchari*

Hagio (1992) investigated on screening method, degree of host plant resistance and inheritance of resistance in order to get information necessary to breed sorghum resistant to sugarcane aphid, *M. sacchari*. In the seedling tests, six varieties were classified as highly resistant and16 were classified as resistant, out of 160 varieties. Among these, three highly resistant varieties and 15 resistant ones were Chinese local (Kaoliang group) varieties. Field tests were also performed to confirm the results of the seedling tests. Correlation coefficients among factors such as dead plant percentage in the seedling tests, plant injury scores and aphid density scores in the field tests were high and significant. Therefore, the varietal reactions in the field were considered generally stable and the results of the seedling test were in general comparable with the field test.

Teetes *et al.* (1995) screened seedlings of 462 sorghum lines in Botswana to identify their resistance to sugarcane aphid, *M. sacchari*. About 7 per cent of the lines exhibited resistance in the seedling stage in greenhouse trials. In an advanced screening experiment, 12 sorghum lines had resistance ratings of 1.0-3.0 (highly resistant or resistant). In a similar test, older and larger plants of the same lines were as resistant as in the seedling stage. Lines IS 12664C, IS 12609C, IS 12158C, and IS 12661C were highly resistant in preliminary and advanced screening trials. Antixenosis was shown to be a mechanism of resistance. The sorghum lines, IS 12664C, IS 1144C, IS 1598C, and IS 12661C were less preferred than cv. Mtode, a susceptible sorghum.

Ghuguskar *et al.* (1999) tested new hybrids of sorghum for their resistance to *M. sacchari* in Maharashtra. A total of 26 hybrids were tested, 22 of which were new hybrids. Hybrids CSH 16 and 9728 were resistant to aphids, with the lowest infestation levels. Hybrids 9738, 9726, 9729, 9735, 9730, 9739, 9739 and 9727 also showed resistance, at a similar level or better than the released hybrids SPH 388, CSH 9 and CSH 14. Balikai (2001) reported that, SPV 570, RS 29 and C 49 were highly resistant to aphid, *M. sacchari.*

Van Den Berg (2002) conducted four field trials over four seasons during 1996-97 and 2000-01 to determine the status of resistance of South African sorghum hybrids to natural infestation by the aphid *M. sacchari*. Aphid damage symptoms were evaluated on a scale of 1 to 5. Pronounced differences were observed in levels of resistance of hybrids. However, hybrid reaction was, in many cases, not similar over seasons. PAN 8446, SNK 3939 and NS 5511 exhibited medium to severe damage symptoms in some seasons, whereas light to medium damage was observed in the other hybrids. The hybrid NK 283, which is the most commonly planted in South Africa, was highly susceptible to aphid damage and exhibited severe damage symptoms in most of the seasons. In 2000-01, the yield of hybrids was determined under fields infested with aphids and under insecticide treated fields. Significant differences in yield loss between hybrids were observed during 2000-01, ranging from 24 to 73 per cent. Tolerance to aphid damage was identified in some hybrids.

2.2 Morphological characters of *rabi* sorghum genotypes conferring resistance to shoot fly, shoot bug and aphid incidence

2.2.1 Shoot fly, *A. soccata*

Omori *et al.* (1983) studied the extent of the direct effect of componental characters on the expression of resistance to shoot fly in sorghum, using two different sets of sorghum plant material. Two of the componental characters *viz.* trichome intensity and glossiness intensity showed negative significant associations with the shoot fly resistance but did not play any direct role in building up the total variability in the shoot fly resistance. It also became evident that the major portion of the variability in shoot fly resistance was contributed by the character *i.e.*, number of eggs per plant. The glossy seedling expression in sorghum could be a simple and reliable selection criterion for shoot fly resistance. Singh and Rana (1986) reported that, glossy leaf surface and trichomes are frequently associated with shoot fly resistance.

Mote *et al.* (1986) carried out a study during the *kharif* season of 1983 with 19 shoot fly resistant sorghum cultivars and one sorghum cultivar susceptible to shoot fly, *A. soccata*, to examine the role of morphological plant characters in conferring resistance. The 16 lines IS 1082, IS 2146, IS 2312, IS 3962, IS 4663, IS 4646, IS 4661, IS 4666, IS 4712, IS 5214, IS 5470, IS 5490, IS 5604, IS 5613, IS 5622 and IS 5633 had high resistance levels to shoot fly. Egg laying was also less on these cultivars, oviposition was positively correlated with dead heart percentage. Non-preference for oviposition was the primary mechanism of shoot fly resistance. The plant characters *viz*., faster growth and tall plant habit, light green (yellowish) leaves and relatively narrow and long leaves were associated with shoot fly resistance. These characters could be used as a selection criterion while handling segregating generations.

Patel and Sukhani (1990a) correlated a number of plant characters with sorghum resistance to infestation by *A. soccata* in the field in Delhi, India. On the basis of the findings, they opined that, long and thin but sweet stem with long internodes; yellowish-green leaves (glossy) with high trichome density at the seedling stage and a short peduncle characters should be considered for selecting resistant genotypes.

Sree *et al.* (1994) reported that, leaf surface wetness (LSW) of the central whorl leaf originated from the plant and was not due to condensation of atmospheric moisture. The presence of trichomes was indirectly associated with LSW and resistance to the muscid but stomatal density was not associated with LSW production. The amount of wax extracted per 100 mg of fresh weight varied significantly between cultivars and seedling age. It was more in susceptible than in resistant cultivars; however, cuticular thickness was not associated with resistance. It was suggested that LSW could be the result of some form of cuticular movement of water to the leaf surface.

According to Sivaramakrishnan *et al.* (1994) also, the leaf surface wetness of the central whorl leaf of sorghum seedlings has been associated with susceptibility to *A. soccata*. Previous physical and physiological evidence suggested that LSW originates from the plant. This was confirmed by radioactive labelling methods using tritium and carbon-14. Tritiated water applied to the soil of potted seedlings was translocated to the surface of the whorl leaf. There were significant differences in the amount of tritiated water collected from susceptible (CSH 5) and resistant (IS 18551) genotypes. Studies with carbon-14 labelling of sorghum seedlings indicated the presence of (small amounts of) solutes in the surface water that might have affected the larval movement and survival.

Maiti *et al.* (1994) carried out studies with 520 sorghum lines varying in the intensity of leaf surface glossiness at the seedling stage to investigate the effect of plant height and days to flowering on the incidence of *A. soccata*. The results indicated that tall, late-maturing genotypes with high glossy intensity were the most resistant.

Maiti (1994b) analyzed the associations of some morpho-physiological traits such as intensity of glossiness, seedling vigour and trichomes of 520 sorghum germplasm with resistance traits of shoot fly. The differences in means among glossiness scores were significant, followed by trichomes and seedling vigour. It was concluded that high glossiness score and trichomes on both leaf surfaces can be used as highly reliable selection criteria for resistance to *A. soccata.*

Thamrongsilpa *et al.* (1997) reported that, two sets of insect pest resistant lines of sorghum were grown and selected at the National Corn and Sorghum Research Center, Bangkok, Thailand. First set composed of 30 shoot fly resistant lines, tested in late rainy season. They had good seeding vigor and took 59-71 days to flower. Most of entries were tall stature with 11-14 leaves per plant, 25-29 cm panicle length, 6-20 cm head exertion and low foliar diseases infection. Their grain yield ranged from 3,676 to 6,910 kg/ha.

Singh (1998) evaluated ten sorghum genotypes for shoot fly resistance in field trials at Hisar during rainy seasons. There was a positive correlation of seedling mass with leaves per plant and leaf width with oviposition and deadheart formation and concluded that rapid seedling growth and long, thin leaves during the seedling stage make plants less susceptible to shoot fly.

Tarun *et al.* (2000) conducted experiments in Hisar, Haryana, India, to determine the correlation between morpho-physiological traits and shoot fly resistance in sorghum. The plants comprised 40 genotypes (35 forage hybrids/varieties, 3 resistant controls and 2 susceptible controls). Shoot fly oviposition was negatively correlated with seedling height, leaf length, stem length, green fodder yield and dry fodder yield, but positively correlated with number of leaves per plant, leaf width, stem girth and panicle initiation. Shoot fly deadhearts were negatively correlated with seedling height, leaves per plant, leaf length, leaf width, stem length, green fodder yield and dry fodder yield, but positively correlated with stem girth and panicle initiation. The results suggested that genotypes having fast seedling growth, long and thin stems and glossy leaves during the seedling stage were comparatively resistant to shoot fly. Sajjanar (2002) reported that, predicted correlated genetic gain was high for shoot fly resistance when seedling vigour was used as indirect selection criteria.

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

Kamatar and Salimath (2003) conducted correlation, regression and path analyses by screening 650 sorghum germplasm collections for resistance to shoot fly during *rabi* seasons in Karnataka, India. High glossiness of leaf, light green colour of leaves, high seedling vigour, taller seedlings, narrow and erect leaves conferred resistance to sorghum shoot fly as indicated by correlation studies. Regression analysis explained this relationship for all the characters. Indirect effects of these traits through oviposition percentage were substantial, whereas ovipositional percentage contributed directly to maximum deadheart formation.

2.2.2 Shoot bug, *P. maidis*

Shekar *et al.* (1993a) investigated on the antixenosis component of resistance to corn plant hopper, *P. maidis* in ten selected sorghum genotypes at three plant growth stages (30, 45 and 60 DAG) under laboratory and field (rainy and post rainy seasons) conditions. In a free-choice test, the orientation and settling responses of nymphs and brachypterous adults on all genotypes although was influenced by the olfactory and visual responses, their feeding was not sustained due to gustatory stimuli indicating their significant role in determining the degree of antixenosis. The genotypes IS 18676, IS 19349 and IS 18677 showed a high degree of antixenosis in settling fewer nymphs and adults consistently at 30, 45 and 60 DAG. This finding was supported with low colonization of nymphs and brachypterous and macropterous adults under field conditions. In addition, high degree of antixenosis for oviposition in both laboratory and field tests was evidenced on IS 18676 and IS 19349 at 30, 45 and 60 DAG, but on SPV 472 and SPV 475 only at specific plant growth stages. The variability in the rate of adult colonization together with suitability of plant growth stages for oviposition has contributed to variable degrees of antixenosis for oviposition.

Mote and Shahane (1994) selected twelve sorghum varieties consisting of resistant, moderately resistant or susceptible to the delphacid, *P. maidis*, the aphid, *M. sacchari* and leaf sugary exudation (LSE) from 78 entries and their biophysical and biochemical characters were studied with the aim of determining their association with pest resistance, if any. The varieties with greater height, greater distance between two leaves, smaller leaf angle and the presence of waxy lamina were less susceptible to the aphid. The development of aphid and delphacid populations and LSE was more pronounced in varieties with higher nitrogen, sugar and total chlorophyll content of leaves (IS 105, IS 2217, IS 1063 and IS 553). The varieties ICSCTV 9, BTP 28, IS 1640, ICSV 148 and SPV 504, with higher contents of phosphorus, potassium and polyphenols, were less preferred by delphacids and aphids and also showed less development of LSE.

2.2.3 Aphid, *M. sacchari*

Balikai and Lingappa (2002a) reported that, the increase in the plant height and number of leaves, there was a reduction in aphid population. There was a positive correlation between leaf angle and distance between two leaves and aphid incidence.

2.3 Bio-chemical parameters of *rabi* sorghum genotypes conferring resistance to shoot fly, shoot bug and aphid incidence

2.3.1 Shoot fly, *A. soccata*

Archar and Bynum (1982) reported that, increasing N fertilizer enhanced sorghum fitness as a green bug host. Similarly, Patel and Sukhani (1990) reported that, per cent of N, reducing sugars, total sugars, moisture and chlorophyll contents of leaf in susceptible cultivars were higher than in resistant ones against shoot fly.

Chavan *et al.* (1990) evaluated six genotypes under three sowing dates (early *kharif*, late *kharif* and early *rabi*) for their response to shoot fly. Percentage infestation (based on number of plants with deadhearts) ranged from 21.1 in M 35-1 to 50.9 per cent in E 302; infestation was generally lower under early *kharif* sowing. Cultivars with low infestation had low HCN, nitrogen and magnesium and high silicon and calcium contents, as well as light green, hairy leaves.

Maiti (1994a) reported that, at the early seedling stage (7 days after emergence), the chlorophyll content was higher in less glossy and non-glossy genotypes compared to highly glossy. As age advanced, differences in chlorophyll contents became negligible. There were no significant differences in levels of chlorophylls a and b among the 12 genotypes studied. Epicuticular wax (EW) was at trace levels for all genotypes at 7 days after emergence but at 14, 21 and 28 days it was higher in the non-glossy line CSH 1 than in the highly glossy line IS 18551. This was not true in all cases and decreased with an increase in glossy intensity. EW content increased with age of crop up to 21 days after emergence. In another experiment, 28 glossy genotypes showed highly significant differences in EW content. Among them IS 5604, IS 2146 and IS 2312 contained low EW content and were tolerant of shoot fly, while lines IS 4661, IS 4776 and IS 5622 contained high EW contents and were moderately susceptible.

Bhise *et al.* (1996) reported that, cultivars resistant to *A. soccata* had higher activities of both polyphenoloxidase and peroxidase. Bhise *et al.* (1997) analyzed leaves of nine varieties of sorghum of varying susceptibility to *A. soccata* for chemical composition at 10, 17 and 24 days after germination. There was a positive relationship between N and P content and degree of damage by shoot fly, although N and P contents also decreased with age of leaves in all varieties. Reducing sugars increased slightly between days 17 and 20 in resistant varieties, but decreased in susceptible varieties. Starch content was not correlated to shoot fly resistance.

Singh *et al.* (2004b) evaluated the stability of bio-chemical constituents and their association with resistance to shoot fly for reducing sugars, total sugars, nitrogen, phosphorus, potassium, chlorophyll and moisture contents at weekly intervals of seedling growth (7, 14, 21 and 28 days after emergence) in 14 selected grain sorghum cultivars (five resistant accessions (IS nos. 1054, 2146, 2312, 3962 and 4664); three susceptible controls (CK 60B, CSV 1 and CSH 1); one national cultivar (CSV 8R); and five post rainy advanced generation (F_6) breeding lines (148 x CS 3541, SPV 103 x IS 4664, CSV 8R x SPV 104, SPV 104 x M 35-1, and PD 3-1-11 derivative). The cultivar IS 2312 and IS 4664 showed stability of antixenosis for oviposition during post rainy season in advanced generation lines compared to the susceptible controls. Deadheart formation was low and the expression of resistance was stable across different seedling growth stages in IS 1054 and IS 2146. Depletion in levels of reducing sugars and phosphorus in resistant cultivars played a significant role in deadheart formation in the test cultivars. Positive association of nitrogen and potassium with oviposition at early seedling stages indicated their role in releasing chemical cues for oviposition. Low levels of reducing sugars and total sugars seemed to enhance the degree of resistance to sorghum shoot fly. The total chlorophyll content had no relationship with antixenosis for oviposition. No relationship was observed between moisture content of sorghum seedlings and shoot fly resistance. Low concentrations of reducing sugars, total sugars, nitrogen, phosphorus and potassium in sorghum seedlings greatly enhanced the degree of antixenosis for oviposition/feeding and deadheart formation and could be used as selection criteria for resistance to shoot fly.

2.3.2 Shoot bug, *P. maidis*

Shekar *et al.* (1993b) evaluated ten sorghum genotypes at three plant growth stages in field trials conducted in India for the antibiosis component of resistance to *P. maidis* expressed in terms of survival, duration and population build-up of nymphs as well as the longevity and fecundity of adults. The results suggested that, antibiosis levels in IS 18676, IS 18677 and IS 19349 increased proportionately with plant age and the variability at different growth stages might be attributed to differences in host genotypes, which may greatly aid in resistance breeding programmes.

Anaji and Balikai (2006) reported that, there was no significant correlation between shoot bug population and the biochemical constituents of all the 20 sorghum genotypes selected for comparison, although, reducing sugars were positively correlated, the total sugars and total phenols were negatively correlated.

2.3.3 Aphid, *M. sacchari*

Rustamani *et al.* (1992) tested sixteen cultivars of corn [maize], two of sorghum, two of rice, nine of barley, eight of wheat and *Echinochloa oryzicola* (Ard.) Fritsch. [*E. oryzoides*], *E. crus-galli* and *E. crus-galli* subsp. *formosensis* for their resistance to aphids (*R. maidis* and *M. sacchari*) in the field in Japan. The acid soluble components of the plants were extracted. A concentration of 200-µg aconitic acid/g wet weight of leaves was sufficient to make maize and sorghum varieties resistant to aphids. *E. crus-galli* had large concentration of aconitic acid when mature, in contrast to the other grasses and rice. Barley and wheat contained less than 60 µg/g of aconitic acid. This concentration was insufficient to convey resistance. It was concluded that aconitic acid had moderate antifeedant properties towards aphids.

Mote and Shahane (1994) selected twelve sorghum varieties consisting of resistant, moderately resistant or susceptible to the delphacid, *P. maidis*, the aphid, *M. sacchari* and leaf sugary exudation from 78 entries and their biophysical and biochemical characters were studied with the aim of determining their association with pest resistance, if any. The development of aphid and delphacid populations and LSE was more pronounced in varieties with higher nitrogen, sugar and total chlorophyll content of leaves (IS 105, IS 2217, IS 1063 and IS 553). The varieties ICSCTV 9, BTP 28, IS 1640, ICSV 148 and SPV 504, with higher contents of phosphorus, potassium and polyphenols, were less preferred by delphacids and aphids and also showed less development of LSE.

Tsumuki *et al.* (1995) compared the differences in the amounts of leaf surface wax and nutritional components such as sugar and free amino acids among sorghum varieties that were resistant (PE 954177), moderately resistant (IS 84) and susceptible (Redlan B) to *M. sacchari*. Leaf surface wax was similar among varieties. The total sugar content and the free amino acid concentration were slightly more in the two resistant varieties than in the susceptible variety. Balikai and Lingappa (2002a) reported that, phosphorus, potash and polyphenol in healthy leaves were negatively correlated with aphid incidence.

2.4 Multiple pest resistance

Kulkarni *et al.* (1980) reported that, the entries SPV 97, SPV 108, SPH 111 and SPH 112 possessed high amount of resistance to shoot fly and stem borer. Mote and Bapat (1983) reported that, sorghum genotypes *viz.,* E 303, E 501, E 502 and E 503 were moderately resistant to both shoot fly and stem borer. Lad *et al.* (1985) tested CSH 1, CSH 5 and CSH 9 checks separately for their reactions to shoot fly and white grub and reported that they possess multiple resistances to both the pests.

Patel *et al.* (1989) tested twenty promising sorghum genotypes for multiple resistance to *A. soccata* and *C. partellus* in Delhi, India, in 1987-88. Of these eight (IS 1054,

IS 2205, IS 3962, IS 5459, IS 5619, IS 18577, IS 18584 and SPV 102) showed multiple resistance, SPV 102 was recommended as a resistant variety, while IS 2205, IS 18584 and IS 3962 were recommended for incorporation as sources of resistance.

Patel and Sukhani (1990b) conducted field trials in New Delhi, India, during 1987 and 1988 to estimate damage and yield loss in five sorghum cultivars (CSH 1, CSH 9, CSV 1, CSV 10 and GJ 35) following infestation by the pyralid, *C. partellus* and the muscid, *A. soccata*. Avoidable losses calculated for the new cultivars (CSH 9, CSV 10 and GJ 35) were less than those for old cultivars (CSH 1 and CSV 1).

Nwanze *et al.* (1991) developed a technique to test entries to be subjected to combinations of shoot fly [*A. soccata*], stem borer [*C. partellus*] and midge [*C. sorghicola*] infestations and evaluated for resistance to one or more of these insects. IS 18551 and IS 2195 were the best entries with resistance to shoot fly and stem borer and IS 22464 was the best midge resistant line. Advanced breeding lines showed a wide range of resistance to all three pests and had a higher frequency of resistance to stem borer. After two more seasons of testing, 35 promising lines with various combinations of resistance to all three pests were re-evaluated in 1989-90. Entries were also evaluated for recovery resistance to shoot fly and stem borer at 50 and 90 days after seedling emergence and for overall plant performance at harvest when yield data were recorded. Genotypes that combined reasonable levels of resistance to shoot fly and/or stem borer, recovered better and gave higher yields than those with good levels of resistance to midge. IS 2122 and IS 5613 were the best performing entries with yields of over 3 t/ha. PS 28060-3 had the best combination of resistance to all three pests, but grain yield was very low (1.05 t/ha).

Prem Kishore (1992a) reported that, in India, released sorghum varieties and hybrids, developed from temperate x tropical crosses, were attacked by various insect pests: the shoot fly, *A. soccata*, the stem borer, *C. partellus*, the midge, *C. sorghicola* and the earhead bug, *C. angustatus*. New sources of resistance (P 217, P 297, P 500) were identified and stem borer resistant var. P 311 and multiple pest resistant var. SPV 1015 (PGS 1) were developed. The already released hybrids CSH 9 and CSH 12R were also developed using this approach.

Prem Kishore (1992b) developed SPV 1015 (PGS 1), a variety of sorghum with resistance to *A. soccata* and *C. partellus*, in 1987 by pedigree selection from the cross P 601 x P 201. This variety was shown in tests at various places in India to have multiple resistance to two pests together with all the desirable agronomic traits. Hairiness of the ligule and midrib; stout stem and small internodes were identified in this variety to affect the establishment of the immature stages of these two key pests.

Prem Kishore (1993) screened 11 sorghum germplasm for resistance to *A. soccata* and *C. partellus*. The entries E 103, E 108, E 109, E 112 and E 358 showed multiple resistance to both pests. Prem Kishore (1994) developed six dual purpose sorghums *viz*., DS 1, DS 2, DS 3, DS 4, DS 5 and DS 6 after an extensive breeding programme involving parents with moderate levels of resistance to *A. soccata* and *C. partellus*, *i.e.,* moderate x moderate crosses. These dual purpose sorghum lines showed resistance to both *A. soccata* and *C. partellus* and possessed other desirable quality traits such as plant height, stem girth, total number of leaves, ear head length and breadth as well as grain and green fodder yield.

Mote and Shahane (1994) carried out studies on resistance to delphacid (*P. maidis*) and aphid (*M. sacchari*) and revealed that IS 2587 was the least susceptible to delphacid while IC/CI 109 was the least susceptible to aphids. The most promising cultivars for resistance to these insects were IS 1840, BTR 28, ICSCTV 9, ICVS 148 and SPV 504.

Jalaluddin *et al.* (1995) observed nineteen promising ICRISAT lines plus a local and a susceptible standard in the field at Bhavanisagar during *kharif* and summer 1990 and 1991 for shoot fly (*A. soccata*) oviposition at 7, 14 and 21 days after germination and for deadhearts caused by stem borer (*C. partellus*) at 35 and 45 DAG. Fourteen entries were rated as resistant to shoot fly and nine as resistant to stem borer. Six entries were resistant to both pests. The most promising as sources of multiple resistance being ICSV 705, IS 4881 and IS 13674. Maiti (1996) reported glossiness to have multiple resistance to shoot fly, stem borer, drought, salinity and high temperature

Singh and Grewal (1997) screened twenty six advanced sorghum genotypes from ICRISAT against shoot fly (*A. soccata*) and stem borer (*C. partellus*) under natural infestation conditions at Hisar during *kharif* 1994 and 1996. Pooled data revealed that deadhearts formed by shoot fly varied from 8.5 to 76.5 per cent. IS 18551 and ICSV 93091 had less than 10.0 per cent deadhearts due to shoot fly. Deadheart formation due to shoot fly was 15.0-20.0 per cent in ICSV 700, ICSV 93093, PB 15438 and IS 2312. Deadhearts formed by stem borer varied from 12.0 to 78.5 per cent. IS 2205, PB 15925, ICSV 700 and IS 2312 exhibited less than 20.0 per cent deadhearts due to stem borer. More than 70.0 per cent deadhearts due to both pests were recorded in susceptible controls CSH 1, CSH 9 and ICSV 1. It was concluded that ICSV 700 and IS 2312 were highly promising sources of multiple resistance to both shoot fly and stem borer.

Patil *et al.* (1998) developed GRS 1 which had resistance to charcoal rot (*Macrophomina phaseolina* (Tassi.) Goid.) and tolerances to shoot fly (*A. soccata*) and rust (*Puccinia purpurea*, Cooke) with superior grain and fodder yield.

Singh and Shankar (2000) carried out field experiment in Kanpur, India, during *kharif* 1997 and showed that, with regard to the incidence of the stem borer and shoot fly, MASV 33/93, ICSV 700 and PB 15438 were found to be consistently superior. These entries could be utilized in further breeding programmes for evolving resistant/tolerant varieties against stem borer/shoot fly. The genotype MASV 33/93 had good agronomic attributes including grain yield and accordingly, this genotype could be extensively used as a donor parent for evolving high yielding varieties resistant/tolerant to stem borer.

Prem Kishore (2001) reported presence of multiple resistance to shoot fly, *A. soccata* and stem borer, *C. partellus* in four entries *viz.*, KC 1, PGN 1, PGN 20 and PGN 64 in Delhi, India, during *kharif* 2000. Resistance to shoot fly was observed in ten entries *viz.*, PGN 1, KC 1, PGN 8, PGN 19, PGN 20, PGN 64, SHE 2, PFGS 2, PFGS 57 and PFGS 8 while five entries *viz.*, PGN 1, PGN 64, PGN 20, AKENT 20 and KC 1 showed resistance to stem borer compared to released variety CSV 15 which showed higher percentage of damage by both shoot fly and stem borer.

Balikai and Jamadar (2001) evaluated thirty sorghum germplasm lines including three checks (M 35-1, IS 2312 and SPV 86) for multiple resistance to charcoal rot, shootfly and aphids during 1991-94 in *rabi* season. Results indicated that, only one line, IS 33843 was found to possess multiple resistance to charcoal rot, shoot fly and aphid. The entries IS 2238, IS 33751, IS 33859 and M 35-1 were moderately resistant to both charcoal rot and shootfly while the entries IS 2312, IS 33764, IS 33820 and IS 33839 were moderately resistant to charcoal rot and resistant to shoot fly. The entry IS 44 was moderately resistant to shoot fly and aphid, while the entry IS 4657 was moderately resistant to charcoal rot and aphid.

Prem Kishore *et al.* (2002) identified new sources of resistance against shoot fly, *A. soccata*, stem borer, *C. partellus* and sugarcane leafhopper, *Pyrilla perpusilla* Walker. Eleven lines namely, SPV 1517, SPV 1518, SPH 1270, SPH 1183, SPH 1148, SPH 1280, SPV 1562, SPV 1572, SPV 1575, SPV 1576 and SPH 1363 showed resistance against shoot fly, thirteen lines namely, SPV 1518, SPV 1489, SPV 462, SPH 1148, SPH 1270, SPH 1280, CSH 17, SPV 1572, SPV 1563, SPV 1565, CSH 16, SPH 1335 and CSV 15 showed resistance against stem borer and five lines namely, SPV 1489, CSH 18, SPH 1270, SPV 1567 and SPH 1365 showed resistance against *Pyrilla*. The parental lines, which were resistant against different pests, were: AKMS 14A and C 43N against shoot fly, 463A and 27A against stem borer and C 43 against *Pyrilla*. Two entries namely, SPV 1518 and SPV 1572 were identified as multiple resistance sources showing resistance to both shoot fly and stem borer.

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

2.5 Management of sorghum pests by eco-friendly approaches

Thirumurthi *et al.* (1973) conducted field trials in summer and winter with sorghum variety CSH 1 using 10 per cent granules at 1.5 g/m seed furrow for phorate, fensulfothion, mephosfolan, aldicarb, carbofuran and Bux and at 3 g/m seed furrow for disulfoton, monocrotophos and Bux. The most successful seed furrow application treatments were aldicarb, carbofuran, phorate, mephosfolan and disulfoton.

According to Srivastava and Jotwani (1979), three applications of carbofuran in leaf whorls proved to be superior to disulfoton and endosulfan treatments against three major pests of sorghum, the shoot fly (*A. soccata*), stem borer (*C. partellus*) and midge (*C. sorghicola*). Carbofuran 3G and carbofuran 50 SP as a seed treatment gave highest yields.

Subhedar *et al.* (1992) carried out field trials in Maharashtra, India where in carbofuran used as a seed treatment gave better control of *A. soccata* on sorghum up to 28 days after planting than any other treatment applied. By harvest, plots treated with phorate (granules at 10 kg/ha), carbofuran (granules at 2 g/m row) and benfuracarb (granules at 2 g/m row) gave yields as good as those using carbofuran seed treatment.

Panchbhavi and Kotikal (1992) conducted experiments by soaking sorghum M 35-1 seeds in solutions of 0.07 per cent endosulfan, 0.04 per cent monocrotophos and water for 4 and 8 h, before sowing in the field in Karnataka, India. Treatment with monocrotophos resulted in reduced germination, while treatment with endosulfan increased germination. Two weeks after sowing, seeds soaked in monocrotophos had no deadhearts due to *A. soccata*, while those soaked in endosulfan had fewer deadhearts than in the control.. Patil *et al.* (1992) reported that, soaking sorghum seeds in endosulfan 35 EC at 0.07 per cent for 4 h reduced infestation of the muscid, *A. soccata* in the field in Karnataka, India and increased the percentage germination and yield.

Chaudhari *et al.* (1994) conducted experiments in Maharashtra with different insecticides to control the *A. soccata*, *P. maidis*, *M. sacchari* and leaf sugar malady (chikta) caused by *Claviceps sorghi* on CSH 8R and M 35-1 sorghum genotypes in *rabi.* Among the insecticides tried, three sprays of quinalphos (0.05%) were effective in controlling the *A. soccata*, in CSH 8R. *P. maidis* populations were controlled by all chemicals tested, except in carbofuran seed treated plots of M 35-1. Aphid populations were significantly controlled by quinalphos sprays in M 35-1 than the other chemicals under study. Three sprays of cypermethrin (0.01%) controlled the chikta in both (CSH 8R and M 35-1) genotypes.

Sharma *et al.* (1996) and Balikai (1998) reported that, treating sorghum seeds with imidacloprid 70 WS @ 7.5 and 10g/100 g seed, respectively was the most effective treatment in reducing damage by *A. soccata*.

Balikai *et al.,* (1998a) carried out field trials with sorghum cultivar M 35-1 to determine a cost effective method for the management of sorghum shoot fly, *A. soccata*. The results revealed that, soaking seeds for 8-10 h either in $CaCl_2$ (2%) + endosulfan (0.07%) or in endosulfan (0.07%) alone reduced the shoot fly incidence effectively and increased the seed yield by 44.8 and 41.9%, respectively, over untreated control.

Balikai (1999) reported that seed treatment with imidacloprid 70 WS @ 10 g/100 g sorghum seeds was effective in reducing the incidence of *A. soccata*. Soil application of Padan [cartap] 4G and Furadan [carbofuran] 3G @ 2 g/m row failed to control *A. soccata*.

Kandalkar *et al.* (1999) reported that, seed treatment with Imidacloprid 70 WS (75 g/kg) and carbosulfan 25 ST (200 g/kg), soil application of carbofuran 3 G (2 g/m row), foliar sprays of Curacron 50 EC (profenofos, 1 ml/litre), methomyl 12.5 L (2 or 3 ml/litre) and Endosulfon 35 EC (1.5 ml/litre) along with a resistant cultivar IS 18551 were evaluated for their efficacy against sorghum shoot fly (*A. soccata*) in a field experiment. Imidacloprid as seed treatment exhibited the best performance in controlling shoot fly damage at 14 and 28 days after eclosion, while highest infestation values at 14 and 28 DAE were recorded from methomyl (3 ml/litre, 51.41%) and Endosulfan (85.52%), respectively.

Balikai (2001) reported that, seed dressing with imidacloprid 70 WS @ 10g/kg was highly effective in lowering aphid population. Subbarayudu *et al.* (2002) reported that soil application of neem (0.375-0.5%) could repel the shoot fly from egg laying. The seed treatment with imidacloprid at 10 and 14 ml/kg effectively reduced the damage due to shoot fly. Soil application of potash at 30 kg/ha reduced the deadheart percentage without a significant effect on egg laying. Neem spray (0.5%) recorded the least number of deadhearts and was statistically on par with intercropping of sorghum and red gram at 2:1 ratio. A combination of soil application of muriate of potash (30 kg/ha) followed by seed treatment with imidacloprid (10-14 ml/kg) and neem (0.5%) spray was recommended for integrated pest management.

Balikai and Lingappa (2003a) conducted field studies during the post rainy seasons in Bijapur, Karnataka, India to evaluate the efficacy of different insecticides against the aphid, *M. sacchari*, in sorghum cultivar, M 35-1. Dimethoate 30 EC @ 1.7 ml/l recorded 95.25 per cent reduction in aphid population at 10 days after spraying, followed by endosulfan (93.22%) and chlorpyrifos (91.13%). Dimethoate also gave significantly higher grain yield (27.17 q/ha), fodder yield (6.66 t/ha) and 1000 grain weight (31.88 g) followed by endosulfan (26.43 q/ha, 6.46 t/ha and 31.42 g, respectively).

Prem Kishore *et al.* (2004) compared the new insecticide thiamethoxam (Cruiser) tested as seed treatment of sorghum cultivar CSV 15 with conventionally recommended insecticides, carbofuran 3 G and phorate 10 G. Bioefficacy and persistence studies with two formulations, *i.e.*, 350 FS (6.0 ml+20 ml water and 9.0 ml+20 ml water/kg seed) and 70 WS (3.0 g+10 ml water and 4.5 g+10 ml water/kg seed) of thiamethoxam showed that both the formulations in low and high doses were effective against sorghum shoot fly (*A. soccata*) and stem borer (*C. partellus*) and gave higher grain yield compared to carbofuran and phorate. Both the formulations were found safe.

Karibasavaraja *et al*. (2005) reported that, Thiamethoxam 70WS @ 3g/kg seeds was promising against shoot fly. Anaji and Balikai (2007) found Thiamethoxam 70WS @ 3g/kg seeds to be highly effective against shoot bug and Vijaykumar (2004) showed Thiamethoxam 70WS @ 2g/kg seeds to be highly effective against shoot bug.

3. MATERIAL AND METHODS

The studies on objective set out in the introductory chapter were carried out during *rabi* 2006-07 at the Regional Agricultural Research Station, Bijapur, Karnataka. The details of location of the experimental site, weather conditions, soil characteristics, experimental materials used, experimental procedures adopted during the course of investigation and statistical methods employed are presented in this chapter.

3.1 Location of the experimental site

Bijapur is situated in the Northern Dry Zone (Region-II, Zone-3) of Karnataka between 16° 49' N latitude and 77° 20' E longitude and at 398.37 m above mean sea level.

3.2 Weather conditions

The average rainfall is 580 mm confined to monsoon period from June to November with occasional showers in pre-monsoon months of April and May. Mean maximum temperature is usually more than 28 $^{\circ}$C throughout the year except in December. The relative humidity is high during monsoon months from July to September and uniformly low during summer months from March to May. The mean weekly meteorological data such as rainfall, temperature, sunshine hours and relative humidity recorded during the crop growth period are presented in Appendix 1.

3.3 Soil characteristics

The soil of the experimental site used for field studies *viz*., varietal screening and sorghum pest management was deep black soil.

3.4 Reaction of different *rabi* sorghum genotypes to shoot fly, shoot bug and aphid

The entries from Advanced Varietal and Hybrid Trial-I, Advanced Varietal and Hybrid Trial-II, Initial varietal and Hybrid Trial, Shoot Pest Nursery and Aphid and Shoot bug Nursery Trials were selected for the experiment along with resistant (IS2312 for shoot fly, Y 75 for shoot bug and T x 428 for aphid) and susceptible checks (DJ6514 for shoot fly, Hathi Kuntha for shoot bug and 296B for aphid). These entries were obtained from the National Research Centre for Sorghum, Hyderabad under All India Co-ordinated Sorghum Improvement Project. The details of pedigree of these entries are presented in Appendices 2, 3 and 4. The experiments were conducted in a Randomized Block Design (RBD) with three replications in a plot size of 1.2 x 4.0 m (2 lines of 4 m length) during *rabi* season using fish meal technique.

3.4.1 Shoot fly, *A. soccata*

3.4.1.1 Deadheart percentage

The shootfly incidence was recorded at 7, 14, 21 and 28 days after emergence of the crop. Total number of plants and number of plants showing deadheart symptoms were recorded in each entry. The percentage of deadhearts caused by shootfly was worked out and subjected to angular transformations before statistical analysis.

3.4.1.2 Seedlings with shoot fly eggs

All the plants in each plot were inspected for shoot fly eggs and recorded as number of plants with eggs. Total numbers of plants in each entry were also counted at 7, 14 and 21 days after emergence and percentage of seedlings with shoot fly eggs was computed.

3.4.1.3 Shoot fly eggs per 10 plants

Ten seedlings in each entry were selected randomly and total number of eggs laid on all the leaves were counted and recorded at 7, 14 and 21days after seedling emergence.

3.4.2 Aphid, *M. sacchari*

3.4.2.1 Aphid population density

The aphid population density was recorded on all the five randomly selected plants in each treatment at peak incidence during third week of January. Six leaves in each plant from apex to downward excluding flag leaf as well as dried leaves at the bottom were observed for aphid colonies and rated using 0-9 scale as detailed below (Kadam and Mote, 1983).

Per cent leaf area covered by aphids	Score
0	0
1-10	1
11-20	2
21-30	3
31-40	4
41-50	5
51-60	6
61-70	7
71-80	8
> 81	9

The tolerance/resistance of entry against aphid was judged on the basis of scores using the following resistance categories/classes (Balikai and Biradar, 2003a).

Score	Category
0.0-2.0	Resistant
2.1-3.0	Moderately resistant
3.1-5.0	Moderately susceptible
5.1-7.0	Susceptible
7.1-9.0	Highly susceptible

3.4.3 Shoot bug, *P. maidis*

3.4.3.1 Shoot bug population density

The shoot bug population density (both nymphs and adults) was recorded on five randomly selected plants in each genotype at 45 days after emergence. The average population per plant was worked out.

3.4.3.2 Shoot bug plant damage (Sorghum stripe disease incidence)

Total number of plants in each entry was recorded and number of plants showing yellowing, girdling and stunted growth were recorded at 70 days after emergence and percentage of plant damage due to sorghum stripe disease was worked out. The data were subjected to arcsin transformations before statistical analysis.

3.4.3.3 Percentage of girdled plants

Total number of plants in each entry was recorded and number of plants showing girdling of topmost leaves without panicle development was recorded at 70 days after emergence and percentage of girdled plants was worked out. The data were subjected to arcsin transformations before statistical analysis.

3.4.3.4 Percentage of stunted plants

Total number of plants in each entry was recorded and number of plants showing stunted plants was recorded at 70 days after emergence and percentage of stunted plants was worked out. The data were subjected to arcsin transformations before statistical analysis.

3.4.3.5 Percentage of panicle emergence

Total number of plants in each entry was recorded and numbers of plants with clear panicle emergence were also recorded at 80 days after emergence and percentage of panicle emergence was worked out. The data were subjected to angular transformations before statistical analysis.

3.5. Correlation of morphological characters of *rabi* sorghum genotypes with shoot fly, shoot bug and aphid incidence

3.5.1 Shoot fly, *A. soccata*

3.5.1.1 Trichome density

For recording leaf trichome density, the central portion of the fifth leaf from the base was taken from three randomly selected seedlings in each entry at 12-14 days after seedling emergence from each replication. Leaf bits (approximately 0.5 cm^2) were placed in 20 ml of acetic acid:alcohol (2:1) in small vials (1.5 cm diameter, 5.75 cm height) for overnight. The cleared samples were transferred to 90 per cent lactic acid in small vials and stored for later observations. For microscopic examination, the leaf samples were mounted on a slide in a drop of water and observed under stereomicroscope at a magnification of 10 X. The number of trichomes on the lower leaf surfaces was counted in three microscopic fields selected at random and expressed as trichome density per square millimeter (No./mm^2) (Plate 3).

3.5.1.2 Leaf glossiness

Intensity of leaf glossiness was recorded at 14 days after seedling emergence in the morning 6.30 to 9.30 hours for clear vision by using 1-5 scale (1 = lines with light green, shining, narrow, upward pointed leaves and 5 = lines with dark green, dull, broad and drooping leaves). Based on this scale the following categories were made.

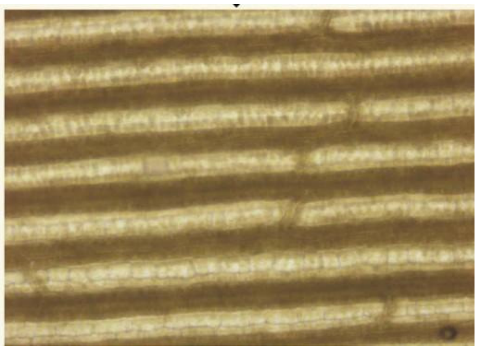
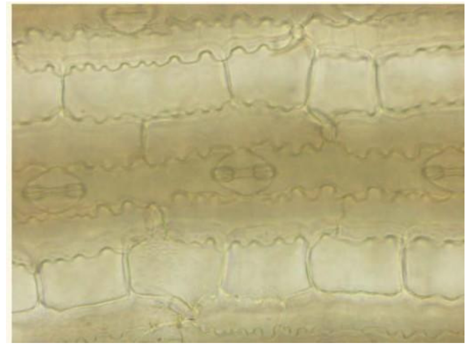
Score	Glossiness category
1.00 – 2.00	High
2.01 – 4.00	Medium
4.01 – 5.00	Low

3.5.1.3 Seedling vigour

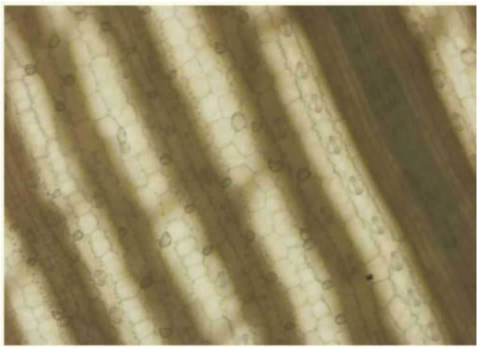
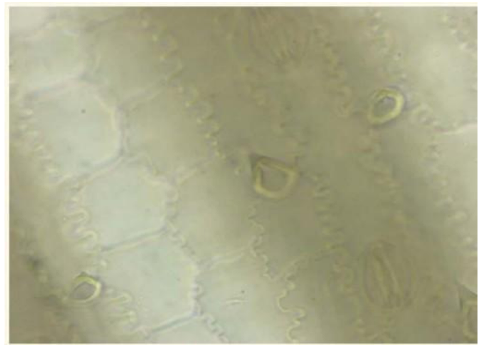
The seedlings were evaluated for vigour at 14 and 21 days after seedling emergence in the morning 6.30 to 9.30 hours, when seedling growth can be measured properly by using 1-5 scale (1 = plants showing maximum growth, leaf expansion and robustness and 5 = plants showing minimum growth, less leaf expansion and poor adaptation). Based on this scale the following categories were made.

Score	Seedling vigour category
1.00 – 2.00	High
2.01 – 4.00	Medium
4.01 – 5.00	Low

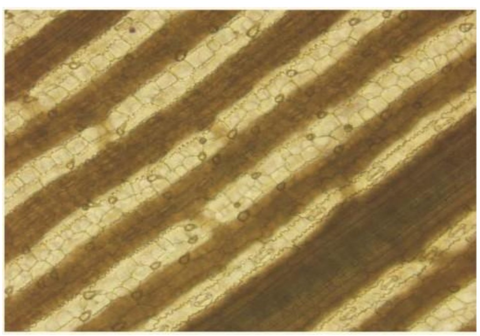
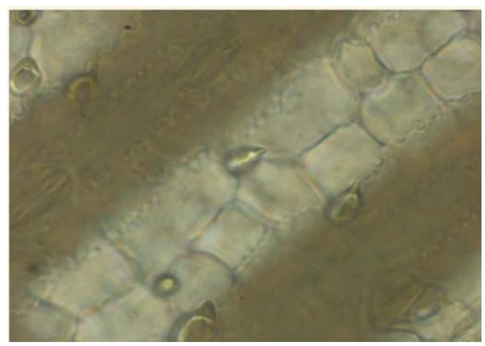
Normal view (10 x) **Close up View (40 x)**

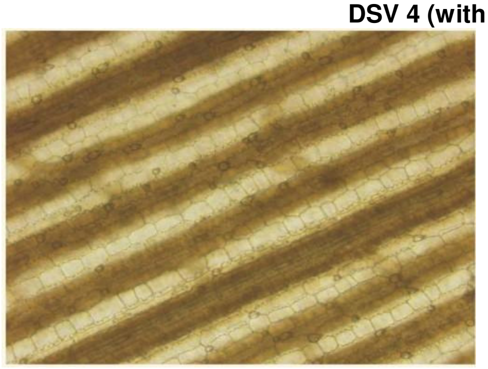
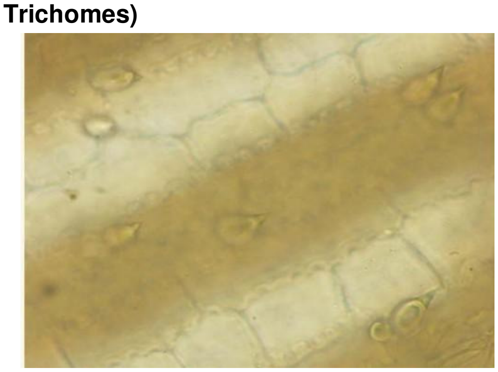
DJ 6514 (Free from Trichomes)

IS 2312 (with Trichomes)

DSV 4 (with Trichomes)

DSV 5 (With Trichomes)

Plate 3 : Trichome density on under surface of leaves

The dead hearts caused by shoot fly at 28 DAE, number of eggs per 10 plants and percentage of shoot fly seedlings with eggs were correlated with above morphological characters (*ie.*, trichome density, leaf glossiness and seedling vigour).

3.5.2 Shoot bug, *P. maidis*

From each entry, in each replication, five plants were selected randomly and observations on plant height (cm), distance between two leaves (cm), number of leaves per plant and leaf angle (degrees) and leaf area (length x breadth x 0.7) were recorded at milky stage of the crop. These morphological characters were correlated with shoot bug population density and percentage of plant damage due to shoot bug.

3.5.3 Aphid, *M. sacchari*

From each entry, in each replication, five plants were selected randomly and observations on number of leaves per plant, leaf area (length x breadth x 0.7), plant height (cm), distance between two leaves (cm) and leaf angle (degrees) were recorded at milky stage of the crop. The aphid density was correlated with above morphological characters.

3.6 Correlation of bio-chemical parameters of *rabi* sorghum genotypes with shoot fly, shoot bug and aphid incidence

Fifty genotypes with varied level of pest infestation were selected for sampling form different trials for the purpose of bio-chemical analysis. Leaf samples from these plants were collected at 60 days after emergence of the crop and were subjected to biochemical analysis of nitrogen, phosphorous and potash by following the analytical procedure prescribed by AOAC. (Anon., 1980). Chlorophyll index was also recorded using leaf chlorophyll meter (CCM 200). These biochemical parameters were correlated with the respective shoot fly, shoot bug and aphid incidences.

3.7 Management of sorghum pests by eco-friendly approaches

To evaluate different seed dressers, sprays and granules for the management of shoot fly, shoot bug and aphid, a field experiment was laid out in a Randomized Block Design at the Regional Agricultural Research Station, Bijapur during *rabi* 2006-07. The experiment consisted of eight treatments including an untreated check with three replications. The details of the treatments imposed are given below. The popular sorghum variety M 35-1 was raised in the plots measuring 5 x 3.6 m with 60 and 15 cm spacing between the rows and plants, respectively. All the agronomic practices were followed as per the package of practices for higher yields except plant protection schedule (Anon., 2005).

Treatments (IPM Strategies)

1. Seed treatment with 5 ml chlorpyriphos + 20 ml water/kg seeds + Two sprays with NSKE @ 5% at 30 and 60 DAE
2. Seed treatment with thiamethoxam 70WS @ 3 g/kg seeds + One spray each with NSKE @ 5% at 30 DAE and *Verticillium lecanii* at 60 DAE
3. Seed treatment with imidacloprid 70 WS @ 5 g/kg seeds + Two sprays with *Verticillium lecanii* at 30 and 60 DAE
4. Seed soaking for 8-10 h in Endosulfan 35 EC @ 3 ml + 30 g $CaCl_2$ per litre of water per kg seeds + Whorl application of carbofuran 3G @8 kg/ha at 30 DAE
5. Soil application of carbofuran 3G @ 20 kg/ha + Whorl application of carbofuran 3G @ 8 kg/ha + *Pongemia pinnata* Leaf extract @ 5% spray at 60 DAE
6. Endosulfan 35 EC @ 2 ml/lit – Three sprays at 7, 30 and 60 DAE
7. Soil application of crushed neem seeds @ 25 kg/ha + Two sprays with NSKE @ 5% at 30 and 60 DAE
8. Untreated check

Seed treatment was done in treatment T_1 by mixing recommended quantity of chemical and water in a polythene bag to which known quantity of seeds were mixed and then dried under shade before sowing. Seed treatment was done in treatment T_2 and T_3 by taking the recommended quantity of chemical in a polythene cover and mixed with seeds thoroughly by adding few drops of water and gum. For seed soaking in treatment T_4, one kilogram of seeds were soaked for 8-10 hours in a solution containing 3 ml of endosulfan 35 EC and 30 g of $CaCl_2$ in 1.5 litre of water, followed by shade drying for 10 minutes before sowing. In soil application treatment (T_5), chemical was applied in furrows and covered with soil before sowing. Whorl application was done (T_4 and T_5), by applying recommended quantity of insecticides into leaf whorls at 25 days after germination. In treatment T_7, crushed neem seeds were applied in furrows and covered with soil before sowing. Spraying was done by using Knapsack sprayer by using spray solution of 375 litres per hectare.

3.7.1 Deadheart percentage

The shoot fly incidence was recorded at 28 days after emergence of the crop. Total number of plants and number of plants showing deadheart symptoms were recorded from each plot. The percentage of deadhearts caused by shoot fly was worked out and subjected to angular transformations before statistical analysis.

3.7.2 Shoot bug population density

The Shoot bug population density (both nymphs and adults) was recorded on ten randomly selected plants in each plot at 45 days after emergence of the crop. The average population per five plants was worked out.

3.7.3 Per cent aphid index

The aphid population density (0-9 scale) was recorded on five randomly selected plants in each treatment as described in the first objective. Based on the scores (0-9 scale), the per cent aphid index (PAI) was worked out by the following formula generally used for computing percent disease index (Balikai and Lingappa, 2002b).

$$\text{PAI} = \frac{\text{Sum of all numerical ratings}}{\text{Number of plants observed} \times \text{Number of leaves per plant} \times \text{Maximum rating}} \times 100$$

3.7.4 Grain yield

Grains harvested from net plot of each treatment were dried and weighed. The grain weight of each plot was expressed in quintals per hectare.

3.7.5 Fodder yield

The data on fodder yield were recorded from the net plot of each treatment separately and converted to per hectare for statistical analysis.

3.7.6 Economics

Based on the prevailing market prices of produce (both grain and fodder yield), cost of insecticides, cost of labours and cost of others inputs, the net profit for each treatment was worked out.

4. EXPERIMENTAL RESULTS

The results of the experiment conducted during 2006-07 at the Regional Agricultural Research Station, Bijapur, on *rabi* sorghum pests like shoot fly (*A. soccata*), shoot bug (*P. maidis*) and aphid (*M. sacchari*) are elucidated in this chapter.

4.1 Reaction of *rabi* sorghum genotypes to shoot fly, shoot bug and aphid incidence

4.1.1 Advanced Varietal and Hybrid Trial- I (AVHT-I)

4.1.1.1 Shoot fly, *A. soccata*

4.1.1.1.1 Percentage of seedlings with shoot fly eggs

Increased percentage of seedlings with shoot fly eggs was noticed as the seedling age advanced from 7 to 21 days after emergence (DAE) among different genotypes. All the genotypes tested recorded significantly lower percentage of seedlings with eggs than the susceptible check DJ 6514 at 7, 14 and 21 DAE.

At 7 DAE, the seedlings with shoot fly eggs ranged from 15.4 to 64.7 per cent. The genotypes *viz.,* Maulee (15.8%), SPV 1709 (16.4%), SPV 1768 (17.6%), SPV 1762 (17.8%), SPH 1449 (18.8%), SPV 1680 (18.8%), SPV 1672 (19.2%) and DSV 4 (19.5%) were found to be superior and on par with the resistant check IS 2312 (15.4%). Significantly highest seedlings with shoot fly eggs were recorded on susceptible check DJ 6514 (64.1%). At 14 DAE, percentage of seedlings with shoot fly eggs ranged from 25.7 in SPV 1709 to 36.1 in CSV 18 and all the test entries were on par with the resistant check IS 2312 (28.9). At 21 DAE, percentage of seedlings with shoot fly eggs ranged from 32.9 in SPV 1709 to 47.2 in SPV 1755 and DSV 4 and all the test entries were on par with the resistant check IS 2312 (36.9) (Table 1).

4.1.1.1.2 Shoot fly eggs per 10 plants

The number of eggs per 10 plants increased from 7 to 21 DAE in all genotypes of advanced varietal and hybrids Trial-I. All the genotypes recorded significantly less number of eggs per 10 plants at 7, 14 and 21 DAE as compared to susceptible check DJ 6514 (Table 1).

At 7 DAE, lowest number of eggs per 10 plants were deposited on SPV 1709 (3.0) followed by Maulee (3.3), SPV 1762 (3.3), CSV 216R (3.7), SPV 1680 (4.0), SPH 1449 (4.3) and SPV 1768 (4.3) and were on par with the resistant check IS 2312 (2.7). At 14 DAE, lowest number of eggs per 10 plants were observed on SPV 1709 (3.3) followed by Maulee (4.0), SPV 1762 (4.3), CSV 216R (4.3), SPV 1680 (5.3), SPH 1449 (5.0) and SPV 1768 (5.3) and were on par with the resistant check IS 2312 (3.0) in comparison with susceptible check DJ 6514 (14.0). At 21 DAE, the genotypes *viz*., SPV 1709 (5.0), Maulee (5.3), SPV 1672 (5.7), CSV 216R (6.0) and SPV 1768 (6.7) recorded significantly lowest number of eggs per 10 plants and were on par with resistant check IS 2312 (4.0) (Table 2).

4.1.1.1.3 Deadheart percentage

The percentage of deadhearts due to shoot fly recorded at different days after emergence of the crop showed increasing trend as the age of the plant increased. All the entries recorded significantly lowest per cent deadhearts caused by shoot fly at 7, 14, 21 and 28 DAE as compared to susceptible check DJ 6514.

At 7 DAE, the deadhearts ranged from 0.8 to 8.4 per cent among the different genotypes in comparison with resistant check IS 2312 which recorded zero deadhearts. However, less deadhearts were observed in SPV 1680 (0.8%) and SPV 1762 (0.8%) followed by SPV 1709 (1.6%), SPV 1768 (1.6%) and SPV 1672 (2.5%) and were on par with each other (Table 2).

At 14 DAE, the deadhearts varied form 6.6 to 16.7 per cent among the all genotypes in comparison with resistant check IS 2312 (5.7%). The entries *viz*., SPV 1709 (6.6%), SPV 1768 (8.7%), Maulee (8.7%), SPV 1762 (9.1%), SPV 1672 (10.1%), SPV 1680 (10.4%) and SPH 1449 (12.2%) recorded significantly lowest deadhearts and were as best as resistant check IS 2312. At 21 DAE all the genotypes (12.9 to 22.5%) tested were on par with resistant check IS 2312 (12.4%) except CSV 18 (27.3%) (Table 2).

Table 1: Response of sorghum genotypes in Advanced Varietal Trial-I (AVHT-I) to oviposition by shoot fly

Sl. No.	Entry	% Seedlings with shoot fly eggs			Shoot fly eggs/10 plants (No.)		
		7 DAE	14 DAE	21 DAE	7 DAE	14 DAE	21 DAE
1	SPH 1449	18.8 (25.6)*	32.6 (34.6)	41.5 (40.1)	4.3	5.0	7.3
2	SPV 1680	18.8 (25.7)	28.4 (32.2)	39.8 (39.1)	4.0	5.3	7.3
3	SPV 1709	16.4 (23.8)	25.7 (30.4)	32.9 (35.0)	3.0	3.3	5.0
4	SPV 1672	19.2 (25.9)	26.9 (31.3)	36.7 (37.3)	3.3	4.3	5.7
5	SPV 1768	17.6 (24.8)	27.2 (31.3)	37.7 (37.8)	4.3	5.3	6.7
6	SPV 1762	17.8 (24.9)	27.2 (31.3)	38.5 (38.2)	6.3	6.3	8.0
7	SPV 1755	22.0 (27.9)	35.0 (36.2)	47.2 (43.3)	6.3	8.0	10.0
8	CSH 15R	22.4 (28.0)	30.8 (33.5)	42.9 (40.8)	6.0	8.7	8.8
9	CSV 216R	23.8 (29.1)	31.1 (33.7)	40.8 (39.5)	3.7	4.3	6.0
10	Maulee	15.8 (23.4)	26.8 (31.2)	35.5 (36.6)	3.3	4.0	5.3
11	M 35-1	22.3 (27.9)	30.4 (33.2)	43.3 (41.0)	7.7	9.3	10.3
12	CSV 18	24.6 (29.5)	36.1 (36.9)	46.3 (42.9)	6.3	8.3	9.7
13	DSV 4 (LC)	19.5 (26.1)	35.2 (36.4)	47.2 (43.4)	6.0	7.0	8.7
14	IS 2312 (R)	15.4 (22.9)	28.9 (32.4)	36.9 (37.9)	2.7	3.0	4.0
15	DJ 6514 (S)	64.7 (53.6)	80.5 (63.8)	99.7 (88.1)	11.0	14.0	17.3
	S.Em.±	2.2	3.0	3.9	0.7	0.8	1.0
	C.D. (0.05)	6.3	8.8	11.4	2.0	2.4	2.9
	C.V. (%)	13.5	14.9	16.0	23.5	22.8	22.0

DAE= Days after emergence,
R= Resistant check, S= Susceptible check, LC= Local check
* Figures in the parentheses are arcsin transformations

Table 2: Response of sorghum genotypes in Advanced Varietal Trial-I (AVHT-I) to deadhearts caused by shoot fly

Sl. No.	Entry	Shoot fly deadhearts (%)			
		7 DAE	14 DAE	21 DAE	28 DAE
1	SPH 1449	3.4 (10.5)*	12.2 (20.2)	19.8 (25.6)	25.8 (30.0)
2	SPV 1680	0.8 (5.2)	10.4 (18.7)	15.2 (22.9)	24.2 (29.4)
3	SPV 1709	1.6 (5.7)	6.6 (14.4)	12.9 (21.0)	20.7 (27.0)
4	SPV 1672	2.5 (8.8)	10.1 (18.4)	17.5 (24.7)	25.5 (30.3)
5	SPV 1768	1.6 (7.2)	8.7 (17.0)	13.6 (21.4)	21.5 (27.2)
6	SPV 1762	0.8 (5.2)	9.1 (17.5)	15.5 (22.9)	24.0 (28.9)
7	SPV 1755	7.6 (15.9)	16.7 (24.0)	22.5 (27.8)	34.1 (35.4)
8	CSH 15R	4.5 (11.9)	13.4 (20.8)	17.9 (24.6)	27.7 (31.2)
9	CSV 216R	4.8 (12.4)	12.6 (20.6)	19.2 (25.6)	27.9 (31.4)
10	Maulee	1.8 (7.6)	8.7 (17.1)	14.9 (22.6)	23.2 (28.7)
11	M 35-1	4.6 (12.2)	12.7 (20.5)	22.5 (27.8)	30.5 (33.1)
12	CSV 18	8.4 (16.7)	16.5 (23.6)	27.3 (31.2)	34.8 (35.9)
13	DSV 4 (LC)	7.3 (15.6)	15.4 (23.0)	22.0 (27.9)	33.1 (35.0)
14	IS 2312 (R)	0.0 (0.0)	5.7 (13.8)	12.4 (20.6)	18.9 (25.7)
15	DJ 6514 (S)	36.1 (36.9)	56.1 (48.5)	69.5 (56.5)	94.2 (76.1)
	S.Em.±	1.4	2.3	3.3	3.9
	C.D. (0.05)	4.0	6.7	9.4	11.5
	C.V. (%)	20.8	18.8	21.0	20.1

DAE= Days after emergence
R= Resistant check, S= Susceptible check, LC= Local check
* Figures in the parentheses are arcsin transformations

At 28 DAE, all the genotypes *viz*. SPV 1709, SPV 1768, Maulee, SPV 1762, SPV 1680, SPV 1672, SPH 1449, CSH 15R, CSV 216R, M 35-1, DSV 4, SPV 1755 and CSV 18 recorded 20.7, 21.5, 23.2, 24.0, 24.2, 25.5, 25.8, 27.7, 27.9, 30.5, 33.1, 34.1 and 34.8 per cent deadhearts, respectively and were on par with resistant check IS 2312 (18.9%) (Table 2).

4.1.1.2 Aphid, *M. sacchari*

4.1.1.2.1 Aphid population density

Among different genotypes screened, none of entries were found to be resistant to aphid based on aphid population density recorded on 1-9 scale at 80 DAE. The entry Y 75 was moderately resistant with 3.0 grade. However, the genotypes *viz*., Hathi kuntha (3.3) SPV 1755 (3.33), SPV 1762 (4.3), SPV 1768 (4.3), SPV 1680 (4.67), CSV 216R (5.0) and M 35-1 (5.0) were grouped under moderately susceptible category and remaining entries varied from 5 to 7 grade were grouped under susceptible category. The susceptible check 296B recorded highest grade of 8.3 (Table 3).

4.1.1.3 Shoot bug, *P. maidis*

4.1.1.3.1 Shoot bug population density

Significantly lowest shoot bug population density per plant was recorded in T x 428 (2.3) as compared to remaining entries (12.2 to 32.0) and was on par with resistant check Y 75 (0.9) (Table 3).

4.1.1.3.2 Plant damage due to shoot bug

Significantly lowest percentage of plant damage due to sorghum stripe disease caused by shoot bug was recorded in T x 428 (0.9) as compared to remaining entries (6.5 to 32.6) and was on par with resistant check Y 75 (1.1) (Table 3).

4.1.1.3.3 Percentage of girdled plants

Significantly lowest percentage of girdling of topmost leaves was recorded in T x 428 (0.6) as compared to remaining entries (2.7 to 26.5) and was on par with resistant check Y 75 (0.7) (Table 3).

4.1.1.3.4 Percentage of stunted plants

Significantly lowest percentage of stunted plants was recorded in T x 428 (0.3) as compared to remaining entries (2.7 to 7.0) and was on par with resistant check Y 75 (0.4) (Table 3).

4.1.1.3.5 Percentage of ear head emergence

Highest ear head emergence was recorded in T x 428, CSV 216R, SPV 1672 and SPH 1449 with 99.1, 93.5, 90.5 and 90.2 per cent, respectively and were on par with resistant check Y 75 (98.9%) (Table 3).

4.1.2 Advanced Varietal and Hybrid Trial-II (AVHT-II)

4.1.2.1 Shoot fly, *A. soccata*

4.1.2.1.1 Percentage of seedlings with shoot fly eggs

Increased percentage of seedlings with shoot fly eggs was noticed as the seedling age advanced from 7 to 21 days after emergence among different genotypes. All the genotypes tested recorded significantly lowest percentage of seedlings with eggs than the susceptible check DJ 6514 at 7, 14 and 21 DAE.

At 7 DAE, the seedlings with shoot fly eggs ranged from 15.9 to 50.0 per cent. The genotypes *viz.,* M 35-1(15.9%), SPV 1762 (17.4%), Maulee (19.4%), SPV 1704 (20.3%), SPH 1501 (20.6%), SPH 1449 (21.7%), CSV 216R (22.0%), CSH 15R (22.2%), SPV 1761 (22.4%), SPH 1579 (24.4%), DSV 4 (25.1%) SPV 1626 (25.8%) and CSV 18(29.4%), were found to be superior and on par with the resistant check IS 2312 (18.7%). Significantly highest seedlings with shoot fly eggs were recorded on susceptible check DJ 6514 (68.9%) (Table 4).

Table 3: Response of sorghum genotypes in Advanced Varietal Trial-I (AVHT-I) to aphid and shoot bug incidence

Sl. No.	Entry	Aphid population density (1-9) 80 DAE	Shoot bug population density 45 DAE	Shoot bug plant damage (%) 70DAE	% girdling 70 DAE	% stunted plants 70 DAE	% ear head emergence 80 DAE
1	SPH 1449	7.00	13.9	9.8 (18.1)	6.5 (14.7)	3.3 (10.1)	90.2 (73.0)
2	SPV 1680	4.67	16.6	10.6 (18.9)	4.8 (12.6)	5.8 (13.9)	89.4 (71.3)
3	SPV 1709	5.33	18.7	11.9 (19.9)	8.0 (16.4)	3.9 (11.3)	88.1 (70.0)
4	SPV 1672	5.67	13.4	9.5 (15.8)	5.7 (13.8)	3.8 (11.2)	90.5 (73.0)
5	SPV 1768	4.33	26.0	22.6 (28.1)	16.2 (23.7)	6.4 (14.6)	77.4 (62.0)
6	SPV 1762	4.33	32.0	32.6 (34.7)	26.5 (30.9)	6.1 (14.3)	67.4 (55.4)
7	SPV 1755	3.33	24.7	18.8 (25.5)	16.1 (23.6)	2.7 (9.5)	81.2 (64.4)
8	CSH 15R	5.33	17.4	10.7 (18.8)	4.4 (12.1)	6.3 (14.5)	89.3 (72.4)
9	CSV 216R	5.00	12.7	6.5 (14.7)	2.7 (9.3)	3.8 (11.2)	93.5 (75.5)
10	Maulee	5.67	26.9	24.4 (29.0)	20.3 (26.7)	4.1 (11.6)	75.6 (60.5)
11	M 35-1	5.00	22.9	18.1 (25.0)	12.4 (20.6)	5.7 (13.8)	81.9 (65.0)
12	CSV 18	5.33	21.7	20.6 (26.1)	14.5 (22.3)	6.1 (14.3)	79.4 (63.5)
13	T x 428 (RA)	1.0	2.3	0.9 (5.2)	0.6 (4.4)	0.3 (3.1	99.1 (84.6)
14	296B (SA)	8.3	12.2	10.7 (19.1)	6.7 (15.0)	4.0 (11.5)	89.3 (70.9)
15	Y 75 (RS)	3.0	0.9	1.1 (6.0)	0.7 (4.8)	0.4 (3.6)	98.9 (84.0)
16	Hathi Kuntha(SS)	3.3	31.4	22.5 (28.3)	15.5 (23.2)	7.0 (15.3)	77.5 (61.7)
	S.Em.±	-	2.6	2.8	0.8	0.6	3.8
	C.D. (0.05)	-	7.6	8.0	2.2	1.9	11.1
	C.V. (%)	-	24.9	23.0	7.7	9.7	9.6

DAE= Days after emergence,
RA= Resistant check to aphid, SA= Susceptible check to Aphid,
RS= Resistant check to shoot bug, SS= Susceptible check to shoot bug,
* Figures in the parentheses are arcsin transformations

Table 4: Response of sorghum genotypes in Advanced Varietal Trial-II (AVHT-II) to oviposition by shoot fly

Sl. No.	Entry	% Seedlings with shoot fly eggs			Shoot fly eggs/10 plants (No.)		
		7 DAE	14 DAE	21 DAE	7 DAE	14 DAE	21 DAE
1	SPV 1626	25.8 (30.2)	37.1 (37.0)	50.2 (45.4)	5.0	7.0	7.7
2	SPV 1704	20.3 (26.8)	26.0 (30.6)	33.1 (35.1)	3.0	4.0	5.0
3	SPH 1449	21.7 (27.7)	23.9 (29.2)	32.8 (34.9)	3.7	5.7	6.7
4	SPH 1501	20.6 (27.0)	29.7 (33.0)	39.5 (38.9)	3.3	5.0	5.7
5	SPH 1582	50.0 (44.9)	61.8 (52.1)	73.2 (59.9)	7.7	9.0	9.3
6	SPH 1579	24.4 (29.5)	36.4 (36.9)	52.5 (46.5)	5.3	7.3	7.7
7	SPV 1761	22.4 (28.2)	29.8 (33.1)	42.1 (40.4)	4.3	6.0	6.3
8	SPV 1762	17.4 (24.6)	21.3 (27.4)	31.8 (34.3)	2.3	4.0	4.3
9	SPV 1757	32.3 (34.5)	41.5 (40.0)	56.6 (48.9)	6.3	8.3	9.3
10	CSH 15R	22.2 (28.1)	27.3 (31.5)	38.1 (38.1)	3.3	5.3	6.3
11	CSV 216R	22.0 (27.7)	30.7 (33.6)	40.2 (39.4)	4.0	6.0	6.7
12	Maulee	19.5 (25.9)	28.6 (32.3)	35.7 (36.7)	3.3	5.0	6.0
13	M 35-1	15.9 (23.5)	26.0 (30.6)	35.5 (36.6)	2.7	4.7	5.7
14	CSV 18	29.4 (32.5)	48.4 (44.1)	62.5 (53.0)	6.3	8.3	9.7
15	DSV 4 (LC)	25.1 (30.0)	37.3 (37.6)	50.9 (45.5)	6.3	8.0	9.7
16	IS 2312 (R)	18.7 (25.6)	22.2 (28.1)	35.2 (36.3)	3.0	3.7	5.0
17	DJ 6514 (S)	68.9 (56.2)	82.7 (65.5)	100 (90.0)	11.0	14.0	15.3
	S.Em.±	2.7	3.3	3.9	0.7	0.8	0.8
	C.D. (0.05)	7.9	9.5	11.1	1.9	2.4	2.4
	C.V. (%)	15.4	15.6	14.9	24.5	21.8	19.6

DAE= Days after emergence
R= Resistant check, S= Susceptible check, LC= Local check
* Figures in the parentheses are arcsin transformations

At 14 DAE, the percentage of seedlings with shoot fly eggs ranged from 21.3 in SPV 1762 to 61.8 in SPH 1582 and the test entries SPV 1762 (21.3%), SPH 1449 (23.9%), M 35-1 (26.0%), SPV 1704 (26.0%), CSH 15R (27.3%), Maulee (28.6%), SPH 1501 (29.7%), SPV 1761 (29.8%), CSV 216R (30.7%), SPH 1579 (36.4%), SPV 1626 (37.1%) and DSV 4 (37.3%) were on par with the resistant check IS 2312 (28.9%) (Table 4).

At 21 DAE, the percentage of seedlings with shoot fly eggs ranged from 31.8 in SPV 1762 to 73.2 in SPH 1582 and the test entries SPV 1762 (31.8%), SPH 1449 (32.8%), SPV 1704 (33.1%), M 35-1 (35.5%), Maulee (35.7%), CSH 15R (38.1%), SPH 1501 (39.5%), CSV 216R (40.2%), SPV 1761 (42.1%), SPV 1626 (50.2%), DSV 4 (50.9%) and SPH 1579 (52.5%) were on par with the resistant check IS 2312 (36.9%) (Table 4).

4.1.2.1.2 Shoot fly eggs per 10 plants

The number of eggs per 10 plants increased from 7 to 21 DAE in all the genotypes of Advanced Varietal and Hybrids Trial-I. All the genotypes recorded significantly less number of eggs per 10 plants at 7, 14 and 21 DAE as compared to susceptible check DJ 6514 (Table 4).

At 7 DAE, the lowest number of eggs per 10 plants were deposited on SPV 1762 (2.3), M 35-1 (2.7), SPV 1704 (3.0), SPH 1501 (3.3), Maulee (3.3), CSH 15R (3.3), SPH 1449 (3.7), CSV 216R (4.0) and SPV 1761 (4.3) and were on par with the resistant check IS 2312 (3.0) (Table 4).

At 14 DAE, the lowest number of eggs per 10 plants were deposited on SPV 1704 (4.0), SPV 1762 (4.0), M 35-1 (4.7), SPH 1501 (5.0), Maulee (5.0), CSH 15R (5.3), SPH 1449 (5.7), CSV 216R (6.0) and SPV 1761 (6.0) and were on par with the resistant check IS 2312 (3.7) (Table 4).

At 21 DAE, the lowest number of eggs per 10 plants was deposited on SPV 1762 (4.3), SPV 1704 (5.0), M 35-1 (5.7), SPH 1501 (5.7), Maulee (6.0), CSH 15R (6.3), SPV 1761 (6.3) SPH 1449 (6.7) and CSV 216R (6.7) and were on par with the resistant check IS 2312 (5.0) (Table 4).

4.1.2.1.3 Deadheart percentage

The percentage of deadhearts recorded at different days after emergence of the crop showed increasing trend as the age of the crop increased. All the entries under study recorded significantly lower per cent deadhearts caused by shoot fly at 7, 14, 21 and 28 DAE as compared to susceptible check DJ 6514. At 7 DAE, the deadheart formed ranged from 0.4 to 17.0 per cent among the different genotypes. The genotypes *viz.,* SPH 1449 (0.4), M 35-1 (0.8), SPV 1762 (0.8) recorded significantly lowest per cent of deadhearts than resistant check IS 2312 (2.5) and SPV 1704 (3.0) was on par with the resistant check. Remaining entries recorded higher per cent deadhearts compared to resistant check (Table 5).

At 14 DAE, the deadhearts recorded varied from 8.9 to 39.5 per cent among the all genotypes in comparison with resistant check IS 2312 (10.3%). The entries *viz.,* SPV 1762 (8.9%), M 35-1 (9.1%) SPH 1449 (9.9%), SPV 1704 (13.5%), Maulee (13.6%), SPH 1501 (14.4%), CSH 15R (14.4%), SPV 1761 (16.1%), CSV 216R (16.6%), SPV 1626 (17.9%) and DSV 4 (19.9%) recorded significantly lowest deadhearts and were as good as resistant check IS 2312 (Table 5).

At 21 DAE, the genotypes SPH 1449 (14.8%), SPV 1762 (15.5%), M 35-1 (16.0%), Maulee (19.7%), CSH 15R (20.6%), SPV 1704 (21.0%), SPH 1501 (22.0%), SPV 1761 (23.0%), CSV 216R (24.4%), SPV 1626 (27.8%) and SPH 1579 (30.4%) and were on par with the resistant check IS 2312 (16.7 %) (Table 5).

At 28 DAE, the genotypes SPV 1762 (21.3%), SPH 1449 (22.8%), M 35-1(23.0%), CSH 15R (26.8%), Maulee (26.8%) SPV 1704 (27.3%), SPH 1501 (28.7%), SPV 1761 (31.7%) and CSV 216R (31.8%) were on par with resistant check IS 2312 (22.2%) (Table 5).

4.1.2.2 Aphid, *M. sacchari*

4.1.2.2.1 Aphid population density

Among the different genotypes screened none of the entries were found to be resistant except resistant check T x 428 (1.0) whereas Y 75 (3.0) was moderately resistant. The genotypes Hathi Kuntha (3.3), SPH 1449 (4.33), SPH 1501 (4.33), SPH 1582 (4.67), SPV 1762 (4.67), SPV 1757 (4.67), SPV 1626 (5.0), SPV 1704 (5.0) and SPH 1579 (5.0) were grouped under moderately susceptible category. Remaining genotypes (from 5.1 to 7.0) were grouped under susceptible category. Susceptible check 296B recorded highest grade of 8.3 (Table 6).

Table 5: Response of sorghum genotypes in Advanced Varietal Trial-II (AVHT-II) to deadhearts caused by shoot fly

Sl. No	Entry	Shoot fly deadhearts (%)			
		7 DAE	14 DAE	21 DAE	28 DAE
1	SPV 1626	9.6 (18.0)*	17.9 (23.9)	27.8 (30.7)	39.7 (38.7)
2	SPV 1704	4.0 (11.4)	13.5 (21.5)	21.0 (27.2)	27.3 (31.5)
3	SPH 1449	0.4 (2.1)	9.9 (18.4)	14.8 (22.6)	22.8 (28.5)
4	SPH 1501	7.0 (15.3)	14.4 (22.2)	22.0 (27.9)	28.7 (32.3)
5	SPH 1582	17.0 (24.3)	39.5 (38.4)	48.8 (44.1)	65.4 (54.3)
6	SPH 1579	12.9 (20.9)	21.3 (27.5)	30.4 (33.4)	43.6 (41.3)
7	SPV 1761	7.4 (15.8)	16.1 (23.6)	23.0 (28.7)	31.7 (34.2)
8	SPV 1762	0.8 (2.9)	8.9 (17.3)	15.5 (23.1)	21.3 (27.5)
9	SPV 1757	12.6 (20.8)	24.4 (29.4)	34.1 (35.6)	46.6 (43.0)
10	CSH 15R	6.1 (14.3)	14.4 (22.0)	20.6 (26.9)	26.8 (31.1)
11	CSV 216R	6.0 (14.1)	16.6 (23.7)	24.4 (29.4)	31.8 (34.2)
12	Maulee	5.9 (14.0)	13.6 (21.3)	19.7 (26.2)	26.8 (31.0)
13	M 35-1	0.8 (3.0)	9.1 (17.5)	16.0 (23.6)	23.0 (28.7)
14	CSV 18	11.0 (18.1)	26.3 (30.5)	35.8 (36.4)	48.9 (44.3)
15	DSV 4 (LC)	8.2 (16.6)	19.9 (26.4)	32.1 (34.4)	44.1 (41.6)
16	IS 2312 (R)	2.5 (7.2)	10.3 (18.7)	16.7 (24.1)	22.2 (28.1)
17	DJ 6514 (S)	31.8 (34.3)	61.9 (52.0)	73.7 (59.2)	91.4 (73.1)
	S.Em.±	2.1	3.0	3.2	3.5
	C.D. (0.05)	6.2	8.6	9.3	10.1
	C.V. (%)	24.9	20.2	17.8	16.1

DAE= Days after emergence
R= Resistant check, S= Susceptible check, LC= Local check
* Figures in the parentheses are arcsin transformations

Table 6: Response of sorghum genotypes in Advanced Varietal Trial-II (AVHT-II) to aphid and shoot bug incidence

Sl. No.	Entry	Aphid populat-ion density (1-9) 80 DAE	Shoot bug population density 45 DAE	Shoot bug plant damage (%) 70 DAE	% girdling 70 DAE	% stunted plants 70 DAE	% ear head emerge-nce 80 DAE
1	SPV 1626	5.00	23.9	28.7 (31.6)*	16.7 (24.1)	12.0 (20.3)	71.3 (57.7)
2	SPV 1704	5.00	20.2	28.4 (31.3)	22.4 (28.2)	6.0 (14.1)	71.6 (58.0)
3	SPH 1449	4.33	21.4	23.4 (27.1)	20.1 (26.6)	3.3 (10.4)	76.6 (61.2)
4	SPH 1501	4.33	23.3	31.2 (33.5)	24.9 (29.9)	6.3 (14.4)	68.8 (56.1)
5	SPH 1582	4.67	24.0	26.5 (30.2)	15.2 (22.9)	11.3 (19.6)	73.5 (59.0)
6	SPH 1579	5.00	22.7	22.7 (27.7)	13.5 (21.5)	9.2 (17.6)	77.3 (61.6)
7	SPV 1761	6.33	32.1	44.6 (41.9)	36.1 (36.9)	8.5 (16.9)	55.4 (48.1)
8	SPV 1762	4.67	41.0	59.3 (50.5)	54.2 (47.4)	5.1 (13.0)	40.7 (39.6)
9	SPV 1757	4.67	28.3	38.1 (38.0)	28.6 (32.3)	9.5 (17.9)	61.9 (51.9)
10	CSH 15R	5.33	29.5	41.2 (39.4)	34.0 (35.3)	7.2 (15.6)	58.8 (50.1)
11	CSV 216R	6.00	32.3	39.5 (38.1)	31.8 (34.3)	7.7 (16.1)	60.5 (51.2)
12	Maulee	6.33	30.4	29.8 (32.0)	21.0 (27.3)	8.8 (17.2)	70.2 (56.9)
13	M 35-1	6.67	31.9	44.2 (41.6)	36.3 (37.0)	7.9 (16.3)	55.8 (48.4)
14	CSV 18	6.00	24.3	23.5 (28.3)	17.8 (24.9)	5.7 (13.8)	76.5 (61.1)
15	T x 428 (RA)	1.0	2.3	0.9 (5.2)	0.6 (4.4)	0.3 (3.1	99.1 (84.6)
16	296B (SA)	8.3	12.2	10.7 (19.1)	6.7 (15.0)	4.0 (11.5)	89.3 (70.9)
17	Y 75 (RS)	3.0	0.9	1.1 (6.0)	0.7 (4.8)	0.4 (3.6)	98.9 (84.0)
18	Hathi Kuntha(SS)	3.3	31.4	22.5 (28.3)	15.5 (23.2)	7.0 (15.3)	77.5 (61.7)
	S.Em.±	-	3.4	4.2	1.1	0.9	3.5
	C.D. (0.05)	-	9.9	12.2	3.3	2.6	10.0
	C.V. (%)	-	24.8	24.1	7.5	10.9	10.2

DAE= Days after emergence
RA= Resistant check to aphid, SA= Susceptible check to Aphid,
RS= Resistant check to shoot bug, SS= Susceptible check to shoot bug,
* Figures in the parentheses are arcsin transformations

4.1.2.3 Shoot bug, *P. maidis*

4.1.2.3.1 Shoot bug population density

Significantly lower shoot bug population density per plant was recorded in T x 428 (2.3) as compared to remaining entries (12.2 to 41.0) and was on par with resistant check Y 75 (0.9) (Table 6).

4.1.2.3.2 Plant damage due to shoot bug

Significantly lower percentage of plant damage caused by sorghum stripe disease due to shoot bug was recorded in T x 428 (0.9) as compared to remaining entries (10.7 to 59.3) and was on par with resistant check Y 75 (1.1) (Table 6).

4.1.2.3.3 Percentage of girdled plants

Significantly lower percentage of girdling of topmost leaves was recorded in T x 428 (0.6) as compared to remaining entries (6.7 to 54.2) and was on par with resistant check Y 75 (0.7) (Table 6).

4.1.2.3.4 Percentage of stunted plants

Significantly lowest percentage of stunted plants were recorded in T x 428 (0.3) as compared to remaining entries (3.3 to 12.0) and was on par with resistant check Y 75 (0.4) (Table 6).

4.1.2.3.5 Percentage of ear head emergence

Highest ear head emergence was recorded in T x 428 (99.1%) as compared to remaining entries (40.7 to 89.3) and was on par with resistant check Y 75 (98.9 %) (Table 6).

4.1.3 Initial Varietal and Hybrid Trial (IVHT)

4.1.3.1 Shoot fly, *A. soccata*

4.1.3.1.1 Percentage of seedlings with shoot fly eggs

The percentage of seedlings with shoot fly eggs increased as the seedling age advanced from 7 to 21 days after emergence among different genotypes. All the genotypes tested in this trial recorded significantly lowest percentage of seedlings with eggs than the susceptible check DJ 6514 at 7, 14 and 21 DAE (Table 7).

At 7 DAE, the number of seedlings with shoot fly eggs ranged from 13.7 to 29.2 per cent. The genotypes *viz*., SPV 1796 (13.7%), Maulee (15.3%), CSV 216R (15.8%), SPV 1797 (18.1%), SPV 1803 (18.6%) SPV 1795 (18.8%), SPV 1804 (19.9%) SPV 1806 (20.6%), SPV 1800 (20.7%) and CSV 18 (20.8%) recorded less number of seedlings with eggs and were on par with the resistant check IS 2312 (11.9%) (Table 7).

At 14 DAE, the genotypes *viz.,* SPV 1804 (19.9%), Maulee (22.8%), SPV 1796 (22.8%), CSV 216R (23.7%), SPV 1797 (25.0%), SPV 1803 (25.9%) SPH 1601 (26.9%), SPV 1800 (27.9%), SPV 1799 (29.6%), M 35-1 (30.2%), SPV 1806 (30.6%) and CSH 15R (30.8) and were on par with the resistant check IS 312 (18.2%) with respect to number of seedlings with shoot fly eggs (Table 7).

At 21 DAE, the genotypes *viz.,* Maulee (26.0%), SPV 1797 (27.4%), SPV 1796 (29.4%), SPV 1803 (30.5%), SPV 1800 (31.1%), SPV 1804 (33.0%), CSV 216R (35.7%), SPH 1601 (36.3%), SPV 1795 (38.6%), SPV 1799 (39.9%), M 35-1 (40.1%), CSH 15R (40.5%), SPV 1806 (40.6%), SPV 1801 (41.7%), SPV 1794 (42.6%), SPV 1798 (44.2) and CSV 18 (44.3%) were as best as resistant check IS 2312 (23.8%) with respect to number of seedlings with shoot fly eggs (Table 7).

4.1.3.1.2 Shoot fly eggs per 10 plants

The number of eggs per 10 plants increased from 7 to 21 DAE in all genotypes of Initial Varietal and Hybrids Trial. All the genotypes from this trial recorded significantly less number of eggs per 10 plants at 7, 14 and 21 DAE as compared to susceptible check DJ 6514 (Table 7).

Table 7: Response of sorghum genotypes in Initial Varietal and Hybrid Trial (IVHT) to oviposition by shoot fly

Sl. No.	Entry	% Seedlings with shoot fly eggs			Shoot fly eggs/ 10 plants (No.)		
		7 DAE	14 DAE	21 DAE	7 DAE	14 DAE	21 DAE
1	SPV 1805	29.2 (32.6)*	40.8 (39.7)	61.7 (52.1)	6.0	7.7	8.7
2	SPV 1806	20.6 (26.3)	30.6 (33.0)	40.6 (39.3)	3.3	5.3	6.3
3	SPV 1794	28.1 (31.3)	35.8 (36.3)	42.6 (40.7)	4.0	6.7	8.3
4	SPV 1795	18.8 (25.2)	31.8 (34.3)	38.6 (38.3)	2.7	4.7	6.3
5	SPV 1796	13.7 (21.6)	22.8 (28.5)	29.4 (32.8)	2.7	5.0	6.7
6	SPV 1797	18.1 (24.9)	25.0 (30.0)	27.4 (31.5)	2.7	5.0	5.7
7	SPV 1798	25.2 (29.8)	32.7 (34.8)	44.2 (41.6)	4.3	6.0	7.7
8	SPV 1799	23.8 (29.2)	29.6 (32.9)	39.9 (39.1)	4.0	7.0	7.7
9	SPV 1800	20.7 (27.0)	27.9 (31.8)	31.1 (33.9)	2.7	5.7	6.0
10	SPH 1601	21.8 (27.8)	26.9 (31.2)	36.3 (36.9)	3.7	7.0	8.3
11	SPV 1801	24.5 (29.6)	32.9 (34.9)	41.7 (40.2)	4.3	6.7	8.3
12	SPV 1802	27.1 (31.2)	37.8 (37.7)	51.1 (46.2)	4.7	7.0	8.7
13	CSH 15R	22.5 (28.1)	30.8 (33.6)	40.5 (39.5)	3.7	5.0	6.0
14	CSV 216R	15.8 (22.9)	23.7 (28.7)	35.7 (36.5)	3.0	5.3	6.7
15	Maulee	15.3 (22.6)	22.8 (28.3)	26.0 (30.7)	2.0	4.0	5.0
16	M 35-1	23.7 (28.6)	30.2 (33.0)	40.1 (39.1)	4.7	5.3	6.7
17	CSV 18	20.8 (26.9)	33.2 (35.1)	44.3 (41.6)	5.0	8.3	9.7
18	SPV 1803	18.6 (25.3)	25.9 (30.5)	30.5 (33.4)	2.7	5.7	6.0
19	SPV 1804	19.9 (26.4)	27.0 (31.2)	33.0 (35.0)	3.3	5.7	6.7
20	DSV 4 (LC)	22.6 (28.2)	32.3 (34.6)	47.6 (43.6)	4.7	7.0	7.3
21	IS 2312 (R)	11.9 (20.1)	18.2 (25.2)	23.8 (29.2)	2.3	3.7	4.3
22	DJ 6514 (S)	53.4 (46.9)	79.1 (63.1)	99.8 (88.5)	11.3	14.7	16.7
	S.Em.±	2.5	3.1	4.7	0.5	0.8	1.0
	C.D. (0.05)	7.1	8.9	13.3	1.5	2.4	2.8
	C.V. (%)	15.5	15.8	19.9	22.4	22.7	22.5

DAE= Days after emergence
R= Resistant check, S= Susceptible check, LC= Local check
* Figures in the parentheses are arcsin transformations

At 7 DAE, the lowest number of eggs per 10 plants were deposited on Maulee (2.0), SPV 1804 (2.3) SPV 1800 (2.7), SPV 1803 (2.7), SPV 1795 (2.7), SPV 1797 (2.7), SPV 1796 (2.7), SPH 1601 (3.0), CSV 216R (3.0), SPV 1806 (3.3) and CSH 15R (3.7) and were on par with the resistant check IS 2312 (2.3) (Table 7).

At 14 DAE, the lowest number of eggs per 10 plants were recorded on Maulee (4.0), SPV 1795 (4.7), SPV 1796 (5.0), SPV 1797 (5.0), CSH 15R (5.0), CSV 216R (5.3), M 35-1 (5.3), SPV 1806 (5.3), SPV 1800 (5.7), SPV 1803 (5.7), SPV 1804 (5.7), SPV 1798 (6.0), SPV 1794 (6.7) and SPV 1799 (7.0) and were on par with the resistant check IS 2312 (3.7) (Table 7).

At 21 DAE, the genotypes *viz.,* Maulee (5.0), SPV 1797 (5.7), SPV 1800 (6.0), CSH 15R (6.0), SPV 1803 (6.0), SPV 1795 (6.3), SPV 1806 (6.3), SPV 1796 (6.7), CSV 216R (6.7), SPV 1804 (6.7) and M 35-1 (6.7) recorded significantly less number of eggs per ten plants and were on par with the resistant check IS 2312 (4.3) (Table 7).

4.1.3.1.3 Deadheart percentage

The percentage of deadhearts recorded at different days after emergence of the crop showed increasing trend as the age of the seedlings increased. All the entries under study recorded significantly lowest per cent deadhearts caused by shoot fly at 7, 14, 21 and 28 DAE as compared to susceptible check DJ 6514.

At 7 DAE, the deadhearts ranged from 1.4 to 11.1 per cent among the different genotypes in comparison with resistant check IS 2312 which recorded no deadhearts. However, less deadhearts were observed in SPV 1796 (1.4%) and Maulee (1.4%) were on par with resistant check (Table 8).

At 14 DAE, the genotypes that recorded significantly lowest percentage of deadhearts included CSV 216R (7.3%), SPV 1796 (7.7%), SPV 1797 (7.9%), Maulee (8.8%) and SPV 1803 (10.6%) and were on par with the resistant check IS 2312 (5.3%) (Table 8).

At 21 DAE, the genotypes *viz.,* SPV 1797(14.8%), Maulee (15.1%), SPV 1796 (16.5%), CSV 216R (17.9%), SPV 1803 (19.8%), SPV 1804 (19.8%), SPV 1601 (20.5%), SPV 1800 (20.6%), SPV 1798 (24.1%), SPV 1799 (25.0), CSH 15R (25.2%), SPV 1795 (25.5%), M 35-1 (25.8%), SPV1806 (27.0%), CSV 18 (27.0%), DSV 4 (27.8), SPV 1794 (28.0%) and SPV 1802 (28.0%) recoded lowest deadheart formation and were on par with the resistant check IS 2312 (14.1 %) (Table 8).

At 28 DAE, the genotypes *viz.,* Maulee(18.8%), SPV 1797(21.9%), SPV 1796(23.4 %), SPV 1800 (25.3%), CSV 216R (25.6%), SPV 1803 (26.8%), SPV 1804 (27.5%),SPV 1601 (29.9%), SPV 1795 (32.3%), SPV 1798 (33.0%), SPV 1799 (33.2%), CSH 15R (33.4%), M 35-1 (34.5%), SPV 1794 (35.8%), SPV 1806 (36.6%), SPV 1801 (37.2%) and SPV 1802 (39.3%) had less deadhearts and were on par with the resistant check IS 2312 (17.4%) (Table 8).

4.1.3.2.1 Aphid population density

Among the different genotypes screened, none of the test entries was found resistant except resistant check T x 428 (1.0) whereas Y 75 (3.0) and CSH 15R (3.0) were moderately resistant. The genotypes *viz.,* Hathi Kuntha (3.3), SPV 1802 (3.67), M 35-1 (4.0), SPV 1794 (4.33), SPV 1796 (4.33), SPV 1798 (4.67), SPV 1803 (4.67), SPV 1795 (5.0), SPV 1797 (5.0), SPV 1801 (5.0), SPV 1804 (5.0) and CSV 18 (5.0) were grouped under moderately susceptible category. The remaining entries from 5.1 to 7.0 grade were grouped under susceptible category. Whereas, 296B was highly susceptible to aphid which recorded score of 8.3 (Table 9).

4.1.3.3.1 Shoot bug population density

Significantly lower shoot bug population density per plant was recorded in T x 428 (2.3) and CSH 15R (4.9) as compared to remaining entries (12.2 to 31.4) and were on par with resistant check Y 75 (0.9) (Table 9).

4.1.3.3.2 Plant damage due to shoot bug

Significantly lower percentage of plant damage due to sorghum stripe disease caused by shoot bug was recorded in T x 428 (0.9) and CSH 15R (8.0) as compared to remaining entries (20.8 to 60.8) and were on par with resistant check Y 75 (1.1) (Table 9).

Table 8: Response of sorghum genotypes in Initial Varietal and Hybrid Trial (IVHT) to deadhearts caused by shoot fly

Sl. No	Entry	Shoot fly deadhearts (%)			
		7 DAE	14 DAE	21 DAE	28 DAE
1	SPV 1805	11.1 (19.2)*	21.4 (27.5)	38.4 (38.1)	52.2 (46.4)
2	SPV 1806	4.2 (11.6)	14.7 (22.5)	27.0 (30.5)	36.6 (36.7)
3	SPV 1794	8.2 (16.5)	20.4 (26.9)	28.0 (30.5)	35.8 (36.0)
4	SPV 1795	6.0 (14.1)	12.5 (20.7)	25.5 (30.2)	32.3 (34.4)
5	SPV 1796	1.4 (4.0)	7.7 (15.8)	16.5 (23.9)	23.4 (28.8)
6	SPV 1797	2.4 (7.1)	7.9 (16.1)	14.8 (22.6)	21.9 (27.8)
7	SPV 1798	5.8 (13.9)	16.0 (23.5)	24.1 (29.0)	33.0 (34.7)
8	SPV 1799	7.7 (16.1)	15.7 (23.2)	25.0 (29.9)	33.2 (35.1)
9	SPV 1800	4.6 (12.3)	13.0 (20.9)	20.6 (26.9)	25.3 (30.2)
10	SPH 1601	3.8 (8.7)	12.6 (20.7)	20.5 (26.8)	29.9 (33.0)
11	SPV 1801	8.5 (17.0)	18.1 (25.1)	29.4 (32.8)	37.2 (37.5)
12	SPV 1802	10.4 (18.8)	19.1 (25.8)	28.0 (31.2)	39.3 (38.4)
13	CSH 15R	6.6 (14.9)	14.8 (22.1)	25.2 (29.6)	33.4 (35.1)
14	CSV 216R	2.0 (6.6)	7.3 (15.3)	17.9 (24.7)	25.6 (30.3)
15	Maulee	1.4 (4.0)	8.8 (17.1)	15.1 (22.8)	18.8 (25.6)
16	M 35-1	8.4 (16.8)	16.7 (22.5)	25.8 (30.0)	34.5 (35.4)
17	CSV 18	7.6 (15.8)	14.7 (22.4)	27.0 (31.0)	38.9 (38.4)
18	SPV 1803	4.8 (12.3)	10.6 (18.8)	19.8 (26.2)	26.8 (30.9)
19	SPV 1804	4.1 (11.3)	12.2 (20.20)	19.8 (26.3)	27.5 (31.4)
20	DSV 4 (LC)	6.5 (14.7)	14.5 (21.9)	27.8 (31.8)	40.8 (39.7)
21	IS 2312 (R)	0.0 (0.0)	5.3 (13.1)	14.1 (22.0)	17.4 (24.6)
22	DJ 6514 (S)	21.7 (27.7)	43.8 (41.4)	70.4 (57.3)	95.7 (78.2)
	S.Em.±	2.1	2.3	3.7	4.5
	C.D. (0.05)	6.0	6.7	10.6	12.9
	C.V. (%)	24.4	18.4	21.6	23.9

DAE= Days after emergence
R= Resistant check, S= Susceptible check, LC= Local check
* Figures in the parentheses are arcsin transformations

Table 9: Response of sorghum genotypes in Initial Varietal and Hybrid Trial (IVHT) to aphid and shoot bug incidence

Sl. No.	Entry	Aphid populat-ion density (1-9) 80 DAE	Shoot bug populat-ion density 45 DAE	Shoot bug plant damage (%) 70 DAE	% girdling 70 DAE	% stunted plants 70 DAE	% ear head emergence 80 DAE
1	SPV 1805	6.00	19.9	28.0 (31.6)*	19.9 (26.5)	8.1 (16.5)	72.0 (58.1)
2	SPV 1806	5.33	26.4	34.6 (35.9)	28.5 (32.5)	6.1 (14.3)	65.4 (54.0)
3	SPV 1794	4.33	14.7	21.0 (25.6)	14.5 (22.4)	6.5 (14.7)	79.0 (63.0)
4	SPV 1795	5.00	25.0	32.6 (33.4)	24.2 (29.4)	8.4 (16.8)	67.4 (55.3)
5	SPV 1796	4.33	42.0	60.8 (53.4)	40.7 (39.6)	20.1 (26.6)	39.2 (38.8)
6	SPV 1797	5.00	31.6	39.5 (38.6)	33.1 (35.0)	6.4 (14.6)	60.5 (51.1)
7	SPV 1798	4.67	34.3	46.2 (42.8)	38.7 (38.5)	7.5 (15.9)	53.8 (47.2)
8	SPV 1799	5.33	19.9	25.8 (30.5)	18.8 (25.7)	7.0 (15.3)	74.2 (59.5)
9	SPV 1800	5.33	14.2	20.8 (26.6)	15.2 (22.9)	5.6 (13.6)	79.2 62.9)
10	SPH 1601	6.33	21.9	29.2 (32.7)	24.4 (29.6)	4.8 (12.6)	70.8 (57.3)
11	SPV 1801	5.00	19.2	22.8 (28.5)	14.2 (22.1)	8.6 (17.0)	77.2 (61.6)
12	SPV 1802	3.67	16.9	25.2 (28.7)	12.0 (20.2)	13.2 (21.3)	74.8 (59.9)
13	CSH 15R	3.00	4.9	8.0 (16.1)	3.9 (11.4)	4.1 (11.6)	92.0 (74.5)
14	CSV 216R	6.00	31.0	41.2 (39.7)	35.3 (36.5)	5.9 (14.0)	58.8 (50.1)
15	Maulee	5.67	12.9	18.0 (24.6)	14.0 (21.7)	4.0 (11.5)	82.0 (65.1)
16	M 35-1	4.00	28.0	39.1 (38.1)	32.5 (34.8)	6.6 (14.9)	60.9 (51.3)
17	CSV 18	5.00	21.8	30.6 (33.4)	23.7 (29.1)	6.9 (15.2)	69.4 (56.4)
18	SPV 1803	4.67	40.0	58.4 (50.0)	51.9 (46.1)	6.5 (14.7)	41.6 (40.4)
19	SPV 1804	5.00	24.7	36.6 (37.0)	30.8 (33.7)	5.8 (13.9)	63.4 (52.8)
20	T x 428 (RA)	1.0	2.3	0.9 (5.2)	0.6 (4.4)	0.3 (3.1	99.1 (84.6)
21	296B (SA)	8.3	12.2	10.7 (19.1)	6.7 (15.0)	4.0 (11.5)	89.3 (70.9)
22	Y 75 (RS)	3.0	0.9	1.1 (6.0)	0.7 (4.8)	0.4 (3.6)	98.9 (84.0)
23	Hathi Kuntha (SS)	3.3	31.4	22.5 (28.3)	15.5 (23.2)	7.0 (15.3)	77.5 (61.7)
	S.Em.±	-	2.9	4.4	1.0	0.9	3.0
	C.D. (0.05)	-	8.3	12.6	2.9	2.6	8.6
	C.V. (%)	-	23.5	24.9	6.6	11.1	8.9

DAE= Days after emergence,
RA= Resistant check to aphid, SA= Susceptible check to Aphid,
RS= Resistant check to shoot bug, SS= Susceptible check to shoot bug,
* Figures in the parentheses are arcsin transformations

4.1.3.3.3 Percentage of girdled plants

Significantly lower percentage of girdling of topmost leaves was recorded in T x 428 (0.6) as compared to remaining entries (3.9 to 51.9) and was on par with resistant check Y 75 (0.7) (Table 9).

4.1.3.3.4 Percentage of stunted plants

Significantly lowest percentage of stunted plants was recorded in T x 428 (0.3) as compared to remaining entries (4.0 to 20.1) and was on par with resistant check Y 75 (0.4) (Table 9).

4.1.3.3.5 Percentage of ear head emergence

Highest ear head emergence was recorded in T x 428 (99.1%), as compared to remaining entries (39.2 to 92.0%) and was on par with resistant check Y 75 (98.9 %) (Table 9).

4.1.4 Shoot Pest Nursery (SPN)

4.1.4.1.1 Percentage of seedlings with shoot fly eggs

Increased percentage of seedlings with shoot fly eggs was noticed as the seedling age advanced from 7 to 21 days after emergence among different genotypes under study. All the genotypes tested recorded significantly lowest percentage of seedlings with eggs than the susceptible check DJ 6514 at 7, 14 and 21 DAE.

At 7 DAE, the lines *viz.*, BRJ 356 (9.3), BRJ 367 (9.6), RSV 790 (9.9), RSV 842 (10.3) and RSV 458 (10.7) recorded significantly lowest percentage of seedlings with eggs compared to resistant check IS 2312 (15.8%). Remaining entries *viz.,* RSV 824 (12.1), IS 18551 (12.1), IS 2205 (12.8), BRJ 376 (12.8), RSV 471 (13.4), M 35-1 (13.6) RSE 03 (14.9), RSV 768 (15.8), RSPENT 4 (16.9), CS 3541 (17.7), RSV 639 (17.9), RSPENT 2 (18.7), RSV 836 (19.2), RSPENT 1 (19.4) and RSPENT 3 (20.2) were on par with resistant check (Table 10).

At 14 DAE, the genotypes *viz.,* RSE 03 (18.5%), M 35-1 (19.8%) BRJ 356 (20.3%), CS 3541 (21.1%), RSV 471 (21.5%), RSV 842 (21.7%), RSV 790 (22.1%), IS 2205 (22.2%), IS 18551 (22.3%), BRJ-367 (22.6%), RSV 458 (23.6%), RSV 824 (23.8%), BRJ 376 (24.1%) and RSV 639 (26.1%) were on par with resistant check IS 2312 (21.1%) with respect to seedlings having shoot fly eggs deposited on them (Table 10).

At 21 DAE, the genotypes RSE 03, M 35-1 RSV 471, IS 18551, RSV 458, RSV 842, IS 2205, RSV 790, BRJ 356, BRJ 367, BRJ 376, RSV 824, RSPENT 4, CS 3541 and RSPENT 2 recorded 21.6, 21.7, 26.6, 26.6, 27.4, 27.6, 28.6, 28.5, 25.8, 27.6, 28.2, 31.3, 34.5, 32.6 and 33.6 percentage seedlings with shoot fly eggs, respectively and were on par with the resistant check IS 2312 (27.7%) (Table 10).

4.1.4.1.2 Shoot fly eggs per 10 plants

The number of eggs per 10 plants increased from 7 to 21 DAE in all genotypes of Advanced Varietal and Hybrids Trial-I. All the genotypes recorded significantly less number of eggs per 10 plants at 7, 14 and 21 DAE as compared to susceptible check DJ 6514 (Table 10).

At 7 DAE, the genotypes IS 2205, RSE 03, M 35-1, BRJ 356, RSV 842, RSV 790, RSV 471, RSV 824, IS 18551, BRJ 367, BRJ 376, RSV 639, RSV 768, RSV 458, RSPENT 1 and RSPENT 3 recorded 1.3, 1.3, 1.3, 1.7, 2.0, 2.0, 2.0, 2.0, 2.0, 2.0, 2.0, 2.7, 2.7, 2.7, 2.7 and 2.7 eggs per 10 plants, respectively and these entries were on par with the resistant check IS 2312 (2.0) (Table 10).

At 14 DAE, the genotype RSE 03 (2.0) recorded significantly lowest number of eggs per ten plants than the resistant check IS 2312 (3.3). Remaining genotypes *viz.,* RSV 790 (2.3), RSV 842 (2.7), RSV 768 (3.0), RSV 458 (3.0), RSV 471 (3.0), RSPENT 3 (3.0), IS 18551 (3.0), BRJ 356 (3.0), BRJ 376 (3.0), RSPENT 2 (3.3), BRJ 367 (3.3), RSV 744 (3.7), RSV 824 (3.4), RSV 834 (4.0), RSV 823 (4.0), RSPENT 5 (4.0), M 35-1 (4.0), RSV 836 (4.3), RSPENT 1 (4.3) and RSPENT 4 (4.3) were as best as the resistant check in respect of number of eggs per 10 plants (Table 10).

Table 10: Response of sorghum genotypes in Shoot Pest Nursery (SPN) to oviposition by shoot fly

Sl. No.	Entry	% Seedlings with shoot fly eggs			Shoot fly eggs/10 plants (No.)		
		7 DAE	14 DAE	21 DAE	7 DAE	14 DAE	21 DAE
1	RSV 639	17.9 (21.5)	26.1 (30.6)	36.8 (37.2)	2.7	5.3	5.7
2	RSV 836	19.2 (25.9)	26.6 (31.0)	39.4 (38.9)	3.3	4.3	4.3
3	RSV 834	17.9 (27.7)	33.6 (35.4)	45.9 (42.7)	3.3	4.0	4.3
4	RSV 768	15.8 (23.4)	31.0 (33.8)	39.8 (39.1)	2.7	3.0	3.7
5	RSV 823	22.7 (28.4)	35.7 (36.7)	44.5 (41.8)	3.7	4.0	4.3
6	RSV 842	10.3 (18.7)	21.7 (27.7)	27.6 (31.7)	2.0	2.7	3.3
7	RSV 790	9.9 (18.3)	22.1 (28.0)	28.5 (32.3)	2.0	2.3	2.7
8	RSV 458	10.7 (19.0)	23.6 (29.1)	27.4 (31.6)	2.7	3.0	3.3
9	RSV 744	28.4 (32.1)	33.0 (35.0)	39.6 (38.9)	3.0	3.7	3.7
10	RSV 471	13.4 (21.4)	21.5 (27.6)	26.6 (31.0)	2.0	3.0	3.7
11	RSV 824	12.1 (20.2)	23.8 (29.2)	31.3 (34.0	2.0	3.7	4.3
12	RSPENT -1	19.4 (26.1)	29.9 (33.1)	39.1 (38.7)	2.7	4.3	4.7
13	RSPENT -2	18.7 (25.5)	28.5 (32.3)	33.6 (35.4)	3.0	3.3	3.7
14	RSPENT-3	20.2 (26.7)	29.2 (32.7)	35.9 (36.8)	2.7	3.0	3.3
15	RSPENT-4	16.9 (24.1)	26.5 (31.0)	34.5 (36.0)	3.3	4.3	4.7
16	RSPENT-5	28.6 (32.4)	36.0 (36.9)	48.0 (43.9)	3.7	4.0	5.0
17	BRJ 356	9.3 (17.7)	20.3 (26.7)	25.8 (30.6)	1.7	3.0	3.3
18	BRJ 367	9.6 (18.0)	22.6 (28.4)	27.6 (31.7)	2.0	3.3	3.7
19	BRJ 376	12.8 (20.9)	24.1 (29.4)	28.2 (32.1)	2.0	3.0	3.7
20	CS 3541	17.7 (24.9)	21.1 (27.3)	32.6 (34.7)	3.0	5.7	6.3
21	RSE 03	14.9 (22.7)	18.5 (25.5)	21.6 (27.7)	1.3	2.0	2.7
22	M 35-1	13.6 (21.4)	19.8 (26.4)	21.7 (27.8)	1.3	4.0	4.7
23	DSV 4 (LC)	25.5 (30.4)	34.6 (35.9)	48.2 (43.9)	4.0	6.0	6.7
24	DSV 5 (LC)	31.1 (33.9)	38.0 (38.1)	49.3 (44.6)	3.3	5.7	6.3
25	IS 2312 (R)	15.8 (23.1)	21.1 (27.2)	27.7 (31.7)	2.0	3.3	3.7
26	IS 2205 (R)	12.8 (20.9)	22.2 (28.1)	28.6 (32.2)	1.3	2.0	2.3
27	IS 18551(R)	12.1 (20.3)	22.3 (28.1)	26.6 (31.0)	2.0	3.0	3.3
28	DJ 6514 (S)	63.0 (52.5)	80.6 (63.9)	100.0(90.0)	11.0	13.7	17.0
	S.Em.±	1.3	1.3	1.6	0.3	0.4	0.4
	C.D. (0.05)	3.7	3.6	4.6	0.9	1.2	1.2
	C.V. (%)	9.2	6.8	7.5	19.9	18.3	15.7

DAE= Days after emergence
R= Resistant check, S= Susceptible check, LC= Local check
* Figures in the parentheses are arcsin transformations

At 21 DAE, the genotypes *viz*., RSV 790 (2.7), RSE 03 (2.7), RSV 842 (3.3) RSV 458 (3.3), RSPENT (3.3), IS 18551 (3.3), BRJ 356 (3.3), RSV 768 (3.7), RSV 744 (3.7), RSV 471 (3.7), RSPENT 2 (3.7), BRJ 367 (3.7), BRJ 376 (3.7), RSV 836 (4.3), RSV 834 (4.3), RSV 823 (4.3), RSV 824 (4.3), RSPENT 1 (4.7), RSPENT 4 (4.7) and M 35-1 (4.7) were on par with the resistant check IS 2312(3.7) in respect of number of eggs per 10 plants (Table 10).

4.1.4.1.3 Deadheart percentage

The percentage of deadhearts recorded at different days after emergence of the crop reflected increasing trend as the age of the seedling increased. All the entries recorded significantly lowest per cent deadhearts caused by shoot fly at 7, 14, 21 and 28 DAE as compared to susceptible check DJ 6514. At 7 DAE, the genotypes BRJ 367, BRJ 356, M 35-1, RSE .3, RSV 842, IS 2205 and IS 18551 were free from deadhearts and the genotypes RSV 790, RSV 471, BRJ 376, RSV 458, RSV 824, CS 3541, RSV 639 and RSPENT 4 recorded 0.8, 0.9, 0.9, 1.0, 1.0, 2.7, 3.6 and 3.6 per cent deadhearts, respectively and all these entries were on par with the resistant check IS 2312 (1.4%) (Table 11).

At 14 DAE, the genotypes BRJ 356, IS 18551, RSE 03, IS 2205, BRJ 367, BRJ 376, RSV 842, M 35-1, RSV 790, RSV 458, RSV 471, RSV 824, CS 3541, RSV 768, RSPENT 4, RSV 639, RSV 836 and RSPENT 3 recorded 2.9, 2.9, 3.1, 3.9, 4.3, 4.8, 5.0, 5.1, 5.5, 5.6, 5.2, 6.1, 8.8, 9.9, 10.3, 11.6, 12.1 and 13.2 per cent of deadhearts, respectively and were on par with resistant check IS 2312 (18.9%) (Table 11).

At 21 DAE, the genotypes IS 2205, RSV 842, RSE 03, M 35-1, BRJ 356, RSV 824, RSV 471, BRJ 367, RSV 790, IS 18551, BRJ 376, RSV 458 and RSV 639 recorded 10.9, 11.7, 12.4, 12.5, 13.0, 14.2, 14.4, 14.8, 15.0, 15.7, 15.9, 16.2 and 18.2 per cent of deadhearts, respectively and were on par with the resistant check IS 2312 (13.3%) (Table 11).

At 28 DAE, the genotypes IS 2205 (16.0), M 35-1 (16.3), BRJ 356 (16.7), RSE 03 (17.1), RSV 842 (18.2), BRJ 367 (18.9), RSV 471 (20.1), IS 18551 (19.6), RSV 824 (21.8), BRJ 376 (22.0) and RSV 790 (23.2) recorded significantly lowest percentage of deadhearts and were on par with resistant check IS 2312 (18.0%) (Table 11).

4.1.4.2.1 Aphid population density

Among the different genotypes screened in this trial, none of the entry was resistant except resistant check T x 428 (1.0) whereas Y 75 (3.0) was moderately resistant. The genotypes *viz.,* Hathi Kuntha (3.3), RSV 790 (4.0) BRJ 367 (4.0), RSV 639 (4.3), RSV 836 (4.3), RSV 768 (4.3), RSV 824 (4.3), RSPENT 1 (4.3), BRJ 356 (4.3), BRJ 376 (4.3), RSE 03 (4.3), M 35-1 (4.3), RSV 834 (4.7), RSV 823 (4.7), RSV 842 (4.7), RSPENT 4 (4.7), CS 3541 (4.7), RSV 458 (5.0), RSPENT 3 (5.0), RSPENT 5 (5.0) and DSV 4 (5.0) were grouped under moderately susceptible. Remaining entries with score from 5.1 to 7.0 were grouped under susceptible category. Susceptible check 296B recorded highest grade of 8.3 (Table 12).

4.1.4.3.1 Shoot bug population density

Significantly lower shoot bug population density per plant was recorded in T x 428 (2.3), BRJ 367 (3.5) and RSV 824 (3.4) as compared to remaining entries (4.9 to 31.4) and were on par with resistant check Y 75 (0.9) (Table 12).

4.1.4.3.2 Plant damage due to shoot bug

Significantly lower percentage of plant damage due to sorghum stripe disease caused by shoot bug was recorded in T x 428 (0.9), RSV 824 (1.9), RSV 744 (2.1), BRJ 356 (2.3), RSV 823 (2.6) and RSV 842 (2.7) as compared to remaining entries (2.8 to 10.7) and were on par with resistant check Y 75 (1.1) (Table12).

4.1.5 Aphid and Shoot bug Nursery (ASBN)

4.1.5.1.1 Deadheart percentage

At 28 DAE, the genotypes, CSV 216R (18.0), EC 8-2 (18.3), PEC-10-1 (20.1), SLR 37 (20.2), SLR 1(20.5), SLR 47 (20.8), IS 33722 (22.4), SLV 35 (23.5), SLR 32 (22.0), Maulee (24.5), PU 10-1 (24.9) and IS 33844-1 (24.6) recorded lowest percentage of deadhearts and were on par with resistant check IS 2312 (25.0 %) (Table 13).

Table 11: Response of sorghum genotypes in Shoot Pest Nursery (SPN) to deadhearts caused by shoot fly

Sl. No.	Entry	Shoot fly deadhearts (%)			
		7 DAE	14 DAE	21 DAE	28 DAE
1	RSV 639	3.6 (8.8)*	11.6 (19.7)	18.2 (25.1)	27.0 (31.2)
2	RSV 836	4.0 (10.6)	12.1 (20.2)	20.8 (27.0)	30.2 (33.3)
3	RSV 834	5.8 (13.8)	15.8 (23.3)	24.6 (29.7)	36.5 (37.1)
4	RSV 768	3.8 (11.0)	9.9 (18.2)	21.1 (27.3)	27.8 (31.8)
5	RSV 823	7.3 (15.7)	17.4 (24.6)	29.2 (32.6)	39.1 (38.6)
6	RSV 842	0.0 (0.0)	5.0 (12.9)	11.7 (20.0)	18.2 (25.2)
7	RSV 790	0.8 (2.9)	5.5 (13.0)	15.0 (22.5)	43.2 (28.8)
8	RSV 458	1.0 (4.7)	5.6 (13.6)	16.2 (23.9)	23.8 (29.1)
9	RSV 744	5.1 (12.9)	21.2 (27.4)	28.8 (32.4)	36.9 (37.3)
10	RSV 471	0.9 (3.2)	5.2 (12.7)	14.4 (22.3)	20.1 (26.6)
11	RSV 824	1.0 (3.4)	6.1 (13.8)	14.2 (22.0)	21.8 (27.7)
12	RSPENT -1	6.4 (14.7)	13.9 (21.9)	24.6 (29.7)	31.6 (34.2)
13	RSPENT -2	6.1 (14.2)	13.7 (21.7)	24.4 (29.6)	27.4 (31.5)
14	RSPENT-3	4.6 (12.1)	13.2 (21.3)	22.3 (28.2)	27.3 (31.4)
15	RSPENT-4	3.6 (8.9)	10.3 (18.1)	20.8 (27.1)	26.9 (31.2)
16	RSPENT-5	8.5 (16.9)	18.7 (25.7)	29.5 (32.9)	40.8 (39.7)
17	BRJ 356	0.0 (0.0)	2.9 (9.5)	13.0 (21.0)	16.7 (24.1)
18	BRJ 367	0.0 (0.0)	4.3 (11.5)	14.8 (22.6)	18.9 (25.8)
19	BRJ 376	0.9 (3.2)	4.8 (12.0)	15.9 (23.5)	22.0 (27.9)
20	CS 3541	2.7 (9.3)	8.8 (17.2)	18.7 (25.6)	28.0 (31.9)
21	RSE 03	0.0 (0.0)	3.1 (10.1)	12.4 (20.5)	17.1 (24.4)
22	M 35-1	0.0 (0.0)	5.1 (12.0)	12.5 (20.7)	16.3 (23.7)
23	DSV 4 (LC)	7.9 (16.3)	22.1 (28.0)	31.6 (34.2)	40.9 (39.7)
24	DSV 5 (LC)	7.7 (16.1)	23.8 (29.1)	32.2 (34.6)	41.6 (40.2)
25	IS 2312 (R)	1.4 (3.9)	8.2 (15.8)	13.3 (21.1)	18.0 (25.0)
26	IS 2205 (R)	0.0 (0.0)	3.9 (11.4)	10.9 (19.2)	16.0 (23.5)
27	IS 18551 (R)	0.0 (0.0)	2.9 (9.6)	15.7 (23.3)	19.6 (26.3)
28	DJ 6514 (S)	30.4 (33.5)	42.7 (40.8)	74.3 (59.5)	91.7 (73.4)
	S.Em.±	2.1	2.0	1.4	1.6
	C.D. (0.05)	6.1	5.7	4.1	4.6
	C.V. (%)	19.6	18.8	9.2	8.8

DAE= Days after emergence
R= Resistant check, S= Susceptible check, LC= Local check
* Figures in the parentheses are arcsin transformations

Table 12: Response of sorghum genotypes in Shoot Pest Nursery (SPN) to aphid and shoot bug incidence

Sl. No.	Entry	Aphid population density (1-9) 80 DAE	Shoot bug population density / plant (No.) 45 DAE	Shoot bug plant damage (%) 70 DAE
1	RSV 639	4.3	6.8	3.7 (11.1)
2	RSV 836	4.3	6.6	3.6 (10.9)
3	RSV 834	4.7	5.7	3.4 (10.6)
4	RSV 768	4.3	6.2	3.3 (10.4)
5	RSV 823	4.7	6.4	2.6 (9.3)
6	RSV 842	4.7	6.1	2.7 (9.1)
7	RSV 790	4.0	4.9	3.3 (10.7)
8	RSV 458	5.0	7.5	4.2 (11.8)
9	RSV 744	5.3	6.1	2.1 (8.4)
10	RSV 471	5.7	8.8	3.6 (10.8)
11	RSV 824	4.3	3.4	1.9 (7.9)
12	RSPENT -1	4.3	7.9	3.8 (11.2)
13	RSPENT -2	5.3	6.3	3.7 (11.0)
14	RSPENT-3	5.0	6.2	3.1 (10.0)
15	RSPENT-4	4.7	8.0	3.7 (10.8)
16	RSPENT-5	5.0	5.7	3.2 (10.2)
17	BRJ 356	4.3	7.5	2.3 (8.1)
18	BRJ 367	4.0	3.5	2.8 (9.4)
19	BRJ 376	4.3	5.5	5.2 (13.0)
20	CS 3541	4.7	5.6	3.6 (10.9)
21	RSE 03	4.3	6.9	3.2 (10.2)
22	M 35-1	4.3	9.0	3.2 (10.3)
23	DSV 4 (LC)	5.0	6.0	4.3 (11.8)
24	DSV 5 (LC)	5.3	7.1	4.6 (12.3)
25	T x 428 (RA)	1.0	2.3	0.9 (5.2)
26	296B (SA)	8.3	12.2	10.7 (19.1)
27	Y 75 (RS)	3.0	0.9	1.1 (6.0)
28	Hathi Kuntha (SS)	3.3	31.4	22.5 (28.3)
	S.Em.±	-	1.1	1.1
	C.D. (0.05)	-	3.0	3.1
	C.V. (%)	-	24.0	17.9

DAE= Days after emergence
RA= Resistant check to aphid, SA= Susceptible check to Aphid,
RS= Resistant check to shoot bug, SS= Susceptible check to shoot bug,
LC= Local check
* Figures in the parentheses are arcsin transformations

Table 13: Response of sorghum genotypes in Aphid Shoot bug Nursery (ASBN) to shoot fly, aphid and shoot bug incidence

Sl. No.	Entry	Shoot fly deadhearts (%) 28 DAE	Sorghum aphid population density (1-9) 80 DAE	Shoot bug population/ plant (No.) 45 DAE	Shoot bug Plant damage (%) 70 DAE
1	SLR 1	20.5 (26.9)*	3.0	16.1	8.2 (16.6)
2	SLR 5	26.2 (30.8)	3.3	23.0	10.0 (18.4)
3	SLR 8	26.3 (30.8)	3.3	12.5	9.1 (17.5)
4	SLR 10	28.3 (32.1)	2.7	6.1	2.4 (8.7)
5	SLR 13	38.9 (38.6)	3.7	16.4	13.4 (21.5)
6	SLR 17	27.4 (31.5)	4.3	23.3	12.5 (20.6)
7	SLR 24	30.0 (33.2)	3.3	18.4	7.7 (15.7)
8	SLR 25	31.7 (34.2)	3.0	26.9	9.1 (17.2)
9	SLR 27	33.9 (35.5)	4.7	19.2	10.1 (18.3)
10	SLR 28	30.7 (33.6)	4.3	18.4	12.4 (20.5)
11	SLR 29	25.7 (30.4)	2.7	10.4	10.6 (19.0)
12	SLR 31	36.2 (36.9)	4.0	27.0	15.4 (23.1)
13	SLR 32	22.0 (27.9)	5.3	26.1	10.0 (18.4)
14	SLR 34	33.8 (35.5)	3.0	12.4	5.6 (13.3)
15	SLR 35	34.3 (35.8)	4.0	6.5	1.3 (6.4)
16	SLR 37	20.2 (26.6)	2.0	5.9	1.3 (6.4)
17	SLR 38	26.0 (30.7)	3.0	16.5	9.3 (17.2)
18	SLR 39	34.6 (36.0)	4.3	24.0	8.1 (16.5)
19	SLR 40	29.1 (32.6)	3.6	26.7	9.0 (17.4)
20	SLR 41	35.7 (36.7)	4.7	13.0	20.7 (26.9)
21	SLR 43	41.1 (39.6)	4.0	27.0	13.9 (21.5)
22	SLR 45	25.0 (30.0)	3.0	13.5	8.6 (16.1)
23	SLR 46	49.7 (44.8)	3.7	14.1	6.7 (15.0)
24	SLR 47	20.8 (27.1)	3.3	14.8	7.8 (16.0)
25	SLV 25	28.8 (32.4)	2.7	9.9	2.4 (8.8)
26	SLV 27	28.9 (32.5)	3.3	12.8	10.6 (18.8)
27	SLV 29	40.3 (39.4)	3.7	6.7	1.5 (6.9)
28	SLV 31	35.6 (36.6)	2.7	4.1	2.3 (8.6)
29	SLV 35	23.5 (29.0)	2.3	8.1	16.9 (23.9)

Table Contd…..

Table 13: (Contd…)

Sl. No.	Entry	Shoot fly deadhearts (%) 28 DAE	Sorghum aphid population density (1-9) 80 DAE	Shoot bug population/ plant (No.) 45 DAE	Shoot bug Plant damage (%) 70 DAE
30	CRS 10	25.8 (30.5)	3.0	12.6	16.4 (23.9)
31	CRS 11	30.1 (33.2)	4.0	15.8	17.4 (24.6)
32	CRS 2	32.5 (34.7)	4.7	22.5	5.6 (13.0)
33	EP 56	42.8 (40.8)	3.3	19.9	10.8 (19.0)
34	IS 33722	22.4 (28.3)	2.7	14.7	17.8 (25.0)
35	IS 3420	34.4 (35.9)	4.0	15.1	11.2 (19.4)
36	EC 8-2	18.3 (25.2)	4.7	17.9	8.9 (16.7)
37	IS 33844-1	24.6 (29.7)	3.0	14.7	8.3 (16.2)
38	EP 65	42.3 (40.6)	2.0	12.2	10.7 (19.0)
39	PEC 10-1	20.1 (26.5)	3.0	10.6	4.8 (12.5)
40	PU 10-1	24.9 (29.9)	2.7	12.9	11.2 (18.8)
41	M 35-1	27.0 (31.3)	3.3	25.9	13.0 (21.1)
42	Maulee	24.5 (29.6)	3.3	23.7	12.6 (20.7)
43	CSV 216R	18.0 (25.0)	4.0	3.4	3.4 (10.5)
44	T x 428 (RA)	88.9 (71.2)	1.0	2.3	0.9 (5.2)
45	296B (SA)	84.3 (66.9)	8.3	12.2	10.7 (10.7)
46	Y 75 (RS)	88.3 (70.6)	3.0	0.9	1.1 (6.0)
47	Hathi Kuntha (SS)	93.5 (75.7)	3.3	31.4	22.5 (28.3)
48	DSV 5 (LC)	37.3 (37.6)	4.0	21.7	22.2 (28.1)
49	DSV 4 (LC)	44.1 (41.6)	4.0	30.6	22.5 (28.3)
	S.Em.±	1.7	-	1.9	2.1
	C.D. ().05)	4.8	-	5.3	5.7
	CV (%)	8.2	-	20.7	20.5

DAE= Days after emergence
RA= Resistant check to aphid, SA= Susceptible check to Aphid,
RS= Resistant check to shoot bug, SS= Susceptible check to shoot bug,
LC= Local check
* Figures in the parentheses are arcsin transformations

4.1.5.2.1 Aphid population density

Aphid population density was recorded on 1 to 9 grade at 80 days after emergence. Among different genotypes *viz.,* T X 428 (1.0), EP 65 (2.0) and SLR 37 (2.0) were grouped under resistant category. Fifteen genotypes whose score varied from 2.1 to 3.0 were grouped under moderately resistant and twenty six entries with score of 3.1 to 5.0 were grouped under moderately susceptible and SLR 32 (5.3) was grouped under susceptible category. Susceptible check 296B recorded highest grade of 8.3 (Table 13).

4.1.5.3.1 Shoot bug population density

Significantly lowest shoot bug population density per plant was recorded in T x 428 (2.3), CSV 216R (3.4), SLV 31 (4.1), SLR 37 (5.9), and SLR 10 (6.1) as compared to remaining entries (6.5 to 30.6) and were on par with resistant check Y 75 (0.9) (Table 13).

4.1.5.3.2 Plant damage due to shoot bug

Significantly lowest percentage of plant damage due to sorghum stripe disease caused by shoot bug was recorded in T x 428 (0.9), SLR 35 (1.3) and SLR 37 (1.3), SLV 29 (1.5), SLV 31 (2.3), SLV 10 (2.4), SLV 25 (2.4) and CSV 216R (3.4) as compared to remaining entries (4.8 to 22.5) and were on par with resistant check Y 75 (1.1) (Table 13).

4.1.6 Response of various *rabi* sorghum genotypes to multiple pest resistance

Among the AVHT-I, AVHT-II and IVHT trials screened against sorghum pests *viz.,* shoot fly, shoot bug and aphid, the genotype SLR 37 was found to possess multiple resistances to shoot fly, shoot bug and aphid. The genotypes viz., CSH 15R, CSV 216R, BRJ 356 and RSV 824 possessed multiple resistance to shoot fly and shoot bug, while the entry T x 428 was found to possess multiple resistance to aphid and shoot bug. Few lines possessed resistance to only one pest. Among them, the only one genotype EP 65 was resistant to aphid, while SLR 35, SLV 29, SLV 31, SLV 10, SLV 25 and Y 75 were resistant to shoot bug. The germplasm *viz.*, SPV 1709, SPV 1768, Maulee, SPV 1762, SPV 1680, SPV 1672, SPH 1449, M 35-1, DSV 4 ,SPV 1755, CSV 18, SPV 1704, SPH 1501, SPV 1761, SPV 1797, SPV 1796, SPV 1800, SPV 1803, SPV 1804, SPV 1601, SPV 1795, SPV 1798, SPV 1799, SPV 1794, SPV 1806, SPV 1801, SPV 1802, BRJ 356, RSE 03, RSV 842, RSV 471, BRJ 376, RSV 790, EC 8-2, PEC-10-1, SLR 1, SLR 47, SLV 35, SLR 32, PU 10-1, IS 33722, IS 33844-1, IS 18551, IS 2205 and IS 2312 were resistant to only shoot fly (Table 14).

4.2 Correlation of morphological characters of *rabi* sorghum genotypes with shoot fly, shoot bug and aphid incidence

4.2.1 Morphological characters of *rabi* sorghum genotypes conferring resistance to shoot fly

4.2.1.1 Advanced Varietal and Hybrid Trial-I (AVHT-I)

4.2.1.1.1 Trichome density

Number of trichomes present on the under surface of the leaves at 12-14 days after emergence of the crop revealed that, significantly highest number of trichomes were observed in SPV 1680 (35.8/mm^2) followed by SPV1672 (33.5/mm^2), SPV 1762 (30.2/mm^2) and SPV 1768 (29.9/mm^2) and were superior than resistant check IS 2312 (18.4/mm^2). The susceptible check DJ 6514 was free from trichomes on the lower surface of the leaves. The remaining entries with trichome density ranging from 15.6 to 26.0 were on par with the resistant check (Table 15).

4.2.1.2.1 Seedling vigour

Seedling vigour recorded on 1-5 scale at 14 and 21 days after emergence of crop indicated that all the genotypes of Advanced Varietal and Hybrid Trial-I recorded highest seedling vigour than susceptible check DJ 6514.

At 14 DAE, genotype SPV 1709 recorded high score of seedling vigour (1.3) fallowed by SPV 1672 (1.7), Maulee (1.7), SPH 1449 (2.0), SPV 1680 (2.0), SPV 1762 (2.0) CSV 216R (2.0), M 35-1 (2.0), and IS 2312 (2.0). The remaining genotypes showed moderate level of vigour with score ranging from 2.01 to 4.0 (Table 15).

Table 14: Response of Various Sorghum Genotypes to Multiple Pest Resistance

Sl. No.	Genotypes	Resistance to			Sl. No.	Genotypes	Resistance to		
		Shoot fly	Aphid	Shoot bug			Shoot fly	Aphid	Shoot bug
1	SLR 37	✓	✓	✓	30	SPV 1806	✓		
2	CSH 15R	✓		✓	31	SPV 1801	✓		
3	CSV 216R	✓		✓	32	SPV 1802	✓		
4	BRJ 356	✓		✓	33	BRJ 356	✓		
5	RSV 824	✓		✓	34	RSE 03	✓		
6	SPV 1709	✓			35	RSV 842	✓		
7	SPV 1768	✓			36	RSV 471	✓		
8	Maulee	✓			37	BRJ 376	✓		
9	SPV 1762	✓			38	RSV 790	✓		
10	SPV 1680	✓			39	EC 8-2	✓		
11	SPV 1672	✓			40	PEC-10-1	✓		
12	SPH 1449	✓			41	SLR 1	✓		
13	M 35-1	✓			42	SLR 47	✓		
14	DSV 4	✓			43	SLV 35	✓		
15	SPV 1755	✓			44	SLR 32	✓		
16	CSV 18	✓			45	PU 10-1	✓		
17	SPV 1704	✓			46	EP 65		✓	
18	SPH 1501	✓			47	SLR 35			✓
19	SPV 1761	✓			48	SLV 29			✓
20	SPV 1797	✓			49	SLV 31			✓
21	SPV 1796	✓			50	SLV 10			✓
22	SPV 1800	✓			51	SLV 25			✓
23	SPV 1803	✓			52	IS 33722	✓		
24	SPV 1804	✓			53	IS 33844-1	✓		
25	SPV 1601	✓			54	IS 18551(RSf)	✓		
26	SPV 1795	✓			55	IS 2205 (RSf)	✓		
27	SPV 1798	✓			56	IS 2312 (RSf)	✓		
28	SPV 1799	✓			57	Y 75 (RS)			✓
29	SPV 1794	✓			58	T x 428 (RA)		✓	✓

RSf= Resistant check to shootfly, RA= Resistant check to aphid,
RS= Resistant check to shoot bug,

Table 15: Morphological characters of sorghum entries in Advanced Varietal Trial-I (AVHT-I) contributing for shoot fly resistance

Sl. No.	Entry	Trichome Density (No./mm^2)	Seedling vigour (1-5)		Leaf glossiness (1-5) 14 DAE
			14 DAE	21 DAE	
1	SPH 1449	22.0	2.0	1.3	1.7
2	SPV 1680	35.8	2.0	1.0	1.7
3	SPV 1709	15.8	1.3	1.3	1.7
4	SPV 1672	33.5	1.7	1.7	2.0
5	SPV 1768	29.9	2.3	2.0	1.7
6	SPV 1762	30.2	2.0	3.0	2.0
7	SPV 1755	20.0	2.7	2.7	2.3
8	CSH 15R	24.9	2.7	2.0	2.0
9	CSV 216R	18.7	2.0	1.7	2.0
10	Maulee	26.0	1.7	2.0	1.7
11	M 35-1	15.6	2.0	2.3	2.0
12	CSV 18	20.1	2.3	2.3	2.3
13	DSV 4 (LC)	22.2	2.7	2.3	4.0
14	IS 2312 (R)	18.4	2.0	1.3	2.0
15	DJ 6514 (S)	0.0	4.3	5.0	4.0
	S.Em.±	2.6	-	-	-
	C.D. (0.05)	7.9	-	-	-
	C.V. (%)	16.6	-	-	-

DAE= Days after emergence,
R= Resistant check, S= Susceptible check, LC= Local check

Score	**Seedling vigour**	**Glossiness**
1.00 – 2.00	High	High
2.01 – 4.00	Medium	Medium
4.01 – 5.00	Low	Low

At 21 DAE, seedling vigour score of different genotypes ranged from highest of 1.0 in SPV 1680 followed by SPH 1449 (1.3), SPV 1709 (1.3), IS 2312 (1.3), SPV 1672 (1.7) and CSV 216R (1.7) and lowest of 5.0 in DJ 6514 (Table 15).

4.2.1.3.1 Glossiness

Leaf glossiness recorded on 1-5 scale at 14 days after emergence of crop indicated that, all the genotypes of Advanced Varietal and Hybrid Trial-I recorded highest leaf glossiness than susceptible check DJ 6514.

At 14 DAE, score of leaf glossiness in different entries varied from 1.7 to 4.0. The genotypes SPH 1449, SPV 1680, SPV 1709, SPV 1768 and Maulee exhibited high glossiness (1.7) followed by SPV 1672, SPV 1762, CSH 15R, CSV 216R, M 35-1 and IS 2312 which recorded 2.0 score. Remaining genotypes recorded moderately glossy grade from 2.01 to 4.0 (Table 15).

4.2.2.1 Advanced Varietal and Hybrid Trial-II (AVHT-II)

4.2.2.1.1 Trichome density

Number of trichomes present on the lower surface of the leaves at 12-14 days after emergence of the crop revealed that, significantly highest number of trichomes were observed in SPH 1449 (37.6/mm^2), CSV 216R (33.2/mm^2), SPV 1767 (31.0/mm2), local check DSV 4 (29.6/mm^2) and SPV 1762 (28.3/mm2) and were superior to resistant check IS 2312 (17.8/mm^2). The susceptible check DJ 6514 was free from trichomes on the lower surface of the leaves. The remaining entries with trichome density ranging from 13.8 to 26.0 mm^2 were on par with the resistant check (Table 16).

4.2.2.2.1 Seedling vigour

Seedling vigour recorded on 1-5 scale at 14 and 21 days after emergence of the crop indicated that, all the genotypes of Advanced Varietal and Hybrid Trial-II recorded highest seedling vigour than susceptible check DJ 6514.

At 14 DAE, genotype SPH 1449 and SPV 1762 recorded high score of seedling vigour (1.0) followed by SPV 1704 (1.3), CSH 15R (1.3), IS 2312 (1.3), Maulee (1.3), M 35-1 (1.7), SPV 1626 (2.0), SPH 1501 (2.0), SPV 1761 (2.0) and CSV 216R (2.0). The remaining genotypes showed moderate level of vigour with score ranging from 2.01 to 4.0 (Table 16).

At 21 DAE, the highest seedling vigour score of 1.3 were recorded in Maulee and IS 2312 followed by SPV 1704 (1.7), SPH 1449 (1.7), SPV 1762 (1.7), CSH 15R (1.7), SPV 1626 (2.0), SPH 1501 (2.0), SPV 1761 (2.0) and M 35-1 (2.0). The remaining genotypes showed moderate level of vigour with score ranging from 2.01 to 4.0 and lowest of 4.0 was recorded in DJ 6514 (Table 16).

4.2.2.3.1 Glossiness

Leaf glossiness recorded on 1-5 scale at 14 days after emergence of the crop indicated that, all the genotypes of Advanced Varietal and Hybrid Trial-II recorded highest leaf glossiness than susceptible check DJ 6514.

At 14 DAE, grade of leaf glossiness in different entries varied from 1.7 to 4.0. The genotype M 35-1 and resistant check IS 2312 exhibited high glossiness of 1.7 followed by SPV 1704 (2.0), SPH 1449 (2.0), SPV 1762 (2.0) and CSH 15R (2.0) and remaining genotype recorded moderately glossiness where in the grade ranged from 2.01 to 4.0 (Table 16).

4.2.3.1 Initial Varietal and Hybrid Trial (IVHT)

4.2.3.1.1 Trichome density

Number of trichomes present on the lower surface of the leaves at 12-14 days after emergence of the crop revealed that, significantly highest number of trichomes were observed in SPV 1800 (25.2/mm^2), Maulee (25.2/mm^2), DSV 4 (24.3/mm^2), SPV 1794 (23.7/mm^2) and SPV 1803 (19.2/mm^2) and were superior than the resistant check IS 2312 (13.2/mm^2). The susceptible check DJ 6514 was free from trichomes on the lower surface of the leaves. The remaining entries with trichome density ranging from 7.7 to 19.0 were on par with the resistant check (Table 17).

Table 16: Morphological characters of sorghum entries in Advanced Varietal Trial-II (AVHT-II) contributing for shoot fly resistance

Sl. No.	Entry	Trichome Density (No./mm^2)	Seedling vigour (1-5)		Leaf glossiness (1-5) 14 DAE
			14 DAE	21 DAE	
1	SPV 1626	24.6	2.0	2.0	2.7
2	SPV 1704	22.8	1.3	1.7	2.0
3	SPH 1449	37.6	1.0	1.7	2.0
4	SPH 1501	13.8	2.0	2.0	2.7
5	SPH 1582	15.7	4.0	3.3	4.0
6	SPH 1579	20.0	2.7	2.7	3.3
7	SPV 1761	31.0	2.0	2.0	2.3
8	SPV 1762	28.3	1.0	1.7	2.0
9	SPV 1757	26.0	3.3	2.7	3.3
10	CSH 15R	22.1	1.3	1.7	2.0
11	CSV 216R	33.2	2.0	2.3	2.3
12	Maulee	18.6	1.3	1.3	2.3
13	M 35-1	23.2	1.7	2.0	1.7
14	CSV 18	22.1	3.0	3.0	3.0
15	DSV 4 (LC)	29.6	3.0	2.7	4.0
16	IS 2312 (R)	17.8	1.3	1.3	1.7
17	DJ 6514 (S)	0.0	4.7	4.0	4.0
	S.Em.±	3.0	-	-	-
	C.D. (0.05)	8.9	-	-	-
	C.V. (%)	18.5	-	-	-

DAE= Days after emergence,
R= Resistant check, S= Susceptible check, LC= Local check

Score	**Seedling vigour**	**Glossiness**
1.00 – 2.00	High	High
2.01 – 4.00	Medium	Medium
4.01 – 5.00	Low	Low

Table 17: Morphological characters of sorghum entries in Initial Varietal Trial (IVHT) contributing for shoot fly resistance

Sl. No.	Entry	Trichome Density (No./mm^2)	Seedling vigour (1-5)		Leaf glossiness (1-5)
			14 DAE	21 DAE	14 DAE
1	SPV 1805	18.2	4.3	4.0	4.0
2	SPV 1806	17.7	2.7	2.0	2.3
3	SPV 1794	23.7	2.3	2.7	2.0
4	SPV 1795	17.3	2.3	2.0	2.7
5	SPV 1796	13.2	1.7	1.3	1.7
6	SPV 1797	15.3	1.7	1.3	1.7
7	SPV 1798	11.5	2.7	2.3	2.7
8	SPV 1799	13.9	2.7	2.3	2.7
9	SPV 1800	25.2	1.7	1.3	2.3
10	SPH 1601	13.4	2.3	2.7	2.0
11	SPV 1801	18.5	3.3	2.7	3.3
12	SPV 1802	7.7	3.0	2.7	2.3
13	CSH 15R	18.3	2.7	2.3	2.7
14	CSV 216R	19.0	2.0	1.7	2.0
15	Maulee	25.2	1.7	1.0	1.3
16	M 35-1	18.0	2.3	2.0	2.7
17	CSV 18	16.2	3.0	2.7	3.0
18	SPV 1803	19.2	2.0	2.0	1.7
19	SPV 1804	18.7	1.7	2.0	2.3
20	DSV 4 (LC)	24.3	3.3	3.7	3.7
21	IS 2312 (R)	13.2	1.0	1.3	2.0
22	DJ 6514 (S)	0.0	5.0	5.0	4.0
	S.Em.±	2.0	-	-	-
	C.D. (0.05)	5.8	-	-	-
	C.V. (%)	16.7	-	-	-

DAE= Days after emergence,
R= Resistant check, S= Susceptible check, LC= Local check

Score	Seedling vigour	Glossiness
1.00 – 2.00	High	High
2.01 – 4.00	Medium	Medium
4.01 – 5.00	Low	Low

4.2.3.2.1 Seedling vigour

Seedling vigour recorded on 1-5 scale at 14 and 21 days after emergence of the crop indicated that, all the genotypes of Initial Varietal and Hybrid Trial recorded highest seedling vigour than susceptible check DJ 6514. At 14 DAE, the resistant check IS 2312 recorded high grade of seedling vigour (1.0) followed by SPV 1796 (1.7), SPV 1797 (1.7), SPV 1800 (1.7), Maulee (1.7), SPV 1804 (1.7), CSV 216R (2.0) and SPV 1803 (2.0). Remaining genotypes showed moderate level of vigour with grade ranging from 2.01 to 4.0. Whereas, SPV 1805 recorded least seedling vigour (4.3) (Table 17).

At 21 DAE, seedling vigour grade of different genotypes ranged from highest of 1.0 in Maulee followed by SPV 1796 (1.3), SPV 1797(1.3), SPV 1800 (1.3), IS 2312 (1.3), CSV 216R (1.7), SPV 1806 (2.0), SPV 1795 (2.0), M 35-1 (2.0), SPV 1803 (2.0) and SPV 1804 (2.0). The remaining genotypes showed moderate level of vigour with score ranging from 2.01 to 4.0 and lowest of 5.0 in DJ 6514 (Table 17).

4.2.3.3.1 Glossiness

Leaf glossiness recorded on 1-5 scale at 14 days after emergence of crop indicated that all the genotypes of Initial Varietal and Hybrid Trial recorded highest leaf glossiness than susceptible check DJ 6514.

At 14 DAE, grade of leaf glossiness in different entries varied from 1.3 to 4.0. The genotype Maulee recorded highest glossiness (1.3) followed by SPV 1796 (1.7), SPV 1797 (1.7), SPV 1803 (1.7), SPV 1794 (2.0), SPH 1601 (2.0), CSV 216R (2.0) and IS 2312 (2.0). Remaining genotypes recorded moderate level of leaf glossiness grade of 2.01 to 4.0 (Table 17).

4.2.4.1 Shoot Pest Nursery (SPN)

4.2.4.1.1 Trichome density

Number of trichomes present on the lower surface of the leaves at 12-14 days after emergence of the crop revealed that, significantly highest number of trichomes were observed in RSV 790 (37.0/mm^2) than the resistant check IS 2312 (27.2/mm^2). The remaining genotypes RSV 836 (31.0/mm^2), RSPENT 4 (27.7/mm^2), RSPENT-2 (26.6/mm^2) and RSV 744 (25.0/mm^2) were as best as resistant check. The susceptible check DJ 6514 was free from trichomes on the lower surface of the leaves. The remaining entries with trichome density ranging from 1.7 to 20.4 were significantly lowest than the resistant check (Table 18).

4.2.4.2.1 Seedling vigour

Seedling vigour recorded on 1-5 scale at 14 and 21 days after emergence of the crop indicated that, all the genotypes of shoot pest nursery recorded highest seedling vigour than susceptible check DJ 6514. At 14 DAE, genotypes IS 2312, RSE 03, BRJ 356, BRJ 367, BRJ 376 recorded high grade of seedling vigour (1.0) followed by RSV 790 (1.3), RSV 471 (1.3), IS 2205 (1.3), RSV 458 (1.7), M 35-1 (1.7), RSV 823 (2.0), RSV 842 (2.0), RSV 824 (2.0), IS 18551 (2.0) and CS 3541 (2.0). The remaining genotypes showed moderate level of vigour with grade ranging from 2.01 to 4.0 (Table 18).

At 21 DAE, the highest seedling vigour score of 1.0 was recorded in RSV 842, RSV 790, RSV 824, IS 2312, IS 2205, BRJ 356, BRJ 367, BRJ 376, followed by RSV 458 (1.3), RSV 471 (1.3), RSPENT 4 (1.3), IS 18551 (1.3), RSE 03 (1.3), M 35-1 (1.3), RSV 639 (1.7), RSV 768 (1.7), RSV 823 (2.0), RSPENT 3 (2.0) and CS 3541 (2.0). The remaining genotypes showed moderate level of vigour with score ranging from 2.01 to 4.0 and lowest of 4.7 in DJ 6514 (Table 18).

4.2.4.3.1 Glossiness

Leaf glossiness recorded on 1-5 scale at 14 days after emergence of the crop indicated that all the genotypes of Shoot Pest Nursery recorded highest leaf glossiness than susceptible check DJ 6514.

At 14 DAE, grade of leaf glossiness in different entries varied from 1.3 to 4.0. The genotypes IS 2312 and IS 2205 exhibited high leaf glossiness (1.3) followed by BRJ 356 (1.7), RSPENT 1 (1.7), RSV 824 (1.7) RSV 842 (1.7), RSV 790 (2.0), RSV 458 (2.0), RSV 471 (2.0), IS 18551 (2.0), RSE 03 (2.0), BRJ 367 (2.0) and BRJ 376 (2.0). Remaining genotypes recorded moderately glossy grade of 2.01 to 4.0 (Table 18).

Table 18: Morphological characters of sorghum entries in Shoot Pest Nursery (SPN) contributing for shoot fly resistance

Sl. No.	Entry	Trichome Density (No./mm^2)	Seedling vigour (1-5)		Leaf glossiness (1-5)
			14 DAE	21 DAE	14 DAE
1	RSV 639	12.5	2.3	1.7	2.3
2	RSV 836	31.0	2.7	2.7	2.3
3	RSV 834	11.8	2.7	3.3	3.3
4	RSV 768	5.2	2.3	1.7	2.3
5	RSV 823	12.6	2.0	2.0	3.7
6	RSV 842	13.5	2.0	1.0	1.7
7	RSV 790	37.0	1.3	1.0	2.0
8	RSV 458	17.3	1.7	1.3	2.0
9	RSV 744	25.0	3.0	2.7	3.7
10	RSV 471	19.8	1.3	1.3	2.0
11	RSV 824	20.4	2.0	1.0	1.7
12	RSPENT -1	6.8	2.7	3.0	1.7
13	RSPENT -2	26.6	3.0	2.7	2.3
14	RSPENT-3	14.6	2.3	2.0	2.7
15	RSPENT-4	27.7	2.3	1.3	2.7
16	RSPENT-5	16.5	4.0	2.7	3.7
17	BRJ 356	12.4	1.0	1.0	1.7
18	BRJ 367	9.3	1.0	1.0	2.0
19	BRJ 376	14.3	1.0	1.0	2.0
20	CS 3541	1.7	2.0	2.0	3.0
21	RSE 03	19.7	1.0	1.3	2.0
22	M 35-1	12.5	1.7	1.3	3.0
23	DSV 4 (LC)	19.0	3.7	3.0	4.0
24	DSV 5 (LC)	11.1	3.3	2.7	3.7
25	IS 2312 (R)	27.2	1.0	1.0	1.3
26	IS 2205 (R)	11.4	1.3	1.0	1.3
27	IS 18551 (R)	13.0	2.0	1.3	2.0
28	DJ 6514 (S)	0.0	4.7	4.7	4.0
	S.Em.±	1.9	-	-	-
	C.D. (0.05)	5.6	-	-	-
	C.V. (%)	16.9	-	-	-

DAE= Days after emergence,
R= Resistant check, S= Susceptible check, LC= Local check

Score	**Seedling vigour**	**Glossiness**
1.00 – 2.00	High	High
2.01 – 4.00	Medium	Medium
4.01 – 5.00	Low	Low

4.2.5.1 Aphid and Shoot bug Nursery (ASBN)

4.2.5.1.1 Trichome density

Number of trichomes present on the lower surface of the leaves at 12-14 days after emergence of the crop revealed that, significantly highest number of trichomes were observed in SLR 34 (37.2/mm^2), EP 56 (37.2/mm^2) followed by SLR 39 (35.3/mm^2). The remaining entries recorded trichome density ranging from 0.5 to 31.0/mm^2 (Table 19).

4.2.2 Correlation between morphological characters of sorghum genotypes and sorghum insect pests

4.2.2.1 Correlation between morphological characters of sorghum genotypes and shoot fly incidence

Results from the table 20 indicated that, positive and highly significant correlation existed between shoot fly deadhearts and percent seedlings with shoot fly eggs (r=0.97), shoot fly eggs per 10 plants (0.84), seedling vigour (0.86), leaf glossiness (0.75) and highly significant and negative correlation with trichome density (-0.41). Where as highly significant and positive correlation between percent seedlings with shoot fly eggs with shoot fly eggs per 10 plant (0.89), seedling vigour (0.86), glossiness (0.71) and negative and highly significant correlation with trichome density (-0.40).

Highly significant and positive correlation existed between the shoot fly eggs per 10 plant and seedling vigour (0.78), glossiness (0.55) while, negative and highly significant correlation with trichome density (-0.32) was observed.

4.2.2.2 Correlation between morphological characters of sorghum genotypes and aphid incidence

The morphological characters of various lines recorded from different trials are presented in Appendices 5, 6, 7, 8 and 9. Results from correlation study revealed a non-significant and positive correlation between aphid density with plant height (0.15), distance between two leaves (0.14) and leaf angle (0.03). Whereas significant and negative correlation between aphid density with number of leaves per plant (-0.33), positive and significant correlation with leaf area (0.25) (Table 21).

4.2.2.3 Correlation between morphological characters of sorghum genotypes and shoot bug incidence

The correlation study indicated that, positive and significant correlation between shoot bug population with plant height (0.28) and negative and significant correlation existed between shoot bug population with leaf angle (0.05), leaf area (0.08) and negative and non significant correlation with distance between two leaves (-0.01) (Table 22)

There was significant and positive correlation between the shoot bug plant damage with plant height (0.38) and leaf area (0.26). Whereas non-significant and positive correlation between shoot bug damage with distance between two leaves (0.09), leaf angle (0.08) and significant and negatively with number of leaves per plant (-0.30).

4.3 Correlation of bio-chemical parameters of *rabi* sorghum genotypes with shoot fly, shoot bug and aphid incidence

Fifty three genotypes with varied degree of resistance were selected from different trials and their biochemical constituents are presented in table 24. From the table it is clearly evident that, there was non-significant and negative correlation between chlorophyll index (-0.27) and phosphorous (-0.27) nitrogen (-0.16) and potash (-0.02) with shoot fly deadheart formation (Table 23).

There was non-significant correlation between any of the biochemical constituents with aphid density, shoot bug population per plant and shoot bug plant damage. However, chlorophyll index (0.20) and nitrogen (0.13) were positively but non-significantly correlated with aphid density. Whereas, phosphorus (-0.20) and potash (-0.41) were negatively but non- significantly correlated with aphid density (Table 23).

Table 19: Morphological characters of sorghum entries in Aphid and Shoot bug Nursery (ASBN) contributing for shoot fly resistance

Sl. No.	Entry	Trichome Density (No./mm^2)	Sl. No.	Entry	Trichome Density (No./mm^2)
1	SLR 1	14.0	27	SLV 29	15.0
2	SLR 5	24.4	28	SLV 31	21.6
3	SLR 8	22.5	29	SLV 35	28.5
4	SLR 10	20.1	30	CRS 10	24.0
5	SLR 13	20.5	31	CRS 11	23.8
6	SLR 17	14.3	32	CRS 2	21.3
7	SLR 24	20.5	33	EP 56	37.2
8	SLR 25	22.3	34	IS 33722	26.6
9	SLR 27	29.9	35	IS 3420	19.9
10	SLR 28	21.7	36	EC 8-2	9.9
11	SLR 29	12.2	37	IS 33844-1	19.3
12	SLR 31	15.7	38	EP 65	30.5
13	SLR 32	28.3	39	PEC 10-1	31.0
14	SLR 34	37.2	40	PU 10-1	22.7
15	SLR 35	26.0	41	M 35-1	26.1
16	SLR 37	16.7	42	Maulee	9.2
17	SLR 38	30.7	43	CSV 216R	15.6
18	SLR 39	35.3	44	T x 428 (RA)	0.8
19	SLR 40	14.7	45	296B (SA)	0.5
20	SLR 41	17.1	46	Y 75 (RS)	0.7
21	SLR 43	21.5	47	Hathi Kuntha (SS)	27.2
22	SLR 45	21.5	48	DSV 5	19.0
23	SLR 46	30.6	49	DSV 4	25.0
24	SLR 47	13.8		S.Em. ±	2.7
25	SLV 25	13.9		C.D. (0.05)	7.8
26	SLV 27	13.5		C.V. (%)	17.9

DAE= Days after emergence
RA= Resistant check to aphid, S= Susceptible check to Aphid,
RS= Resistant check to shoot bug, SS= Susceptible check to shoot bug,
LC= Local check
* Figures in the parentheses are arcsin transformations

Table 20: Correlation coefficients between morphological characters of sorghum genotypes and shoot fly incidence

Parameter	DH 28 DAE	SSE 7 DAE	SSE 14 DAE	SSE 21 DAE	SE 7 DAE	SE 14 DAE	SE 21 DAE	TD 21 DAE	SV 14 DAE	SV 21 DAE	GL 14 DAE
DH 28 DAE	1.00										
SSE 7 DAE	0.94**	1.00									
SSE 14 DAE	0.97**	0.96**	1.00								
SSE 21 DAE	0.97**	0.95**	0.98**	1.00							
SE 7 DAE	0.88**	0.88**	0.90**	0.93**	1.00						
SE 14 DAE	0.86**	0.87**	0.87**	0.89**	0.95**	1.00					
SE 21 DAE	0.84**	0.86**	0.86**	0.89**	0.95**	0.98**	1.00**				
TD 21 DAE	-0.41**	-0.39**	-0.43**	-0.40**	-0.27*	-0.31**	-0.32**	1.00			
SV 14 DAE	0.84**	0.80**	0.82**	0.85**	0.76**	0.74**	0.72**	-0.36**	1.00		
SV 21 DAE	0.86**	0.82**	0.83**	0.86**	0.82**	0.80**	0.78**	-0.33**	0.88**	1.00	
GL 14 DAE	0.75**	0.68**	0.69**	0.71**	0.62**	0.59**	0.55**	-0.30**	0.80**	0.75**	1.00

** Significant at 1 %   * Significant at 5 %

DH= Deadhearts, DAE= Days after emergence, SSE= Shoot fly seedlings with eggs SE= Shoot fly eggs/plant, TD= Trichome density, SV= Seedling vigour, LG= Leaf glossiness

Table 21: Correlation coefficients between morphological characters sorghum genotypes and aphid incidence

Parameter	AD 80 DAE	PH 45 DAE	DBL	NLP	LAG	LAR
AD 80 DAE	1.00					
PH 45 DAE	0.15	1.00				
DBL	0.14	0.33**	1.00			
NLP	- 0.33**	- 0.27**	- 0.24**	1.00		
LAG	0.03	- 0.01	0.06	0.00	1.00	
LAR	0.24**	0.41**	0.37**	- 0.17*	0.12	1.00

** Significant at 1 %   * Significant at 5 %
SBD= Shoot bug damage, AD= Aphid density, PH= Plant height,
DBL= Distance between two leaves, NLP= Number of leaves per plant,
LAG= Leaf angle, LAR= Leaf area, DAE= Days after emergence

Table 22: Correlation coefficients between morphological characters of sorghum genotypes and shoot bug incidence

Parameter	SBD 45 DAE	SBD 60 DAE	PH 45 DAE	DBL	NLP	LAG	LAR
SBD 45 DAE	1.00						
SBD 60 DAE	0.86**	1.00					
PH 45 DAE	0.28**	0.38**	1.00				
DBL	-0.01	0.09	0.49**	1.00			
NLP	- 0.17*	-0.30**	-0.16	-0.24**	1.00		
LAG	0.05	0.08	0.04	0.06	0.00	1.00	
LAR	0.08	0.26**	0.25**	0.37**	- 0.17*	0.12	1.00

** Significant at 1 %   * Significant at 5 %

SBD= Shoot bug damage, AD= Aphid density, PH= Plant height,
DBL= Distance between two leaves, NLP= Number of leaves per plant,
LAG= Leaf angle, LAR= Leaf area, DAE= Days after emergence

Table 23: Biochemical parameters of sorghum genotypes and their correlations with aphid and shoot bug incidence

Sl. No.	Entry	Chlorophyll index	Nitrogen (%)	Phosphorous (%)	Potash (%)
1	RSV 471	37.9	0.98	1.18	0.64
2	BRJ-356	41.6	0.84	0.95	0.58
3	IS 18551	42.8	0.91	2	0.53
4	DJ 6514	36.4	1.05	0.17	0.64
5	DSV 5	37.3	1.19	0.29	0.84
6	RSE 03	40.5	0.91	1.35	0.49
7	M 35-1	45.2	0.98	1.45	0.66
8	IS 2205	24.2	0.84	1.85	0.7
9	IS 2312	40.7	0.98	1.2	0.7
10	DSV 4	29.1	1.05	1.35	0.53
11	SPH 1449	45.7	1.19	1.5	0.67
12	SPV 1680	40.8	1.05	1.65	0.7
13	SPV 1709	49.7	0.7	1.05	0.66
14	SPV 1672	39.2	0.98	1.75	0.77
15	SPV 1768	45.5	0.77	1.95	0.85
16	SPV 1762	49.9	0.77	1.35	0.68
17	SPV 1755	42.6	0.35	1.35	0.9
18	CSH 15R	49.0	0.35	1	0.59
19	CSV 18	42.4	0.49	1.85	0.65
20	SPV 1626	44.3	0.42	1.05	0.69
21	SPV 1704	40.1	1.12	1.1	0.65
22	SPH 1449	37.5	0.42	1	0.64
23	SPH 1501	42.3	0.42	1.9	0.39
24	SPH 1582	35.4	0.35	0.65	0.63
25	SPH 1579	35.6	0.7	1.05	0.63
26	SPV 1761	42.1	0.84	1.5	0.78
27	SPV 1762	40.1	0.63	0.3	0.6
28	SPV 1757	39.4	0.56	0.75	0.82
29	SPV 1805	34.9	0.2	1.05	0.79
30	SPV 1806	42.3	1.05	1.5	0.93

Table Contd….

Table 23: Contd….

Sl. No.	Entry	Chlorophyll index	Nitrogen (%)	Phosphorous (%)	Potash (%)
31	SPV 1794	47.1	1.26	1.05	0.81
32	SPV 1795	28.2	0.56	0.7	0.63
33	SPV 1796	44.7	1.26	1.6	0.86
34	SPV 1797	41.3	1.26	0.45	0.55
35	SPV 1798	39.5	0.49	0.95	0.69
36	SPV 1799	34.1	1.26	0.45	0.71
37	SPV 1800	52.9	0.98	1.5	0.8
38	SPH 1601	46.2	0.63	0.35	0.65
39	SPV 1801	34.5	1.05	1.2	0.76
40	SPV 1802	31.4	1.33	1.5	0.78
41	SPV 1803	38.2	0.63	0.7	0.8
42	SPV 1804	52.0	0.98	0.95	0.64
43	T x 428	47.5	0.7	0.95	0.63
44	Maulee	45.0	0.91	1.3	0.72
45	S-136	39.2	0.77	1.1	0.79
46	S-138	34.5	0.7	1.3	0.79
47	S-139	50.1	0.56	1.4	0.98
48	S-129	42.0	0.56	0.65	0.84
49	Hathi Kuntha	25.0	0.63	1.35	0.79
50	Y 75	33.3	0.84	1.4	0.51
51	S-116	31.0	0.7	1.45	0.78
52	CSV- 216R	39.2	0.63	1.35	0.76
53	RSV 842	44.6	1.05	1.85	0.77
Correlations coefficient with shoot fly (r)		- 0.27	- 0.16	- 0.27	- 0.02
Correlations coefficient with aphid (r)		0.20	0.13	- 0.20	- 0.41
Correlations coefficient with shoot bug population (r)		0.09	- 0.17	- 0.20	0.20
Correlations coefficient with plant damage by shoot bug (Sorghum stripe disease) (r)		0.10	- 0.07	- 0.14	0.16

** Significant at 1 % * Significant at 5 %

Chlorophyll index and potash were positively but non-significantly correlated with shoot bug population density per plant and shoot bug plant damage. Whereas, nitrogen and prosperous were negatively but non-significantly correlated with shoot bug population density per plant and shoot bug plant damage.

4.4 Management of sorghum pests by eco-friendly tactics

An experiment was conducted to manage the sorghum pests *viz*., shoot fly, shoot bug and aphid by eco-friendly IPM tactics during *rabi* 2006-07 under field conditions. The results of the experiment are presented in the tables 24 and 25.

4.4.1 Deadheart percentage

Per cent shoot fly deadhearts recorded in different treatments at 28 DAE revealed that significantly lowest deadhearts were recorded in Soil application of carbofuran 3G @ 20 kg/ha + Whorl application of carbofuran 3G @ 8 kg/ha at 30 DAE + *Pongemia pinnata* Leaf extract @ 5% spray at 60 DAE (4.3 %), Seed treatment with thiamethoxam 70WS @ 3 g/kg seeds + One spray each with NSKE @ 5% at 30 DAE and *Verticillium lecanii* at 60 DAE (4.5 %), Seed treatment with imidacloprid 70 WS @ 5 g/kg seeds + Two sprays with *Verticillium lecanii* at 30 and 60 DAE (4.6 %), Seed soaking for 8-10 h in Endosulfan 35 EC @ 3 ml + 30 g $CaCl_2$ per litre of water per kg seeds + Whorl application of carbofuran 3G @ 8 kg/ha at 30 DAE (5.8 %), Seed treatment with 5 ml chlorpyriphos 20 EC + 20 ml water/kg seeds + Two sprays with NSKE @ 5% at 30 and 60 DAE (6.2 %) and these treatments were on par with each other. The treatments *viz.,* Endosulfan 35 EC @ 2 ml/lit – Three sprays at 7, 30 and 60 DAE (14.2 %) and Soil application of crushed neem seeds @ 25 kg/ha + Two sprays with NSKE @ 5% at 30 and 60 DAE (24.3 %) were next best treatments and were significantly inferior to above treatments (Table 24).

4.4.2 Percent aphid index

Per cent aphid index recorded in different treatments at 80 days after sowing, revealed that significantly lowest Aphid index was recorded in Soil application of carbofuran 3G @ 20 kg/ha + Whorl application of carbofuran 3G @ 8 kg/ha at 30 DAE + *Pongemia pinnata* Leaf extract @ 5% spray at 60 DAE (10.2 %), Seed treatment with thiamethoxam 70WS @ 3 g/kg seeds + One spray each with NSKE @ 5% at 30 DAE and *Verticillium lecanii* at 60 DAE (10.3 %), Seed treatment with imidacloprid 70 WS @ 5 g/kg seeds + Two sprays with *Verticillium lecanii* at 30 and 60 DAE (11.2 %), Endosulfan 35 EC @ 2 ml/lit – Three sprays at 7, 30 and 60 DAE (11.3 %) and Seed soaking for 8-10 h in Endosulfan 35 EC @ 3 ml + 30 g $CaCl_2$ per litre of water per kg seeds + Whorl application of carbofuran 3G @ 8 kg/ha at 30 DAE (12.3 %) and these were on par with each other. The treatments *viz.,* Seed treatment with 5 ml chlorpyriphos + 20 ml water/kg seeds + Two sprays with NSKE @ 5% at 30 and 60 DAE (20.4 %) and Soil application of crushed neem seeds @ 25 kg/ha + Two sprays with NSKE @ 5% at 30 and 60 DAE (21.5 %) were on par with each other and were significantly inferior to above treatments (Table 24).

4.4.3 Shoot bug population

Efficacy of eco-friendly tactics against shoot bug population per plants recorded at 50 days after sowing is presented in the table 24. All the IPM treatments (4.5-26.4/5 plants) were found to be significantly superior in reducing the shoot bug population as compared to untreated check (72.5/5 plants). The lowest shoot bug population of 4.5 per five plants was recorded in Seed soaking for 8-10 h in Endosulfan 35 EC @ 3 ml + 30 g $CaCl_2$ per litre of water per kg seeds + Whorl application of carbofuran 3G @ 8 kg/ha at 30 DAE and was on par with Soil application of carbofuran 3G @ 20 kg/ha + Whorl application of carbofuran 3G @ 8 kg/ha at 30 DAE + *Pongemia pinnata* Leaf extract @ 5% spray at 60 DAE (4.8/5 plants). The next best treatments in this respect were Seed treatment with thiamethoxam 70WS @ 3 g/kg seeds + one spray each with NSKE @ 5% at 30 DAE and *Verticillium lecanii* at 60 DAE and Seed treatment with imidacloprid 70 WS @ 5 g/kg seeds + Two sprays with *Verticillium lecanii* at 30 and 60 DAE by recording 18.2 and 20.7 shoot bugs per five plants, respectively, whereas significantly maximum bug population was observed in Endosulfan 35 EC @ 2 ml/lit – Three sprays at 7, 30 and 60 DAE, Seed treatment with 5 ml chlorpyriphos + 20 ml water/kg seeds + Two sprays with NSKE @ 5% at 30 and 60 DAE and Soil application of crushed neem seeds @ 25 kg/ha + Two sprays with NSKE @ 5% at 30 and 60 DAE with 23.5, 25.3 and 26.4 shoot bugs per five plants, respectively and were on par with each other (Table 24).

4.4.4 Grain yield

The experimental data in table 25 indicate that the mean grain yield, which ranged from 21.4 (q/ha) to 26.5 (q/ha) in different IPM tactics. Significantly highest grain yield was recorded by Soil application of carbofuran 3G @ 20 kg/ha + Whorl application of carbofuran 3G @ 8 kg/ha at 30 DAE + *Pongemia pinnata* Leaf extract @ 5% spray at 60 DAE (26.5 q/ha), Seed soaking for 8-10 h in Endosulfan 35 EC @ 3 ml + 30 g $CaCl_2$ per litre of water per kg seeds + Whorl application of carbofuran 3G @ 8 kg/ha at 30 DAE (25.8 q/ha), Seed treatment with imidacloprid 70 WS @ 5 g/kg seeds + Two sprays with *Verticillium lecanii* at 30 and 60 DAE (25.7 q/ha), Seed treatment with thiamethoxam 70WS @ 3 g/kg seeds + one spray each with NSKE @ 5% at 30 DAE and *Verticillium lecanii* at 60 DAE (25.5 q/ha), Seed treatment with 5 ml chlorpyriphos + 20 ml water/kg seeds + Two sprays with NSKE @ 5% at 30 and 60 DAE (23.4 q/ha) and were on par with each other. The latter two treatments were on par with Soil application of crushed neem seeds @ 25 kg/ha + Two sprays with NSKE @ 5% at 30 and 60 DAE (21.4 q/ha) and Endosulfan 35 EC @ 2 ml/lit – Three sprays at 7, 30 and 60 DAE (22.4 q/ha). Whereas significantly lower grain yield (q/ha) was recorded in untreated check (19.2 q/ha) and was on par with above two treatments.

4.4.5 Fodder yield

The fodder yield data obtained in various treatments are presented in table 25. Significantly highest fodder yield was recorded in Soil application of carbofuran 3G @ 20 kg/ha + Whorl application of carbofuran 3G @ 8 kg/ha at 30 DAE + *Pongemia pinnata* Leaf extract @ 5% spray at 60 DAE (4.35 t/ha), Seed soaking for 8-10 h in Endosulfan 35 EC @ 3 ml + 30 g $CaCl_2$ per litre of water per kg seeds + Whorl application of carbofuran 3G @ 8 kg/ha at 30 DAE (4.26 t/ha), Seed treatment with imidacloprid 70 WS @ 5 g/kg seeds + Two sprays with *Verticillium lecanii* at 30 and 60 DAE (4.20 t/ha) and Seed treatment with thiamethoxam 70WS @ 3 g/kg seeds + one spray each with NSKE @ 5% at 30 DAE and *Verticillium lecanii* at 60 DAE (4.11 t/ha) and were on par with each other. The latter treatment was on par with Seed treatment with 5 ml chlorpyriphos + 20 ml water/kg seeds + Two sprays with NSKE @ 5% at 30 and 60 DAE (3.87 t/ha), Endosulfan 35 EC @ 2 ml/lit – Three sprays at 7, 30 and 60 DAE (3.78 t/ha) and Soil application of crushed neem seeds @ 25 kg/ha + Two sprays with NSKE @ 5% at 30 and 60 DAE (3.70 t/ha). The latter two treatments were on par with untreated check which recorded lowest fodder yield of 3.57 t/ha.

4.4.6 Cost economics

The details of market rates of plant protection materials, labour wages and produce rates considered for working out economics of various treatments are given in Appendix 10. Results from cost economics studies revealed that among different IPM practices, returns from increased yield over untreated check was maximum with Soil application of carbofuran 3G @ 20 kg/ha + Whorl application of carbofuran 3G @ 8 kg/ha at 30 DAE + *Pongemia pinnata* Leaf extract @ 5% spray at 60 DAE (Rs. 6230/ha) followed by Seed soaking for 8-10 h in Endosulfan 35 EC @ 3 ml + 30 g $CaCl_2$ per litre of water per kg seeds + Whorl application of carbofuran 3G @ 8 kg/ha at 30 DAE (Rs. 5625/ha), Seed treatment with imidacloprid 70 WS @ 5 g/kg seeds + Two sprays with *Verticillium lecanii* at 30 and 60 DAE (Rs. 5515/ha) and Seed treatment with thiamethoxam 70WS @ 3 g/kg seeds + one spray each with NSKE @ 5% at 30 DAE and *Verticillium lecanii* at 60 DAE (Rs. 5310/ha). In Soil application of crushed neem seeds @ 25 kg/ha + Two sprays with NSKE @ 5% at 30 and 60 DAE, it was found to be least (Rs. 1825/ha) (Table 25).

Among different IPM practices, cost of protection was minimum in Seed treatment with imidacloprid 70 WS @ 5 g/kg seeds + Two sprays with *Verticillium lecanii* at 30 and 60 DAE (Rs.393/ha) followed by Seed treatment with 5 ml chlorpyriphos + 20 ml water/kg seeds + Two sprays with NSKE @ 5% at 30 and 60 DAE (Rs. 480/ha), Endosulfan 35 EC @ 2 ml/lit – Three sprays at 7, 30 and 60 DAE (Rs. 488/ha), Seed treatment with thiamethoxam 70WS @ 3 g/kg seeds + one spray each with NSKE @ 5% at 30 DAE and *Verticillium lecanii* at 60 DAE (Rs. 488/ha) and maximum in Soil application of carbofuran 3G @ 20 kg/ha + Whorl application of carbofuran 3G @ 8 kg/ha at 30 DAE + *Pongemia pinnata* Leaf extract @ 5% spray at 60 DAE (Rs. 2200/ha) (Table 25).

Table 24: Efficacy of eco-friendly IPM treatments against pests of sorghum

Tr. No.	Treatments	Shoot fly DH (%) 28 DAE	% Aphid Index 80 DAS	Shoot bug population per 5 plants 50 DAS
T_1	Seed treatment with 5 ml chlorpyriphos + 20 ml water/kg seeds + Two sprays with NSKE @ 5% at 30 and 60 DAE	6.2 (14.4)[a]	20.4 (26.8)[b]	25.3 [d]
T_2	Seed treatment with thiamethoxam 70WS @ 3 g/kg seeds + One spray each with NSKE @ 5% at 30 DAE and *Verticillium lecanii* at 60 DAE	4.5 (12.3)[a]	10.3 (18.7)[a]	18.2 [b]
T_3	Seed treatment with imidacloprid 70 WS @ 5 g/kg seeds + Two sprays with *Verticillium lecanii* at 30 and 60 DAE	4.6 (12.4)[a]	11.2 (19.5)[a]	20.7 [bc]
T_4	Seed soaking for 8-10 h in Endosulfan 35 EC @ 3 ml + 30 g $CaCl_2$ per litre of water per kg seeds + Whorl application of carbofuran 3G @ 8 kg/ha at 30 DAE	5.8 (14.0)[a]	12.3 (20.6)[a]	4.5 [a]
T_5	Soil application of carbofuran 3G @ 20 kg/ha + Whorl application of carbofuran 3G @ 8 kg/ha at 30 DAE + *Pongemia pinnata* Leaf extract @ 5% spray at 60 DAE	4.3 (12.0)[a]	10.2 (18.6)[a]	4.8 [a]
T_6	Endosulfan 35 EC @ 2 ml/lit – Three sprays at 7, 30 and 60 DAE	14.2 (22.1)[b]	11.3 (19.6)[a]	23.5 [cd]
T_7	Soil application of crushed neem seeds @ 25 kg/ha + Two sprays with NSKE @ 5% at 30 and 60 DAE	24.3 (29.5)[c]	21.5 (27.6)[b]	26.4 [cd]
T_8	Untreated check	37.8 (37.9)[d]	58.3 (49.8)[c]	72.5 [e]
	S.Em.±	0.9	0.8	1.7
	C.D. (5%)	2.7	2.5	5.2
	C.V. (%)	8.0	5.6	12.0

* Figures in the parentheses are arcsine transformed values
In the vertical columns means followed by same letters are not different statistically (P= 0.05) by DMRT

Table 25: Cost economics of eco-friendly IPM treatments tested against sorghum pests

Tr No	Treatments	Grain Yield (q/ha)	Fodder Yield (t/ha)	Returns from increa-sed yield (Rs/ha)	Cost of Protec t-ion (Rs/ha)	Net profit (Rs/ha)	ICBR
T_1	Seed treatment with 5 ml chlorpyriphos + 20 ml water/kg seeds + Two sprays with NSKE @ 5% at 30 and 60 DAE	$23.4^{a\text{-}c}$	3.87^{b}	3510	480	3030	7.3
T_2	Seed treatment with thiamethoxam 70WS @ 3 g/kg seeds + One spray each with NSKE @ 5% at 30 DAE and *Verticillium lecanii* at 60 DAE	25.5^{ab}	4.11^{ab}	5310	488	4822	10.9
T_3	Seed treatment with imidacloprid 70 WS @ 5 g/kg seeds + Two sprays with *Verticillium lecanii* at 30 and 60 DAE	25.7^{a}	4.20^{a}	5515	393	5123	14.0
T_4	Seed soaking for 8-10 h in Endosulfan 35 EC @ 3 ml + 30 g $CaCl_2$ per litre of water per kg seeds + Whorl application of carbofuran 3G @ 8 kg/ha at 30 DAE	25.8^{a}	4.26^{a}	5625	674	4951	8.3
T_5	Soil application of carbofuran 3G @ 20 kg/ha + Whorl application of carbofuran 3G @ 8 kg/ha at 30 DAE + *Pongemia pinnata* Leaf extract @ 5% spray at 60 DAE	26.5^{a}	4.35^{a}	6230	2200	4030	2.8
T_6	Endosulfan 35 EC @ 2 ml/lit – Three sprays at 7, 30 and 60 DAE	$22.4^{b\text{-}d}$	3.78^{bc}	2665	488	2178	5.5
T_7	Soil application of crushed neem seeds @ 25 kg/ha + Two sprays with NSKE @ 5% at 30 and 60 DAE	21.4^{cd}	3.70^{bc}	1825	550	1275	3.3
T_8	Untreated check	19.2^{d}	3.57^{c}	-	-	-	-
	S.Em.±	1.1	0.10	-	-	-	-
	C.D. (5%)	3.3	0.29	-	-	-	-
	C.V. (%)	7.9	4.1	-	-	-	-

In the vertical columns means followed by same letters are not different statistically (P= 0.05) by DMRT
ICBR= Incremental cost benefit ratio

Maximum net profit was obtained from Seed treatment with imidacloprid 70 WS @ 5 g/kg seeds + Two sprays with *Verticillium lecanii* at 30 and 60 DAE (Rs. 5123/ha) followed by Seed soaking for 8-10 h in Endosulfan 35 EC @ 3 ml + 30 g $CaCl_2$ per litre of water per kg seeds + Whorl application of carbofuran 3G @ 8 kg/ha at 30 DAE (Rs. 4951/ha) and Seed treatment with thiamethoxam 70WS @ 3 g/kg seeds + one spray each with NSKE @ 5% at 30 DAE and *Verticillium lecanii* at 60 DAE (Rs. 4822/ha) with incremental benefit cost ratio of 14.0, 8.3 and 10.9, respectively (Table 25).

5. DISCUSSION

Of the more than 150 species of insect pests associated with sorghum, about a dozen are economically important in India. Among different insect pests, shoot fly, shoot bug and aphid are more predominant in *rabi* season. Both grain and fodder of *rabi* sorghum are considered to be equally important by the farming community, since the quality of grain and fodder are better during *rabi* compared to *kharif*. The aphid and shoot bug, affect not only the grain and fodder yield but also the fodder quality directly and indirectly. As the sorghum is considered as poor man's crop, marginal and sub marginal farmers cannot afford to take up control measures because of increased cost of cultivation and practical difficulties in imposing spraying operations.

As the shoot fly, shoot bug and aphid are now being considered as a key pests of sorghum in *rabi* tracts of Karnataka, and information required to design management practices is lacking, hence it became necessary to take up detailed study on screening of different *rabi* sorghum genotypes against shoot fly, shoot bug and aphid, correlate morphological characters and biochemical parameters with pest incidence and design management of sorghum pests by eco-friendly tactics. The results obtained in this regards during present study are discussed here under.

5.1 Reaction of *rabi* sorghum genotypes to shoot fly, shoot bug and aphid

5.1.1 Shoot fly, *A. soccata*

5.1.1.1 Percentage of shoot fly seedlings with eggs

The percentage of shoot fly seedlings with eggs on sorghum cultivars recorded at weekly intervals starting from 7 DAE steadily increased and reached to a peak at 21 DAE. The results of the present study are in agreement with Dalvi *et al.* (1990) who also reported that, oviposition intensity and preference of *A. soccata* on sorghum varieties at weekly intervals starting from 7 days after sowing steadily increased and reached a peak at 21 days in both the kharif and *rabi* seasons.

Among the AVHT-I, AVHT-II, IVHT and SPN trials, considering the percentage of shoot fly seedlings with eggs the genotypes *viz.,* SPH 1449, SPV 1680, SPV 1709, SPV 1672, SPV 1768, SPV 1762, SPV 1755, CSH 15R, CSV 216R, Maulee, M 35-1, CSV 18, DSV 4, SPV 1762, SPV 1704, SPH 1501, SPV 1761, SPV 1626, DSV 4, SPH 1579, SPV 1797, SPV 1796, SPV 1803, SPV 1800, SPV 1804, SPH 1601, SPV 1795, SPV 1799, SPV 1806, SPV 1801, SPV 1794, SPV 1798, RSE 03, RSV 471, IS 18551, RSV 458, RSV 842, IS 2205, RSV 790, BRJ 356, BRJ 367, BRJ 376, RSV 824, RSPENT-4, CS 3541 and RSPENT 2 were found to be superior. Thus these cultivars could be considered as a source resistance for further varietal improvement programmes in *rabi* sorghum. The results of the present study corroborates with earlier reports of Singh and Narayana (1978) who reported that, oviposition was more on highly susceptible (Swarna and CSH 1) varieties than on resistant (M 35-1 and IS 2269) and moderately resistant groups (IS 2123 and IS 5604).

5.1.1.2 Shoot fly eggs per 10 plants

Number of shoot fly eggs per ten plants of sorghum cultivars recorded at weekly intervals starting from 7 DAE steadily increased and reached to a peak on 21 DAE during *rabi* season. The results of the present study are in agreement with Dalvi *et al.* (1990).

Among the AVHT-I, AVHT-II, IVHT and SPN trials considering shoot fly incidence in terms of egg count per ten plants the genotypes *viz.,* SPV 1709, Maulee, SPV 1672, CSV 216R, SPV 1768, SPV 1762, SPV 1704, SPH 1501, CSH 15R, SPV 1761, SPH 1449, SPV 1797, SPV 1800, SPV 1803, SPV 1795, SPV 1806, SPV 1796, SPV 1804, RSV 790, RSE 03, RSV 842, RSV 458, RSPENT, IS 18551, BRJ 356, RSV 768, RSV 744, RSV 471, RSPENT 2, BRJ 367, BRJ 376, RSV 836, RSV 834, RSV 823, RSV 824, RSPENT 1, RSPENT 4 and M 35-1 were found to be superior. Thus these genotypes could be considered as sources of resistance for further varietal improvement programme in *rabi* sorghum. The results of present study are in line with Mote *et al.* (1986) who reported 16 resistant genotypes including IS 2312 and observed less egg laying by shoot fly on resistant genotypes. The results of present study are also in accordance with earlier reports of Singh *et al.* (1989) who reported that, sorghum germplasm resistant to *A. soccata* (IS 5359 and IS 5470) had the lowest eggs deposited on them. Similarly, Thawari *et al.* (2003) reported that, no shoot fly eggs were observed on AKSV 0013R, whereas only 2 eggs per plant were observed on AKSH 52R and AKSV 0012R. Kumar *et al.* (2003) reported that, ovipositional non-preference or antixenosis was expressed by the resistant controls (IS 2312 and IS 18551) and elite resistant lines (ICSV 700, ICSV 705, ICSV 708, ICSV 93088, ICSV 93089, ICSV 93090, ICSV 93091 and PB 14390-4), as these recorded less number of eggs compared with the other genotypes. In contrast, the susceptible controls (CSV 1 and DJ 6514) were the most preferred groups for shoot fly oviposition.

5.1.1.3 Deadheart percentage

Percentage of deadhearts caused by shoot fly on sorghum cultivars recorded at weekly intervals starting from 7 DAE, steadily increased and reached to a peak at 28 DAE during *rabi* season. The results of the present study are in agreement with the reports of Dalvi *et al.* (1990).

Among the AVHT-I, AVHT-II, IVHT, SPN and ASBN trials considering shoot fly incidence in terms of deadhearts percentage recorded at 28 DAE, the genotypes *viz.,* SPV 1709, SPV 1768, Maulee, SPV 1762, SPV 1680, SPV 1672, SPH 1449, CSH 15R, CSV 216R, M 35-1, DSV 4, SPV 1755, CSV 18, SPV 1762, SPV 1704, SPH 1501, SPV 1761, SPV 1797, SPV 1796, SPV 1800, SPV 1803, SPV 1804, SPV 1601, SPV 1795, SPV 1798, SPV 1799, SPV 1794, SPV 1806, SPV 1801, SPV 1802, IS 2205, BRJ 356, RSE 03, RSV 842, BRJ 367, RSV 471, IS 18551, RSV 824, BRJ 376, RSV 790, EC 8-2, PEC-10-1, SLR 37, SLR 1, SLR 47, IS 33722, SLV 35, SLR 32, PU 10-1 and IS 33844-1 were found to be superior. Thus these genotypes could be considered as promising resistant sources for further varietal improvement programme in *rabi* sorghum. The results of the present investigation are in close agreement with the studies of Sawang *et al.,* (1988) who reported that, for the third and fourth readings (21 and 28 DAE), the line SFIS 3962 (2-1) was the best variety with only 12.00 and 14.00 per cent of dead hearts followed by SFIS 5622 and differed significantly from IS 5604 and SF 5566, respectively. Singh *et al.* (1989) reported that resistant sorghum germplasm IS 5359 and IS 5470 had the lowest dead hearts formation. Balikai and Kullaiswamy (1999) reported that, M 35-1 x SPV 488, M 35-1 x 19B, M 35-1 x Afzalpur local, M 35-1 x Selection 3 and M 35-1 x IS 2315 were promising on the basis of percentage of dead hearts. Thawari *et al.* (2003) reported that percentage of dead hearts was lowest in AKSV 0013R (12.50%) and highest in AKSH 46R (66.66%). Kumar *et al.* (2003) reported that, the genotypes ICSV 708 and ICSV 705 recorded the lowest number of deadhearts, while CSV 1 and DJ 6514 recorded the highest dead heart formation. Balikai and Biradar (2004) reported that, the entries *viz.*, IS 2191, IS 4481, IS 4516, IS 17596, IS 18366, IS 33714, IS 33717, IS 33722, IS 33740, IS 33742, IS 33756, IS 33761, IS 33764, IS 33810, IS 33820, IS 33839, IS 33843 and IS 33889 were identified as resistant to shoot fly by recording lowest percentage of deadhearts and were statistically at par with the resistant check, IS-2312.

5.1.2 Aphid, *M. sacchari*

5.1.2.1 Aphid population density

Among the AVHT-I, AVHT-II, IVHT, SPN and ASBN trials, considering aphid density the genotypes *viz.,* EP 65 and SLR 37 were found to be superior by recording lowest grade of less than 2. Thus these two genotypes could be considered as a promising resistant sources for their use in further varietal improvement programmes in *rabi* sorghum. The results of the present study are in conformity with Balikai (2001) who reported that, SPV 570, RS 29 and C 49 were highly resistant to aphid, *M. sacchari* by recording score of less than 2. Ghuguskar *et al.* (1999) reported that, hybrids CSH 16 and 9728 were resistant to aphids by recording lowest score. Teetes *et al.* (1995) reported that, lines IS 12664C, IS 12609C, IS 12158C, and IS 12661C were highly resistant in preliminary and advanced screening trials by recording lowest score.

5.1.3 Shoot bug, *P. maidis*

5.1.3.1 Shoot bug population density

Among the AVHT-I, AVHT-II, IVHT, SPN and ASBN trials, considering shoot bug population per plant the genotypes *viz.,* T x 428, CSH 15R, BRJ 367, RSV 824, CSV 216R, SLV 31, SLR 37, and SLR 10 were found to be superior by recording lowest shoot bug population per plant. Thus these genotypes could be considered as promising resistant sources in varietal improvement programmes in *rabi* sorghum. The results of the present study are conformity with the reports of Anaji (2005) who reported that, CK60B, Swati and RS 29 were promising against shoot bug by recording lower shoot bug population. Similarly, Subbarayudu (2002) also reported that, the maximum number of shoot bugs per plant was recorded on genotype M 35-1 (25.8) and the fewest on genotype DJ 6514 (3.5).

5.1.3.2 Plant damage due to shoot bug

Among the AVHT-I, AVHT-II, IVHT, SPN and ASBN trials, considering plant damage due to shoot bug (sorghum stripe disease) the genotypes *viz.,* T x 428, CSH 15R, RSV 824, RSV 744, BRJ 356, RSV 823, RSV 842, SLR 35, SLR 37, SLR 29, SLV 31, SLV 10, SLV 25 and CSV 216R were found to be superior by recording lowest disease incidence. Thus these genotypes could be considered as promising sources for further varietal improvement programmes in *rabi* sorghum. The results of present study are in close agreement with the results of Subbarayudu (2002) who reported that, the genotype CSV 15 had the maximum number of damaged plants (50.5%) while CSH 6 had the least (9.5%) although differences were not significant.

5.1.3.3 Percentage of girdling

Among the AVHT-I, AVHT-II and IVHT trials considering percentage of girdling due to shoot bug the genotype T x 428 was found to be superior by recording lowest percentage of girdling of top most leaves.

5.1.3.4 Per cent of stunted plants

Among the AVHT-I, AVHT-II and IVHT trials considering per cent of stunted plants due to shoot bug, the genotype T x 428 was found to be superior by recording lowest percentage of stunted plants.

5.1.3.4 Percentage of ear head emergence

The entries namely, T x 428, CSV 216R, SPV 1672, SPH 1449 recorded highest percentage of ear head emergence and were found to be superior, which indirectly indicates that they had lowest incidence of disease.

5.1.4 Response of various *rabi* sorghum genotypes to multiple pest resistance

Among the AVHT-I, AVHT-II and IVHT trials the genotype SLR 37 was found to posses multiple resistance to shoot fly, shoot bug and aphid. The entries, CSH 15R, CSV 216R, BRJ 356 and RSV 824 were resistant to both shoot fly and shoot bug, while the entry T x 428 was found to posses resistance to aphid and shoot bug (Fig. 1). Among the remaining genotypes, the only one entry EP 65 was resistant to aphid, while, the entries, SLR 35, SLV 29, SLV 31, SLV 10, SLV 25 and Y 75 were resistant to shoot bug only. The rest of the genotypes, SPV 1709, SPV 1768, Maulee, SPV 1762, SPV 1680, SPV 1672, SPH 1449, M 35-1, DSV 4 ,SPV 1755, CSV 18, SPV 1704, SPH 1501, SPV 1761, SPV 1797, SPV 1796, SPV 1800, SPV 1803, SPV 1804, SPV 1601, SPV 1795, SPV 1798, SPV 1799, SPV 1794, SPV 1806, SPV 1801, SPV 1802, BRJ 356, RSE 03, RSV 842, RSV 471, BRJ 376, RSV 790, EC 8-2, PEC-10-1, SLR 1, SLR 47, SLV 35, SLR 32, PU 10-1, IS 33722, IS 33844-1, IS 18551, IS 2205, IS 2312 were resistant to shoot fly. These studies are in conformity with the studies of Kulkarni *et al.* (1980) who reported that, the entries SPV 97, SPV 108, SPH 111 and SPH 112 possessed high amount of resistance to shoot fly and stem borer. Mote *et al.* (1983) reported that, sorghum genotypes *viz.*, E 303, E 501, E 502, E 503 were moderately resistant to both shoot fly and stem borer. Prem Kishore (1993) reported that, 11 sorghum germplasm resistance to *A. soccata* and *C. partellus*. The entries E 103, E 108, E 109, E 112 and E 358 showed multiple resistance to both the pests. Mote and Shahane (1994) reported that, IS 1840, BTR 28, ICSCTV 9, ICVS 148 and SPV 504 had multiple resistance to delphacid (*P. maidis*) and aphid (*M. sacchari*), Balikai and Jamadar (2001) reported that, IS 33843 was found to possess multiple resistance to charcoal rot, shootfly and aphid.

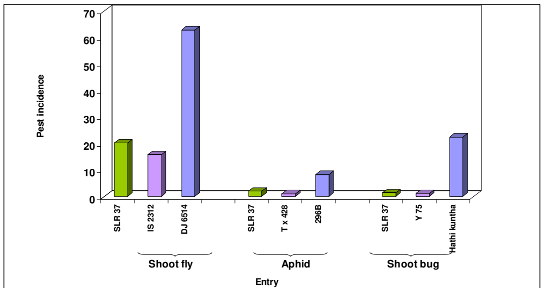


Fig. 1a : Sorghum genotypes possessing multiple pest resistence

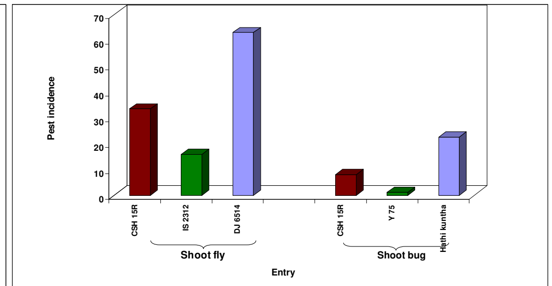


Fig. 1b : Sorghum genotypes possessing multiple pest resistence

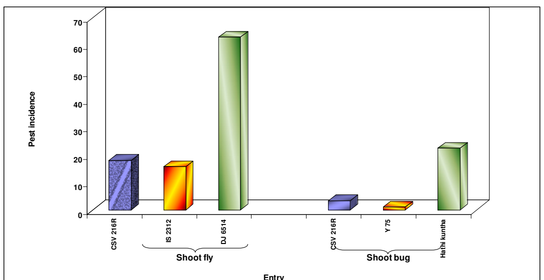


Fig. 1c : Sorghum genotypes possessing multiple pest resistence

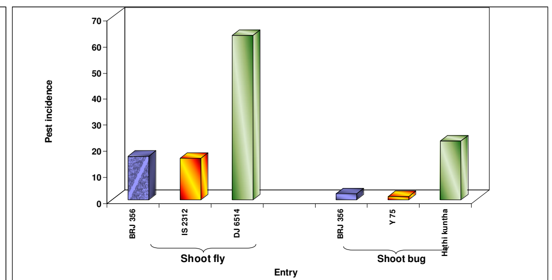


Fig. 1d: Sorghum genotypes possessing multiple pest resistence

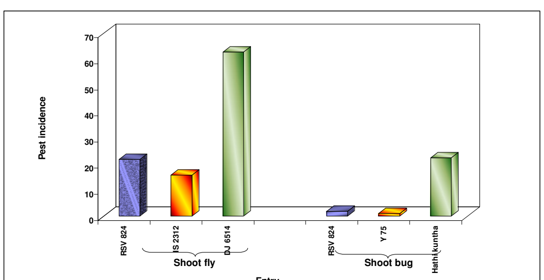


Fig. 1e : Sorghum genotypes possessing multiple pest resistence

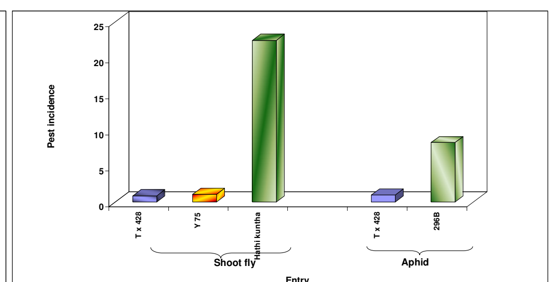


Fig. 1f : Sorghum genotypes possessing multiple pest resistence

Fig. 1: Sorghum genotypes possessing multiple pest resistance

5.2 Correlations of morphological characters of *rabi* sorghum genotypes with shoot fly, shoot bug and aphid resistance

5.2.1 Morphological characters conferring resistance to shoot fly

5.2.1.1 Trichome density

Considering the number of trichomes present on the lower surface of leaves the genotypes *viz.,* SPV 1680, SPV 1672, SPV 1762, SPV 1768, SPH 1449, CSV 216R, SPV 1767, DSV 4, SPV 1762, SPV 1800, Maulee, DSV 4, SPV 1794, SPV 1803, RSV 790, SLR 34, EP 56 and SLR 39 were found to be resistant. Thus these cultivars could be considered as sources of resistance for using in the varietal improvement programmes in *rabi* sorghum. The susceptible check DJ 6514 was free from trichomes on the lower surface of the leaves indicating higher susceptibility to shoot fly. The results of the present studies also corroborate with the reports of Singh and Rana (1986) who reported that, trichomes are frequently associated with shoot fly resistance.

5.2.1.2 Seedling Vigour

The highest seedling vigour was observed entries *viz.,* SPV 1680, SPH 1449, SPV 1709, IS 2312, SPV 1672, CSV 216R, Maulee, IS 2312, SPV 1704, SPH 1449, SPV 1762, CSH 15R, SPV 1626, SPH 1501, SPV 1761, M 35-1, Maulee, SPV 1796, SPV 1797, SPV 1800, IS 2312, CSV 216R, SPV 1806, SPV 1795, M 35-1, SPV 1803, SPV 1804, RSV 842, RSV 790, RSV 824, IS 2312, IS 2205, BRJ 356, BRJ 367, BRJ 376, RSV 458, RSV 471, RSPENT-4, IS 18551 RSE 03, M 35-1, RSV 639, RSV 768, RSV 823, RSPENT-3 and CS 3541 which were found to be resistant to shoot fly. Lowest seedling viguor was observed in susceptible check DJ 6514 indicating their higher susceptibility to shoot fly. This character could be used as one of the selection criterion while handling segregating generations. The results of the present studies are in close agreement with the studies of Tarun *et al.* (2000) who suggested that, genotypes having fast seedling growth, long and thin stems, and glossy leaves during the seedling stage were comparatively resistant to shoot fly. Similarly, Kumar *et al.* (2003) reported that, genotypes IS 18551, ICSV 700 and ICSV 705 with longer roots and shoots, narrow leaves (length greater than width) and greater droopiness of leaves, contributed significantly to shoot fly resistance.

5.2.1.3 Glossiness

The highest score of leaf glossiness was observed in genotypes *viz.,* SPH 1449, SPV 1680, SPV 1709, SPV 1768, Maulee, SPV 1672, SPV 1762, CSH 15R, CSV 216R, M 35-1, IS 2312, SPV 1704, SPH 1449, SPV 1762, SPV 1796, SPV 1797, SPV 1803, SPV 1794, SPH 1601, IS 2205, BRJ 356, RSPENT-1, RSV 824, RSV 842, RSV 790, RSV 458, RSV 471, IS 18551, RSE 03, BRJ 367 and BRJ 376 which were found to be resistant to shoot fly. Lowest leaf glossiness was observed in susceptible check DJ 6514 indicating its susceptibility to shoot fly. This character colud be used as one of the selection criterion while handling segregating generations. The results of the present studies are in close agreement with the studies of Kamatar and Salimath (2003) who reported that, high glossiness of leaf, light green colour of leaves conferred resistance to sorghum shoot fly. Tarun *et al.* (2000) reported that, the lines having glossy leaves during the seedling stage were comparatively resistant to shoot fly. Singh and Rana (1986) reported that, glossy leaf surface was frequently associated with shoot fly resistance. Maiti (1994) reported that, the genotypes possessing high glossy intensity were most resistant to shoot fly.

5.2.6.1 Correlation between morphological characters and shoot fly incidence

Highly significant and positive correlation was observed between shoot fly seedlings with eggs, eggs per ten plants and deadhearts due to shoot fly, indicating that ovipositional preference contributed directly for maximum deadhearts formation. Seedling vigour and leaf glossiness indicated direct significant and positive relationship with shoot fly oviposition and deadhearts. These studies are in close agreement with the results of Kamatar and Salimath (2003) who reported that, high glossiness of leaf, light green colour of leaves, high seedling vigour, taller seedlings, narrow and erect leaves conferred resistance to sorghum shoot fly as indicated by correlation studies. Further they opined that, indirect effects of these traits through oviposition percentage were substantial, whereas ovipositional percentage contributed directly to maximum deadheart formation.

Significant and negative correlation was observed between shoot fly incidence and trichome density. These studies are close in agreement with the studies of Omori *et al.* (1983) who reported that, trichome intensity showed negative and significant associations with the shoot fly resistance. Similarly, Sree *et al.* (1994) also reported that, the presence of trichomes was indirectly associated shoot fly resistance.

5.2.6.2 Correlation coefficient between morphological characters and sorghum genotypes and aphid incidence

A non-significant positive correlation was observed for plant height, distance between two leaves and leaf angle with aphid density. Whereas, increase in number of leaves, there was reduction in aphid population and relations were significant. Leaf area indicated a direct significant positive relationship with aphid density. These findings are in conformity with Balikai and Lingappa (2002a) who reported that, the increase in the plant height and number of leaves, there was a reduction in aphid population. There was a positive correlation between leaf angle and distance between two leaves and aphid incidence.

5.2.6.3 Correlation coefficients between morphological characters of sorghum genotypes and shoot bug incidence

A positive and significant correlation was observed for plant height, a negative and significant correlation for leaf angle and leaf area and negative non-significant correlation for distance between two leaves with shoot bug population.

A significant positive correlation of plant height and leaf area, non-significant positive correlation for distance between two leaves and leaf angle and significant negative correlation between numbers of leaves per plant was observed with shoot bug damage. These findings are in close agreement with Mote and Shahane (1994) who reported that no significant co relations were present between plant morphology, sugary exudates and infestation of *M sacchari* and *P maidis*.

5.3 Correlation between biochemical parameters with shoot fly, aphid and shoot bug incidence

Non-significant and negative correlation was observed between chlorophyll index, nitrogen, phosphorous and potash with shoot fly deadheart formation at 28 DAE. Patel and Sukhani (1990) reported that, per cent of N, reducing sugars, total sugars, moisture and chlorophyll contents of leaf in susceptible cultivars were higher than in resistant ones against shoot fly. Singh *et al.* (2004b) reported that low concentrations of reducing sugars, total sugars, nitrogen, phosphorus and potassium in sorghum seedlings greatly enhanced the degree of antixenosis for oviposition/feeding and deadheart formation, and can be used as selection criteria for resistance to shoot fly. Bhise *et al.* (1997) reported that there was a positive relationship between N and P content and degree of damage by shoot fly, although N and P contents also decreased with age of leaves in all varieties. These differences in the correlations might be due to the variations in the selection of genotypes and soil fertility.

There was no significant correlation between aphid and shoot bug resistance and biochemical constituents of all the 53 sorghum genotypes selected for comparison, although there was positive correlation was observed between chlorophyll index, nitrogen and negative correlation observed between phosphorous and potash with aphid density. These findings are in close agreement with Balikai (2001) who reported that, phosphorus, potash and polyphenol in healthy leaves were negatively correlated with aphid incidence.

There was positive correlation observed between chlorophyll index and potash, whereas negative correlation observed between nitrogen and phosphorus with shoot bug population density and shoot bug plant damage. These findings are in close agreement with Mote and Shahane (1994) who reported that, the development of aphid and delphacid populations was more pronounced in varieties with higher nitrogen, sugar and total chlorophyll content of leaves (IS 105, IS 2217, IS 1063 and IS 553). The varieties ICSCTV 9, BTP 28, IS 1640, ICSV 148 and SPV 504, with higher contents of phosphorus, potassium and polyphenols, were less preferred by delphacids and aphids.

5.4 Management of sorghum pests by eco-friendly tactics

The increased awareness about the harmful effects of chemical insecticides, conservation of natural enemies and use of botanicals diverted the entomologists and farmers for the IPM of sorghum to have a sustainable production in sorghum. Farmers are unable to go for spraying due to increased cost of production and also phytotoxic effect of these insecticides on foliage, hence few workers tested new molecules like neonicotinoids for managing the pest in the form of seed treatment.

5.4.1 Deadheart percentage due to shoot fly

Considering the shoot fly dead hearts, Soil application of carbofuran 3G @ 20 kg/ha + Whorl application of carbofuran 3G @ 8 kg/ha at 30 DAE + *Pongemia pinnata* Leaf extract @ 5% spray at 60 DAE (T_5), Seed treatment with thiamethoxam 70WS @ 3 g/kg seeds + one spray each with NSKE @ 5% at 30 DAE and *Verticillium lecanii* at 60 DAE (T_2), Seed treatment with imidacloprid 70 WS @ 5 g/kg seeds + Two sprays with *Verticillium lecanii* at 30 and 60 DAE (T_3), Seed soaking for 8-10 h in Endosulfan 35 EC @ 3 ml + 30 g $CaCl_2$ per litre of water per kg seeds + Whorl application of carbofuran 3G @ 8 kg/ha at 30 DAE (T_4), Seed treatment with 5 ml chlorpyriphos 20 EC + 20 ml water/kg seeds + Two sprays with NSKE @ 5% at 30 and 60 DAE (T_1) and these treatments were on par with each other and gave satisfactory control of shoot fly (Fig. 2). These results are in close agreement with reports of Karibasavaraja (2003) who reported that, Thiamethoxam 70ws @ 3g/kg seeds was promising against shoot fly. Subbarayudu *et al.* (2002) reported that, soil application of neem (0.375-0.5%) repelled the shoot fly from egg laying and seed treatment with imidacloprid at 10 and 14 ml/kg effectively reduced the damage due to shoot fly and also reported that, neem spray @ 0.5 per cent recorded the least number of deadhearts. Kandalkar *et al.* (1999) reported that, imidacloprid as seed treatment exhibited the best performance in controlling shoot fly damage at 14 and 28 days after eclosion. Balikai (1999) reported that seed treatment with imidacloprid 70 WS at 10 g/100 g sorghum seeds was effective in reducing the incidence of *A. soccata*.

5.4.2 Percent of Aphid index

Considering the percent aphid index (Fig. 2), Soil application of carbofuran 3G @ 20 kg/ha + Whorl application of carbofuran 3G @ 8 kg/ha at 30 DAE + *Pongemia pinnata* Leaf extract @ 5% spray at 60 DAE (T_5), Seed treatment with thiamethoxam 70WS @ 3 g/kg seeds + one spray each with NSKE @ 5% at 30 DAE and *Verticillium lecanii* at 60 DAE (T_2), Seed treatment with imidacloprid 70 WS @ 5 g/kg seeds + Two sprays with *Verticillium lecanii* at 30 and 60 DAE (T_3), Endosulfan 35 EC @ 2 ml/lit – Three sprays at 7, 30 and 60 DAE (T_6) and Seed soaking for 8-10 h in Endosulfan 35 EC @ 3 ml + 30 g $CaCl_2$ per litre of water per kg seeds + Whorl application of carbofuran 3G @ 8 kg/ha at 30 DAE (T_4) and these were on par with each other. All these treatments were significantly superior to other IPM treatments (T_1 and T_7) and over untreated control (T_8). The present studies are in close agreement with Balikai and Lingappa (2003b) who reported that, seed dressing with imidacloprid 70 WS @ 10g/kg was highly effective in lowering aphid population.

5.4.3 Shoot bug population

With respect to shoot bug population per plant (Fig. 2), all the IPM treatments (4.5-26.4/5 plants) were found to be significantly superior in reducing the shoot bug population as compared to untreated check (72.5/5 plants). The lowest shoot bug population of 4.5 per five plants was recorded in Seed soaking for 8-10 h in Endosulfan 35 EC @ 3 ml + 30 g $CaCl_2$ per litre of water per kg seeds + Whorl application of carbofuran 3G @ 8 kg/ha at 30 DAE (T_4) and was on par with Soil application of carbofuran 3G @ 20 kg/ha + Whorl application of carbofuran 3G @ 8 kg/ha at 30 DAE + *Pongemia pinnata* Leaf extract @ 5% spray at 60 DAE (T_5). The next best treatments in this respect were Seed treatment with thiamethoxam 70WS @ 3 g/kg seeds + one spray each with NSKE @ 5% at 30 DAE and *Verticillium lecanii* at 60 DAE (T_2) and Seed treatment with imidacloprid 70 WS @ 5 g/kg seeds + Two sprays with *Verticillium lecanii* at 30 and 60 DAE (T_3) by recording 18.2 and 20.7 Shoot bugs per five plants, respectively, whereas significantly maximum bug population in Endosulfan 35 EC @ 2 ml/lit – Three sprays at 7, 30 and 60 DAE (T_6), Seed treatment with 5 ml chlorpyriphos + 20 ml water/kg seeds + Two sprays with NSKE @ 5% at 30 and 60 DAE (T_1)and Soil application of crushed neem seeds @ 25 kg/ha + Two sprays with NSKE @ 5% at 30 and 60 DAE (T_7)

recorded 23.5, 25.3 and 26.4 shoot bugs per five plants, respectively and they were on par with each other. The present studies are in close agreement with Anaji and Balikai (2006) who reported that, Thiamethoxam 70WS @ 3g/kg seeds was highly effective against shoot bug. Similarly Vijaykumar (2004) also reported that, Thiamethoxam 70WS @ 2g/kg seeds was highly effective against shoot bug.

5.4.4 Grain yield

With regard to grain yield (Fig. 3), Soil application of carbofuran 3G @ 20 kg/ha + Whorl application of carbofuran 3G @ 8 kg/ha at 30 DAE + *Pongemia pinnata* Leaf extract @ 5% spray at 60 DAE (T_5), Seed soaking for 8-10 h in Endosulfan 35 EC @ 3 ml + 30 g $CaCl_2$ per litre of water per kg seeds + Whorl application of carbofuran 3G @ 8 kg/ha at 30 DAE (T_4), Seed treatment with imidacloprid 70 WS @ 5 g/kg seeds + Two sprays with *Verticillium lecanii* at 30 and 60 DAE (T_3), Seed treatment with thiamethoxam 70WS @ 3 g/kg seeds + one spray each with NSKE @ 5% at 30 DAE and *Verticillium lecanii* at 60 DAE (T_2), Seed treatment with 5 ml chlorpyriphos + 20 ml water/kg seeds + Two sprays with NSKE @ 5% at 30 and 60 DAE (T_1) were on par with each other. All these treatments were significantly superior compared to other IPM practice and over control. The results of present study are in agreement with the earlier reports of Shivamurthappa *et al.* (1989) who reported that, application of carbofuran 3G increased yields (47.86%) in comparison to an untreated control. Patil *et al.* (1992) reported that, soaking sorghum seeds with endosulfan 35 EC @ 0.07% for 4 h reduced infestation with the muscid, *A. soccata*, and increased the percentage germination and yield. Balikai (1998) reported that treating sorghum seeds with 10 g imidacloprid 70 WS per 100 g seed was the most effective treatment in reducing damage by *A. soccata* and produced the highest grain and fodder yield. Balikai *et al.,* (1998) reported that, soaking seeds for 8-10 h either in $CaCl_2$ (2%) + endosulfan (0.07%) or in endosulfan (0.07%) reduced the shoot fly incidence effectively and increased the seed yield by 44.8 and 41.9 per cent, respectively over untreated control.

5.4.5 Fodder yield

Considering fodder yield, Soil application of carbofuran 3G @ 20 kg/ha + Whorl application of carbofuran 3G @ 8 kg/ha at 30 DAE + *Pongemia pinnata* Leaf extract @ 5% spray at 60 DAE (T_5), Seed soaking for 8-10 h in Endosulfan 35 EC @ 3 ml + 30 g $CaCl_2$ per litre of water per kg seeds + Whorl application of carbofuran 3G @ 8 kg/ha at 30 DAE (T_4), Seed treatment with imidacloprid 70 WS @ 5 g/kg seeds + Two sprays with *Verticillium lecanii* at 30 and 60 DAE (T_3) and Seed treatment with thiamethoxam 70WS @ 3 g/kg seeds + one spray each with NSKE @ 5% at 30 DAE and *Verticillium lecanii* at 60 DAE (T_2) were on par with each other and gave better fodder yield compared to other IPM treatments and untreated control (Fig. 3). The present studies are in close agreement with the studies of Balikai and Lingappa (2003) who reported that, dimethoate gave significantly higher grain yield (27.17 q/ha), fodder yield (6.66 t/ha) and 1000 grain weight (31.88 g) followed by endosulfan (26.43 q/ha, 6.46 t/ha and 31.42 g, respectively).

5.4.6 Cost Economics

The results of the cost economics studies clearly indicated that among the IPM practices, Seed treatment with imidacloprid 70 WS @ 5 g/kg seeds + Two sprays with *Verticillium lecanii* at 30 and 60 DAE (T_3), Seed soaking for 8-10 h in Endosulfan 35 EC @ 3 ml + 30 g $CaCl_2$ per litre of water per kg seeds + Whorl application of carbofuran 3G @ 8 kg/ha at 30 DAE (T_4) and Seed treatment with thiamethoxam 70WS @ 3 g/kg seeds + one spray each with NSKE @ 5% at 30 DAE and *Verticillium lecanii* at 60 DAE (T_2) were the most economic treatments as they recorded highest net profit with incremental cost benefit ratio of 14.0, 8.3 and 10.9, respectively (Fig. 3).

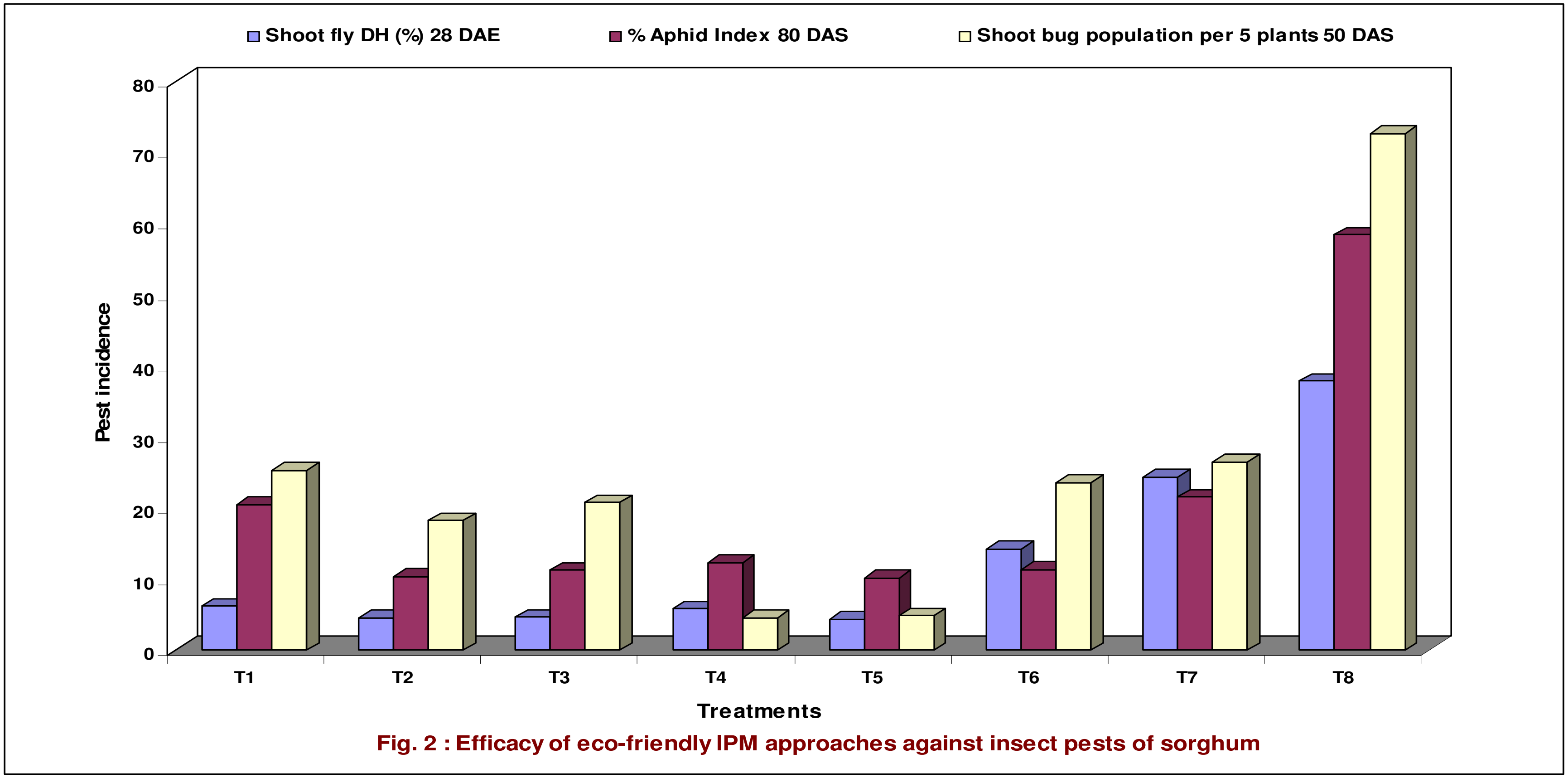


Fig. 2: Efficacy of eco-friendly IPM approaches against insect pests of sorghum

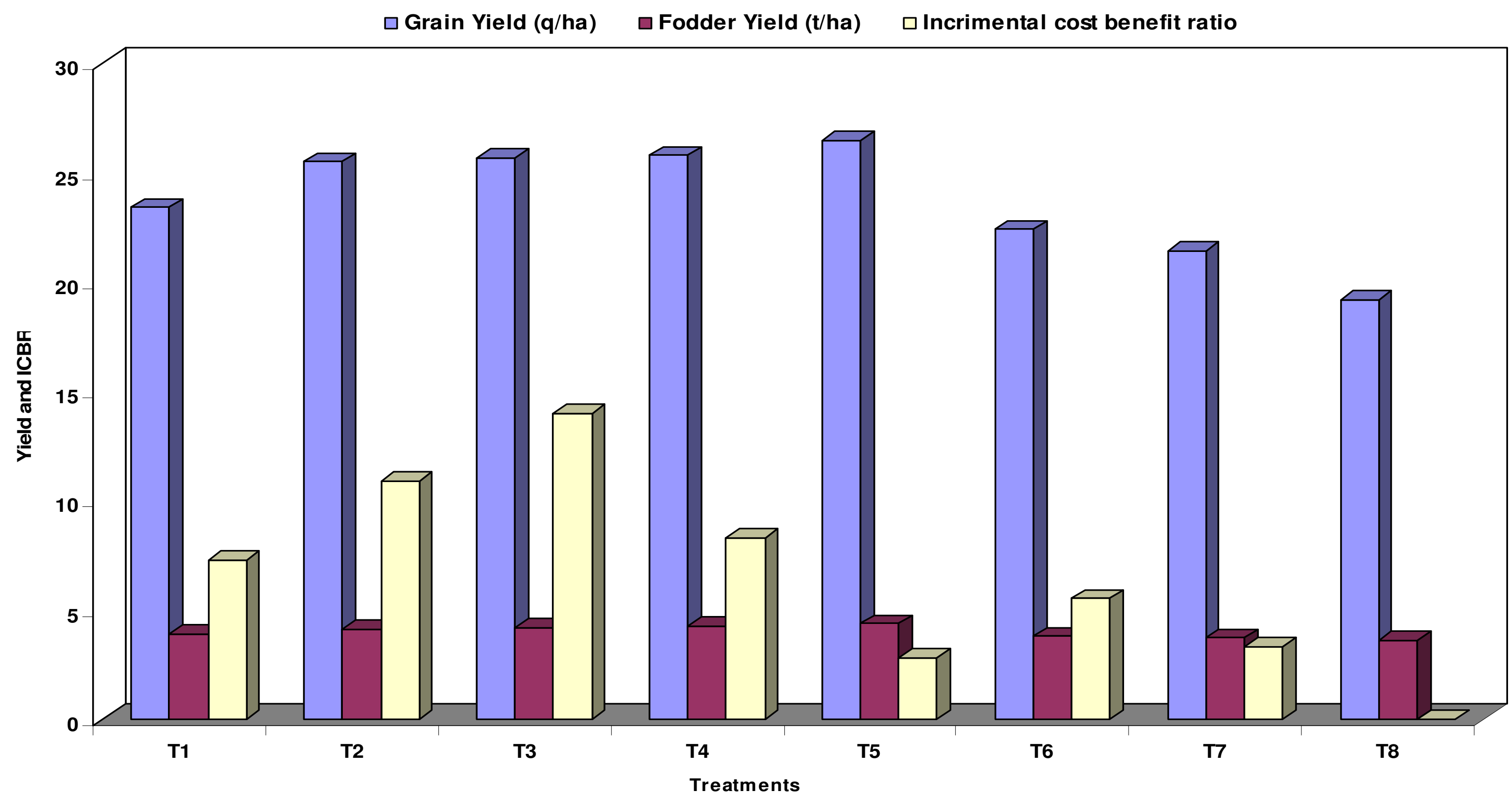


Fig. 3 : Grain yield, fodder yield and ICBR as influenced by eco-friendly IPM approaches

Fig. 3: Grain yield, fodder yield and ICBR as influenced by eco-friendly IPM approaches

Future line of work

- Detailed studies have to be taken up to understand further the mechanism of resistance.
- Extensive studies are required on the host plant resistance to explore the genetic stock and gerplasm for identifying stable new sources of resistance to key pests.
- Investigation on morphological characters conferring resistance to key pests needs to be intensified.
- Detailed studies need to be undertaken on the enzymetic activity and other biochemical parameters responsible for resistance.

6. SUMMARY AND CONCLUSIONS

The present investigations were under taken at the All India Coordinated Sorghum Improvement Project, Regional Agricultural Research Station, Bijapur, Karnataka during *rabi* 2006-07 on shoot fly, shoot bug and aphid related to screening of genotypes, multiple pest resistance, biophysical and biochemical parameters responsible for resistance and management through IPM tactics.

Different entries from the AVHT-I, AVHT-II, IVHT, SPN and ASBN trials were screened against shoot fly, shoot bug and aphid and identified superior genotypes which could be made use in the further varietal improvement programmes in *rabi* sorghum.

The genotypes *viz.,* SPV 1709, SPV 1768, Maulee, SPV 1762, SPV 1680, SPV 1672, SPH 1449, M 35-1, DSV 4 ,SPV 1755, CSV 18, SPV 1704, SPH 1501, SPV 1761, SPV 1797, SPV 1796, SPV 1800, SPV 1803, SPV 1804, SPV 1601, SPV 1795, SPV 1798, SPV 1799, SPV 1794, SPV 1806, SPV 1801, SPV 1802, BRJ 356, RSE 03, RSV 842, RSV 471, BRJ 376, RSV 790, EC 8-2, PEC-10-1, SLR 1, SLR 47, SLV 35, SLR 32, PU 10-1, IS 33722, IS 33844-1, IS 18551, IS 2205, IS 2312 were found to be recorded as resistant to shoot fly.

The higher seedling viguor and leaf glossines was recorded in these resistant genotypes as compared to susceptible checks.

The genotypes *viz.,* SPV 1680, SPV 1672, SPV 1762, SPV 1768, SPH 1449, CSV 216R, SPV 1767, DSV 4, SPV 1800, Maulee, DSV 4, SPV 1794, SPV 1803, RSV 790, SLR 34, EP 56 and SLR 39 were found to be promising by recording highest number of trichomes present on under surface of leaves as compared to resistant check.

The genotypes *viz.,* EP 65 and SLR 37 were found to be superior by recording lowest aphid population density grade. The genotypes *viz.,* T x 428, CSH 15R, BRJ 367, RSV 824, CSV 216R, SLV 31, SLR 37, and SLR 10 were found to be superior by recording lowest shoot bug population per plant.

The genotypes *viz.,* T x 428, CSH 15R, RSV 824, RSV 744, BRJ 356, RSV 823, RSV 842, SLV 10, SLV 25, SLR 29, SLV 31, SLR 35, SLR 37 and CSV 216R were found to be superior by recording lower sorghum stripe disease incidence caused by shoot bug.

The genotype *viz.,* T x 428 was found to be promising by recording lowest percentage of stunted plants and percentage of girdling of topmost leaves. The genotypes *viz.,* T x 428, CSV 216R, SPV 1672, SPH 1449 recorded highest per cent of ear head emergence.

Highly significant positive correlation existed between shoot fly incidence and leaf glossiness and seedling vigour and there was a highly significant negative correlation with trichome density.

Non-significant positive correlation was observed in respect of plant height, distance between two leaves and leaf angle with aphid density, whereas, with increase in number of leaves there was reduction in aphid population. Total leaf area of the plant had a direct significant positive relationship with aphid density.

A positive and significant correlation was observed in respect of plant height, a negative significant correlation in respect of leaf angle and total leaf area and negative non-significant correlation in respect of distance between two leaves with shoot bug population. A significant positive correlation in respect of plant height and total leaf area, a non- significant positive correlation in respect of distance between two leaves and leaf angle, a significant negative correlation of numbers of leaves per plant was observed with sorghum stripe disease caused by shoot bug.

There was non-significant correlation between shoot fly, aphid and shoot bug incidence with biochemical constituents (N. P. K and chlorophyll) of *rabi* sorghum genotypes.

- The genotype SLR 37 exhibited multiple resistance to shoot fly, shoot bug and aphid.
- The genotypes CSH 15R, CSV 216R, BRJ 356 and RSV 824 exhibited multiple resistance to shoot fly and shoot bug.
- The genotype T x 428 was found to posses multiple resistances to aphid and shoot bug.

- The genotype EP 65 was resistant to aphid and the genotypes SLR 35, SLV 29, SLV 31, SLV 10, SLV 25 and Y 75 were resistant to shoot bug.
- Seed treatment with Imidacloprid 70 WS @ 5 g/kg seeds + Two sprays with *Verticillium lecanii* at 30 and 60 DAE, seed soaking for 8-10 h in Endosulfan 35 EC @ 3 ml + 30 g $CaCl_2$ per litre of water per kg seeds + Whorl application of carbofuran 3G @ 8 kg/ha at 30 DAE and seed treatment with thiamethoxam 70WS @ 3 g/kg seeds + One spray each with NSKE @ 5% at 30 DAE and *Verticillium lecanii* at 60 DAE were the most economic treatments as they recorded highest net profit and incremental cost benefit ratio.

REFERENCES

Anaji R., 2005, Studies on crop loss estimation and management of shoot bug, *Peregrinus maidis* (Ashmead) in *rabi* sorghum. *M. Sc. (Agri.) Thesis*, Univ. Agric. Sci. Dharwad (India).

Anaji R. and Balikai, R.A., 2006, Correlations of biophysical and biochemical characters with shoot bug incidence in *rabi* sorghum. *Int. J. Agric. Sci*., 2(2): 450-451.

Anaji R. and Balikai, R.A., 2007, Management of shoot bug, *Peregrinus maidis* (Ashmead) through seed dressers. In *Biotechnology and Insect Pest Management*, (Editors: Ignacimuthi, S. and Jayaraj, S.) Elite Publishing House Pvt Ltd, New Delhi, pp. 232-235.

Anonymous, 1980, *Official methods of analysis of the Association of Official Agricultural Chemists, A.O.A.C.,* P.B. No.540, Benjamin Franklin Station, Washington DC 20044, p. 1018.

Anonymous, 2004, *FAO Bull. Statistics*, pp. 38-44.

Anonymous, 2005, *Package of practices for higher yields in field crops*. (Region-II, Zone-3), Univ. Agric. Sci., Dharwad and Karnataka State Department of Agriculture, Bangalore, p. 320.

Archar, T.L. and Bynum, E.D., 1982, Green bug control on sorghum with low rates of Carbofuran and Chlorpyriphos. *Sorghum Newsl.,* 25: 83-84.

Balikai, R.A., 1998, Evaluation of imidacloprid 70 WS against sorghum shoot fly. *Agric. Sci. Digest,* 18(2): 85-87.

Balikai, R.A., 1999, Bioefficacy of imidacloprid 70 WS on sorghum shoot fly, *Atherigona soccata* Rondani. *Insect Environ*., 5(1): 43.

Balikai, R.A., 2001, Bio-ecology and management of aphid, *Melanaphis sacchari* (Zehntner) on *rabi* sorghum. *Ph.D. Thesis*, Univ. Agric. Sci., Dharwad (India).

Balikai, R.A. and Biradar, B.D., 2003a, Field evaluation of sorghum parental lines for resistance to shoot fly and aphid. Paper presented In: *Nat. Symp. on Frontier Areas of Entomological Research*, Indian Agricultural Research Institute, New Delhi, 5-7 November 2003, (Extended Abstracts), p.393-394.

Balikai, R.A. and Biradar, B.D., 2003b, Field screening of sorghum entries against shoot fly, *Aherigona soccata* (Rondani). *Agric. Sci. Digest*, 23(4): 282-284.

Balikai, R.A. and Biradar, B.D., 2004, Performance of sorghum germplasm lines against shoot fly in *rabi* sorghum. *Agric. Sci. Digest*, 24(1): 63-64.

Balikai, R.A., Biradar, A.P. and Kolhar, R.C., 1998a, Management of sorghum shoot fly, *Atherigona soccata* Rondani. *Adv. Agric. Res. India,* 9: 47-49.

Balikai, R.A. and Jamadar, M.M., 2001, Evaluation of sorghum (*Sorghum bicolor* L.) germplasm stock for multiple pest resistance. *Adv. Agric. Res. India*, 15: 19-24.

Balikai, R.A. and Kullaiswamy, B.Y., 1999, Evaluation of F_2 populations and their parents for resistance to sorghum shoot fly, *Atherigona soccata* Rondani. *Insect Environ*., 5(2): 54-55.

Balikai, R.A., Kullaiswamy, B.Y. and Biradar, B.D., 1999, Development of new sorghum lines for shoot fly resistance, *Insect Environ*., 5(2): 64.

Balikai, R.A. and Lingappa, S., 2002a, Biophysical and biochemical basis of resistance in sorghum genotypes to aphid, *Melanaphis sacchari* (Zehntner) (Homoptera: Aphididae). *J. Aphidol*., 16(1&2): 59-66.

Balikai, R.A. and Lingappa, S., 2002b, Avoidable loss in different genotypes of sorghum due to aphid, *Melanaphis sacchari* (Zehntner) (Homoptera: Aphididae). *J. Aphidol*., 16 (1&2): 125-128.

Balikai, R.A. and Lingappa, S., 2003, Loss estimation due to sorghum aphid, *Melanaphis sacchari* (Zehntner) with respect to fodder yield and its quality. *J. Ent. Res.*, 27(4): 329-334.

Balikai, R.A. and Lingappa, S., 2003a, Chemical control of aphid, *Melanaphis sacchari* (Zehntner) in *rabi* sorghum. *J. Ent. Res.*, 27(2): 121-126.

Balikai, R.A. and Lingappa, S., 2003b, Management of aphid, *Melanaphis sacchari* (Zehntner) on *rabi* sorghum. *J. Aphidol.*, 17(1&2): 67-72.

Balikai, R.A. and Lingappa, S., 2004, Loss estimation due to yellow sugarcane aphid, *Melanaphis sacchari* (Zehntner) on *rabi* season. *Indian J. Ent.,* 66 (2): 159-164.

Balikai, R.A., Singh, C.D. and Jirali, D.I., 1998b, Screening of sorghum genotypes against the shoot fly, *Atherigona soccata* Rond. *Karnataka J. Agric. Sci*., 11(1): 208-211.

Van Den Berg, J., 2002, Status of resistance of sorghum hybrids to the aphid, *Melanaphis sacchari* (Zehntner) (Homoptera: Aphididae). *South African J. Pl. Soil*, 19(3): 151-155.

Bhise, H.T., Desai, B.B. and Chavan, U.D., 1996, Effect of chemical constituents on resistance of shoot fly in sorghum. *J. Maharashtra Agric. Univ*., 21(2): 293-294.

Bhise, H.T., Desai, B.B. and Chavan, U.D., 1997, Assessment of some biochemical parameters responsible for shoot fly resistance in sorghum. *J. Maharashtra Agric. Univ.,* 21(1): 127-129.

Chaudhari, S.D., Karanjkar, R.R. and Chundurwar, R.D., 1994, Efficacy of some insecticides to control shoot fly, delphacid, aphids and leaf sugary disease in sorghum. *Entomon*, 19(1-2): 63-66.

Chavan, M.H., Phadnawis, B.N., Hudge, V.S. and Salunke, M.R., 1990, Biochemical basis of shoot fly tolerant sorghum genotypes. *Ann. Pl. Physiol*., 4(2): 215-220.

Dalvi, C.S., Dataya, V.P. and Khanvilkar, V.G., 1990, Screening of some sorghum varieties for resistance to shoot fly, *Atherigona soccata* (Rondani). *Indian J. Ent.,* 52(2): 279-289.

Deshpande, V.P., Kamatar, M.Y., Kathnalli, D.S., Malleshappa, S.M. and Nayakar, N.Y., 2003, Screening of sorghum genotypes against shoot fly, *Atherigona soccata* (Rondani). *Indian J. Pl. Prot*., 31(1): 90-93.

*Ghuguskar, H.T., Chaudhari, R.V. and Sorte, N.V., 1999, Evaluation of sorghum hybrids for tolerance to aphids, *Melanaphis sacchari* (Zehntner) in field conditions. *PKV Res. J.*, 23(1): 55-56.

Gite, B.D., Thawari, S.B., Datke, S.B. and Kahate, P.A., 2003, Heterobeltiosis for shoot fly resistance in grain sorghum. *Ann. Pl. Physiol.,* 17(2): 114-116.

*Hagio, T., 1992, Host plant resistance and its inheritance in sorghum [*Sorghum bicolor*] to sugarcane aphid (*Melanaphis sacchari* Zehnter). *Bull. Chugoku Nat. Agric. Exp. Station* (No.10): 17-26.

Jalaluddin, S.M., Thirumurthy, S. and Shanmugasundaram, V.S., 1995, Multiple resistance in sorghum to shoot fly and stem borer. *Madras Agric. J.,* 82(11): 611-612.

Jotwani, M. G., Yong, W. R. and Teets, G. L., 1980, Elements of integrated control of sorghum pests. *FAO pl. production and prot. Paper*, No. 39, Rome, Italy, Food and Agriculture Organization, 159pp.

Jyothi, R., Muniyappa, V. and Narayana, Y.D., 1995, Virus vector relationships of maize mosaic virus and plant hopper (*Peregrinus maidis*) in sorghum. *Indian J. Virology,* 11(1): 61-66.

Kadam, J.R. and Mote, U.N., 1983, Evaluation of some sorghums for corn leaf aphid resistance. *Sorghum Newsl.,* 26: 76.

Kamatar, M.Y. and Salimath, P.M., 2003, Morphological traits of sorghum associated with resistance to shoot fly, *Atherigona soccata* Rondani. *Indian J. Pl. Prot.,* 31(1): 73-77.

Kandalkar, H.G., Men, U.B., Atale, S.B., Wanjari, S.S. and Dhope, A.M., 1999, Evaluation of newer insecticides against sorghum shoot fly, *Atherigona soccata* Rondani. *J. Appl. Zool. Res.,* 10(1): 25-26.

Karibasavaraja, L.R., 2003, Bio-ecology and management of sorghum shoot fly, *Atherigance* soccaita Randani. *M.Sc. (Agri.) Thesis*, Univ. Agric. Sci., Dharwad (India).

Karibasavaraja, L.R., Balikai, R.A., and Deshpande, V.P., 2005, Thiamethoxam 70 WS, A new promising seed dress for the suppression of sorghum shootfly, *Ann. Pl. Prot. Sci.*, 13(1): 85-87.

Kulkarni, K.A., Bhuti, S.G., Parameshwarappa, R., Shankaregowda, B.T., Thontadarya, T.S. and Jotwani, M.G., 1980, An overview of the resistance status in advanced sorghum genotypes to sorghum pests. Paper Presented In: *11th All India Sorghum Workshop*, Navasari, 11th May, 1981.

Kumar, V.K., Reddy, K.D., Rao, M.S. and Singh, B.U., 2000, Interactive mechanisms of resistance to shoot fly *Atherigona soccata* with seedling characteristics in sorghum. *Indian J. Ent.,* 62(1): 69-81.

Kumar, V.K., Reddy, K.D., Rao, M.S. and Singh, B.U., 2003, Evaluation of some sorghum genotypes for shoot fly (*Atherigona soccata* Rond.) resistance. *J. Res. ANGRAU,* 28(1-2): 1-6.

Lad, S.K., Mulik, B.B., Gare, B.N. and Bapat, D.R., 1985, Reaction of sorghum hybrids to shoot fly (*Atherigona soccata* Rond.) and white grub (*Holotrichia serrata* F.) under agroclimatic condition of Digraj. *Sorghum Newsl.,* 28: 60.

Maiti, R.K., 1994a, Estimation of chlorophyll and epicuticular wax of some glossy and non glossy sorghum genotypes at the seedling stage. *Int. Sorghum Millets Newsl.,* 35: 119-120.

Maiti, R.K., 1994b, The role of morpho-physiological traits in shoot fly resistance in sorghum. *Int. Sorghum Millets Newsl.,* 35: 107-108.

Maiti, R.K., 1996, *Sorghum Science*. Oxford and IBH Publications, New Delhi, 330 pp.

Maiti, R.K., Rao, K.V., Swaminathan, G. and Vidyasagar Rao, K., 1994, Correlation studies between plant height and days to flowering to shoot fly (*Atherigona soccata* Rond.) resistance in glossy and non glossy sorghum lines. *Int. Sorghum Millets Newsl.,* 35: 109-111.

Mote, U.N. and Bapat, D.R., 1983, Evaluation of some sorghum genotypes for multiple resistance to shoot fly and stem borer. *J. Maharashtra Agric. Univ.,* 8(2): 151-153.

Mote, U.N. and Shahane, A.K., 1988, Studies on cultivar reaction of sorghum to delphacid, aphid and leaf sugary exudation. *Sorghum Newsl.,* 31: 60.

Mote, U.N. and Shahane, A.K., 1994, Biophysical and biochemical characters of sorghum varieties contributing resistance to delphacid, aphid and leaf sugary exudations. *Indian J. Ent.,* 56(2): 113-122.

Mote, U.N., Kadam, J.R. and Bapat, D.R., 1986, Antibiosis mechanism of resistance to sorghum shoot fly. *J. Maharashtra Agric. Univ.,* 11(1): 43-46.

Mote, U.N. and Jadhav, S.S., 1993, Performance of different sorghum entries for shoot fly recovery resistance. *J. Maharashtra Agric. Univ.,* 18(1): 143-144.

Narayana, Y.D. and Muniyappa, V., 1996a, Virus-vector relationships of a plant hopper (*Peregrinus maidis*) borne sorghum stripe tenuivirus. *Int. J. Pest Manag.,* 42(3): 165-170.

Narayana, Y.D. and Muniyappa, V., 1996b, Evaluation of techniques for the efficient transmission of sorghum stripe virus by vector (*Peregrinus maidis*) and screening for disease resistance. *Trop. Agric.,* 73(2): 119-123.

Narkhede, B.N., Karad, S.R., Akade, J.H. and Kachole, U.G., 2002, Screening of *rabi* sorghum local germplasm of Maharashtra tract against shoot fly reaction. *J. Maharashtra Agric. Univ.,* 27(1): 60-61.

Navi, S.S., Bandyopadhyay, R., Blummel, M., Reddy, R.K. and Thomas, D., 2004, Maize stripe virus: a disease of sorghum emerging in South India. *Int. Sorghum Millets Newsl.,* 44: 126-129.

Nwanze, K.F., Taneja, S.L., Sharma, H.C. and Reddy, B.V.S., 1991, Multiple insect resistance in sorghum. *Sorghum Newsl.,* 32: 52.

*Omori, T., Agrawal, B.L. and House, L.R., 1983, Componental analysis of the factors influencing shoot fly resistance in sorghum (*Sorghum bicolor* (L.) Moench). *JARQ (Japan),* 17(3): 215-218.

Panchbhavi, K.S. and Kotikal, Y.K., 1992, Effect of seed soaking in insecticide solution on the germination and on the incidence of sorghum shoot fly. *Curr. Res*., 21(2): 29-30.

Patel, G.M. and Sukhani, T.R., 1990, Screening of sorghum genotypes for resistance to shoot fly, *Atherigona soccata* Rondani. *Indian J. Ent.,* 52(1): 1-8.

Patel, G.M. and Sukhani, T.R., 1990a, Biophysical plant characters associated with shoot fly resistance. *Indian J. Ent.,* 52(1): 14-17.

Patel, G.M. and Sukhani, T.R., 1990b, Estimation of avoidable losses due to shoot fly and stem borer in new sorghum cultivars. *Indian J. Ent.,* 52(4): 595-609.

Patel, G.M., Sukhani, T.R. and Srivastava, K.P., 1989, Studies on multiple resistances in sorghum to shoot fly and stem borer. *Indian J. Ent.,* 51(3): 261-264.

Patil, B, V., Bheemanna, M., Somasekhar and Hiremath, S, C., 1992, Effect of seed soaking of insecticides on sorghum shoot fly, *Atherigona soccata* Rondani. *Indian J. Ent.,* 54(4): 424-427.

Patil, M.S., Mannur, D.M. and Patil, J.R., 1998, GRS 1 - a new *rabi* sorghum variety. *Karnataka J. Agric. Sci*., 11(4): 1063-1064.

Pawar, V.M. Jadhav, G.D. and Kadam, B.S., 1984, Compatibility of Oncol 50 SP with different fungicides on sorghum (CS 3541) against shoot fly (*Atherigona soccata* Rondani). *Pestic*., 18: 9-10.

Peterschmitt, M., Ratna, A.S., Sacks, W.R., Reddy, D.V.R. and Mughogho, L.K., 1991, Occurrence of an isolate of maize stripe virus on sorghum in India. *Ann. Appl. Biol.,* 118(1): 57-70.

Prem Kishore, 2001, Resistance to shoot fly, *Atherigona soccata* Rondani and stem borer, *Chilo partellus* (Swinhoe) in new germplasm of sorghum. *J. Ent. Res.,* 25(4): 273-282.

Prem Kishore, 1992a, Evaluation of twin resistance sources amongst advance generation derivatives in sorghum to shoot fly, *Atherigona soccata* Rondani and stem borer, *Chilo partellus* (Swinhoe). *J. Ent. Res.,* 16(3): 236-241.

Prem Kishore, 1992b, SPV 1015 (PGS-1) A new sorghum variety endowed with multiple resistance to shoot fly, *Atherigona soccata* Rondani and stem borer, *Chilo partellus* (Swinhoe). *J. Ent. Res.,* 16(4): 321-323.

Prem Kishore, 1993, New strategy for improving resistance level in present day cultivars of sorghum to shoot fly, *Atherigona soccata* Rond. and stem borer, *Chilo partellus* (Swinhoe). *J. Ent. Res.,* 17(3): 173-180.

Prem Kishore, 1994, Development of new dual purpose sorghum germplasm showing resistance to shoot fly, *Atherigona soccata* Rondani and stem borer, *Chilo partellus* (Swinhoe). *J. Ent. Res.,* 18(3): 279-281.

Prem Kishore, Babu, S.R., Udai Singh, Ganesh Rai, Kishore, P., Singh, U. and Rai, G., 2002, New sources of resistance against shoot fly, *Atherigona soccata* Rondani, stem borer, *Chilo partellus* (Swinhoe) and sugarcane leafhopper, *Pyrilla perpusilla*

Walker in newly developed sorghum varieties and hybrids *J. Ent. Res.,* 26(2): 101-112.

Prem Kishore, Gupta, R.K., Gajbhiye, V.T., Vinita Mittal, Ganesh Rai and Suman Gupta, 2004, Bioefficacy and persistence of thiamethoxam (Cruiser) in sorghum. *J. Ent. Res.,* 28(3): 253-257.

Reddy, K. V. S. and Davies, J.C., 1979, Pests of sorghum and pearl millet and their parasites and predators recorded at ICRISAT centre up to August.1979. *Cereal Entomology progress Report -2*. Patencheru 502324, Andra Pradesh, India.

*Rizvi, V., 1992, Biochemical selection of sorghum crop varieties resistant to sorghum shoot fly (*Atherigona soccata*) and stem borer (*Chilo partellus*). In *Role of Allelochemicals- Allelopathy basic and applied aspects*. Eds. Alborn, H., Stenhagen, G., Leuschner, K., Rizvisjh, pp. 101-117.

*Rustamani, M.A., Kanehisa, K., Tsumuki, H. and Shiraga, T., 1992, Further observations on the relationship between aconitic acid contents and aphid densities on some cereal plants. *Bull .Res. Inst. Bioresour.,* 1(1): 9-20.

Sahib, K.H., Hasan, M.V., Bhattiprolu, G.R., Basheeruddin, M. and Palem, 2002, Sorghum hybrid-1 (PSH 1) a high yielding sorghum hybrid for Andhra Pradesh. *J. Res. ANGRAU*, 30(2): 133-136.

Sajjanar, G. M., 2002, Genetic analysis and molecular mapping of components of resistance to shoot fly (*Atherigona soccata* Rond.) in Sorghum (*Sorghum bicolor* (L.) Moench). *Ph. D. Thesis*, Univ. Agric. Sci. Dharwad (India).

*Sawang, Charoenying , Somchai, Isichaikul, Weerawan and Amornsak, 1988, Screening of sorghum varieties for resistance to the sorghum shoot fly, *Athrigona soccata* Rond. (Muscidae: Diptera) under field conditions. Kasetsart Univ., Bangkok (Thailand); Dept. of Agriculture, Bangkok (Thailand); Dept. of Agricultural Extension, Bangkok (Thailand); CIMMYT, Bangkok (Thailand). [Research Report of 19th Conference on Thai National Corn and Sorghum], pp. 128-129.

*Schenck, S. and Lehrer, A.T., 2000, Factors affecting the transmission and spread of Sugarcane yellow leaf virus. *American Phytopathological Soc.,* 84(10): 1085-1088.

Sekhar, P.R., Kulkarni, N. and Reddy, D.M., 1995, Field resistance to shoot bug, *Peregrinus maidis* Ashmead in sorghum. *J. Insect Sci.*, 8(1): 102-103.

Sharma, H.C., 1993, Host plant resistance to insects in sorghum and its role in integrated pest management. *Crop Prot.,* 12: 11-34.

Sharma, H.C., Taneja, S.L., Leuschner, K. and Nwanze, K.F., 1992, *Techniques to screen the sorghums for resistance to insects*. Information Bull. No. 32. Patencheru 502 324, Andhra Pradesh, India.

Sharma, M., Kapoor, K.N. and Bharaj, G.S., 1996, Effect of seed treatment of sorghum with some new insecticides for control of shoot fly. *Crop Res.,* 11(1): 90-92.

Shekar, B.M.C., Reddy, K.D., Singh, B.U. and Reddy, D.D.R., 1993a, Antixenosis component of resistance to corn plant hopper, *Peregrinus maidis* (Ashmead) in Sorghum. *Insect Sci. applic.*, 14 (1): 77-84.

Shekar, B.M.C., Singh, B.U., Reddy, K.D. and Reddy, D.D.R., 1993b, Antibiosis component of resistance in sorghum to corn plant hopper, *Peregrinus maidis* (Ashmead) (Homoptera: Delphacidae). *Insect Sci. applic.,* 14(5): 559-569.

Shivamurthappa, Kulkarni, K.A. and Lingappa, S., 1989, Estimation of crop loss in sorghum due to the shoot bug *Peregrinus maidis* (Ashmead). *Karnataka J. Agric. Sci.,* 2(1-2): 82-88.

Singh, B.U. and Rana, B.S., 1986, Resistance in sorghum to the shoot fly, *Atherigona soccata* Rondani . *Insect Sci. applic.*, 7(5): 577-587.

Singh, B.U., Padmaja, P.G. and Seetharama, N., 2004a, Biology and management of the sugarcane aphid, *Melanaphis sacchari* (Zehntner) (Homoptera: Aphididae), in sorghum. *Crop Prot.,* 23(9): 739-755.

Singh, B.U., Padmaja, P.G. and Seetharama, N., 2004b, Stability of biochemical constituents and their relationships with resistance to shoot fly, *Atherigona soccata* (Rondani) in seedling sorghum. *Euphytica,* 136(3): 279-289.

Singh, S. and Narayana, K.L., 1978, Influence of different varieties of sorghum on the biology of sorghum shoot fly. *Indian J. Agric. Sci.,* 48(1): 8-12.

Singh, S.P. and Grewal, R.P.S., 1997, Relative susceptibility of sorghum genotypes against shoot fly and stem borer. *Int. Sorghum Millets Newsl.,* 38: 88-89.

Singh, S.P., 1998, Association of sorghum seedling characters with resistance to shoot fly, *Atherigona soccata* (Rondani). *Int. Sorghum Millets Newsl.,* 39: 115-116.

Singh, V.S. and Shankar K., 2000, Screening of sorghum genotypes for their reaction to stem borer and shoot fly. *Indian J. Ent.,* 62(1): 34-36.

Singh, Y.P., Singh, A.K., Singh, B. and Pandey, N.D., 1989, Susceptibility of sorghum germplasm to *Atherigona soccata* Rondani. *Farm Sci. J.,* 4(1, 2): 28-31.

Sivaramakrishnan, S., Soman, P., Nwanze, K.F., Reddy, Y.V.R. and Butler, D.R., 1994, Resistance in sorghum to shoot fly *Atherigona soccata*: evidence for the source of leaf surface wetness. *Ann. Appl. Biol.,* 125(1): 215-218.

Sree, P.S., Nwanze, K.F., Butler, D.R., Reddy, D.D.R. and Reddy, Y.V.R., 1994, Morphological factors of the central whorl leaf associated with leaf surface wetness and resistance in sorghum to shoot fly, *Atherigona soccata*. *Ann. Appl. Biol.,* 125(3): 467-476.

Srivastava, K.P. and Jotwani, M.G., 1979, Persistence and residues of Carbofuran, Disulfoton and Endosulfan used for the control of major pests of sorghum crop. *J. Ent. Res.,* 3(2): 148-156.

Subbarayudu, B., 2002, Shoot bug incidence on sorghum in southern India. *Int. Sorghum Millets Newsl.,* 43: 56-57.

Subbarayudu, B., Indira, S. and Rana, B.S., 2002, Effect of integrated pest management modules on the incidence of sorghum shoot fly. *J. Res. ANGRAU,* 30(2): 22-29.

Subhedar, A.B., Dhope, A.M., Shekar, V.B., Wanjari, S.S. and Deshmukh, V.R., 1992, Efficacy of new insecticides against sorghum shoot fly, *Atherigona soccata* (Rondani). *Crop Res.,* 5(3): 537-540.

Tarun Verma, Singh, S.P. and Verma, T., 2000, Morpho-physio plant characters associated with shoot fly resistance in sorghum. *Haryana Agric. Univ. J. Res.,* 30(1-2): 41-43.

Teetes, G.L., Manthe, C.S., Peterson, G.C., Leuschner, K. and Pendleton, B.B., 1995, Sorghum resistant to the sugarcane aphid, *Melanaphis sacchari* (Homoptera: Aphididae) in Botswana and Zimbabwe*. Insect Sci. Applic.,* 6(1): 63-71.

*Thamrongsilpa, Pothisoong, Sutee, Rayakaew, Somchai, Piyapantavanon, Ref. Tawill, Nilpayak, 1997, Selection of insect pest resistant lines. Kasetsart Univ., Bangkok (Thailand). National Corn and Sorghum Research Center. [1997 Annual Research Report: Sorghum Breeding Project (So. 2.1), Bangkok (Thailand), pp. 17-30.

Thawari, S.B., Gite, B.D., Datke, S.B. and Thawari, S.B., 2003, Preliminary evaluation of new *rabi* sorghum hybrids to shoot fly infestation. *Insect Environ.,* 9(1): 21-22.

Thirumurthi, S., Subramaniam, T.R. and Palaniswamy, P. 1973, Evaluation of certain granular insecticides in the control of the sorghum shoot fly *Atherigona varia soccata* Rond. *Madras Agric. J.,* 60(7): 449-450.

*Tsumuki, H., Kanehisa, K. and Moharramipour, S.S., 1995, Sorghum resistance to the sugarcane aphid, *Melanaphis sacchari* (Zehntner) amounts of leaf surface wax and nutritional components. *Bull. Res. Inst. Bioresour.,* 3(1): 27-34.

Vijaykumar, L., 2004, Bio-ecology, seasonal incidence and management of sorghum shoot bug, *Peregrinus maidis* (Ashmead) (Homoptera: Delphacidae). *M. Sc. (Agri.) Thesis*. Univ. Agric. Sci., Dharwad (India).

* Originals not seen

Appendix 1: Weekly Weather Data for the year 2006-07

Std. wk.	Months & Dates		Rain fall (mm)	Temperature (^{o} C)		Relative Humidity (%)		Sunshine hours
				Maximum	Minimum	RH1 8-00 hrs	RH2 14-30 hrs	
14	Apr	02 - 08	0.0	38.0	23.9	45.0	18.0	9.8
15		09 - 15	2.6	39.0	25.0	51.0	23.0	8.7
16		16 - 22	1.4	36.6	21.9	68.0	26.0	9.2
17		23 - 29	0.0	38.6	25.1	48.0	23.0	9.6
18		30 - 06	33.8	38.3	24.5	63.0	30.0	7.4
19	May	07 - 13	2.6	39.5	23.4	78.3	20.3	9.5
20		14 - 20	0.0	34.0	24.0	66.0	24.0	8.7
21		21 - 27	82.4	35.6	22.5	80.7	41.4	8.0
22		28 - 03	13.3	30.7	22.3	87.9	58.7	4.9
23	Jun	04 - 10	76.7	32.3	21.3	90.6	50.3	5.5
24		11 -17	28.0	32.7	21.9	87.7	50.4	6.0
25		18 - 24	87.9	32.8	22.3	92.1	58.4	6.0
26		25 - 01	19.5	29.9	22.5	89.3	74.8	3.1
27	Jul	02 - 08	9.6	28.9	21.9	91.3	63.6	4.2
28		09 - 15	3.0	30.3	21.5	89.2	66.8	4.2
29		16 - 22	0.0	26.7	18.5	76.6	52.1	7.0
30		23 - 29	10.0	28.7	21.3	89.4	68.3	2.6
31		30 - 05	12.8	27.1	21.3	89.0	80.9	2.0
32	Aug	06 - 12	20.0	26.7	21.1	91.4	69.6	2.6
33		13 - 19	4.4	29.5	21.6	88.9	58.4	4.1
34		20 - 26	0.0	31.6	20.8	87.6	48.9	7.8
35		27 - 02	9.4	31.3	20.4	89.3	48.7	6.3
36	Sep	03 - 09	24.2	32.7	21.4	90.4	71.6	6.7
37		10 - 16	122.8	31.5	21.3	92.4	66.4	6.0
38		17 - 23	20.3	27.5	20.9	94.6	69.0	2.0
39		24 - 30	70.0	30.7	20.8	93.3	58.9	6.7
40	Oct	01 - 07	74.8	29.5	21.1	94.7	72.7	4.6
41		08 - 14	4.4	31.5	20.1	87.1	52.4	7.5
42		15 - 21	0.0	32.3	19.5	81.6	40.0	8.1
43		22 - 28	0.2	32.1	18.2	76.1	40.9	9.3
44		29 - 04	23.2	29.1	19.2	93.1	61.3	4.0
45	Nov	05 - 11	22.4	29.3	18.2	91.0	51.0	6.3
46		12 - 18	0.0	30.0	16.7	90.0	44.0	9.5
47		19 - 25	0.0	29.6	18.7	91.0	59.0	4.9
48		26 - 02	0.0	30.7	17.0	90.0	44.0	8.1
49	Dec	03 - 09	0.0	29.7	13.1	91.0	39.0	9.6
50		10 - 16	0.0	29.8	13.3	90.0	41.0	9.1
51		17 - 23	0.0	28.7	11.1	82.0	36.0	9.1
52		24 - 31	0.0	29.5	10.7	89.0	39.0	9.0
1	Jan	01 - 07	0.0	29.3	9.9	85.7	40.1	9.6
2		08 - 14	0.0	29.6	11.2	84.4	35.9	10.0
3		15 - 21	0.0	31.4	12.8	80.0	37.0	10.0
4		22 - 28	0.0	32.1	14.1	80.1	34.6	10.2
5		29 - 04	0.0	32.3	16.3	73.0	35.4	9.1
6	Feb	05 -11	0.0	32.2	14.9	74.0	29.9	9.7
7		12 - 18	0.0	31.3	14.3	76.6	31.3	9.5
8		19 - 25	0.0	32.1	15.2	73.7	32.6	9.6
9		26 - 04	0.0	33.8	15.6	66.2	28.0	10.4
10	Mar	05 - 11	0.0	35.2	18.7	54.0	29.0	9.7
11		12 - 18	0.0	35.4	20.5	65.0	33.0	9.6
12		19 - 25	0.0	37.7	23.8	60.0	27.0	8.7
13		26 - 01	0.0	37.2	23.0	55.0	21.0	9.2

Source: AICRP on Agrometeoroloy, RARS, Bijapur

Appendix 2: Details of pedigree for the entries used in the Advanced Varietal and Hybrid Trial-I (AVHT-I)

S. No.	Entries	Centre code	Centre	Pedigree
1	SPH 1449	SR 203	Proagro	*
2	SPV 1680	BRJ 376	Bijapur	Multagi Selection
3	SPV 1709	RSV 458	Rahuri	RSLG 559 x RSLG 1175 (Both are local landraces)
4	SPV 1672	CRS 7	Solapur	Selection from phul mallige
5	SPV 1768	SV Rao	NRCS	CRR 117
6	SPV 1762	RSV 657	Rahuri	(RSLG 112 x IS 4913) x CSV 216-93 (RSLG 112 and CSV 216 are landraces)
7	SPV 1755	BRJ 378	Bijapur	Selection fron Bidarkundi (chandaki) Village in Muddebihal Taluk of Bijapur
8	CSH 15R	Check		Check
9	CSV 216R	Check		Check
10	Maulee	Check		Check
11	M 35-1	Check		Check
12	CSV 18	Check		Check
13	Local check	Local check		Local check

* Pedigree is not given for private sector hybrids

Appendix 3: Details of pedigree for the entries used in the Advanced Varietal and Hybrid Trial-II (AVHT-II)

Sl. No.	Entries	Centre code	Centre	Pedigree
1	SPV 1626	RSV 491	Rahuri	CSV 216 X RSP 2 (CSV 216= Local land race; RSP 2= SPV 504 x IS 1104)
2	SPV 1704	RSV 423	Rahuri	RSLG 206 x SPV 1047 (RSLG 206= Local landrace; SPV 1047 = No. 8635 L.P))
3	SPH 1449	SR 203	Proagro	*
4	SPH 1501	RSH 20	Rahuri	1409 A X RR 9826 (1409 A= 104 B x IS 36209; RR 9826 = SPV 655 x SPV 1090)
5	SPH 1582	GK 4041	Ganga Kaveri	*
6	SPH 1579	RSH 35	Rahuri	104 A x RR 20103 (104 A = 296 B x SPV 504); (RR 20103 = RSLG 206 x C 26)
7	SPV 1761	RSV 639	Rahuri	(RSLG 112 x IS 4913) x CSV 216-38 (RSLG 112 and CSV 216 are landraces)
8	SPV 1762	RSV 657	Rahuri	(RSLG 112 x IS 4913) x CSV 216-93 (RSLG 112 and CSV 216 are landraces)
9	SPV 1757	CRS 6	Solapur	(CSV-14R x M35-1)-1-8-12
10	CSH 15R	Check		Check
11	CSV 216R	Check		Check
12	Maulee	Check		Check
13	M 35-1	Check		Check
14	CSV 18	Check		Check
15	Local check	Local check		Local check

* Pedigree is not given for private sector hybrids

Appendix 4: Details of pedigree for the entries used in the Initial Varietal and Hybrid Trial (IVHT)

S. No.	Entries	Centre code	Centre	Pedigree
1	RSV 816	SPV 1805	Rahuri	Selection from RSLG 871-3
2	RSV 827	SPV 1806	Rahuri	(CSV 216 x RSE 3)-2
3	RSV 647	SPV 1794	Rahuri	[(RSLG 112 x IS 4913) x CSV 216]-9
4	PVR 638	SPV 1795	Parbhani	PVR 453 x Gidda Maldandi
5	PVR 453	SPV 1796	Parbhani	Selection from local land race (Nankheda area) improved Dagdi selection
6	PVR 637	SPV 1797	Parbhani	SPV 655 x Phule Yashoda, SPV 655 = Maldandi x IS 148
7	RSV 768	SPV 1798	Rahuri	(RSLG 112 x IS 4913) x CSV 216-209
8	CRS 9	SPV 1799	Solapur	(CSV 14R x CSM 78)-6
9	CRS 12	SPV 1800	Solapur	(SPV 1538 x SPV 1537)-1-1-9
10	BRJH 129	SPH 1601	Bijapur	1409 A x BRJ 358
11	BRJ 380	SPV 1801	Bijapur	Dodda maldandi selection from Kauta village from Bidar
12	BRJ 381	SPV 1802	Bijapur	Nagai maldandi selection from Kodia village of chitrapur taluka
13	CSH 15R	CSH 15R	Check	Check
14	CSV 216R	CSV 216R	Check	Check
15	Maulee	Maulee	Check	Check
16	M 35-1	M 35-1	Check	Check
17	CSV 18	CSV 18	Check	Check
18	AKSV 47R	SPV 1803	Akola	(SPV 1201 x Ringani) - 99.8, SPV 1201 = Line Received from NRCS trial, Ringani = Local cultivar of Eastern Vidarbha
19	AKSV 44R	SPV 1804	Akola	(Selection from Ekarjuna local cultivar) - 12
20	Local check	Local check		

Appendix 5: Morphological characters of AVHT-I genotypes conferring to shoot bug and aphid resistance

Sl. No	Entry	Plant height (cm)		No. of leaves/ plant	Distance between two leaves	Leaf angle (º)	Leaf area (cm^2)
		45 DAE	Milky stage				
1	SPH 1449	128.8	177.7	8.2	16.0	61.8	236.6
2	SPV 1680	150.5	170.5	10.2	17.5	68.3	323.1
3	SPV 1709	143.5	167.9	8.0	16.3	57.5	347.7
4	SPV 1672	168.7	190.4	8.2	18.0	55.0	323.2
5	SPV 1768	127.0	152.9	9.3	15.2	53.3	259.5
6	SPV 1762	133.5	201.9	9.2	16.2	53.3	278.1
7	SPV 1755	135.7	178.2	10.8	15.9	58.3	343.0
8	CSH 15R	148.0	191.1	8.5	18.3	59.2	313.6
9	CSV 216R	165.2	203.2	9.8	17.5	54.2	335.6
10	Maulee	142.0	178.3	8.2	16.5	61.7	308.5
11	M 35-1	153.7	162.9	9.3	16.1	60.0	274.4
12	CSV 18	128.5	177.2	10.3	16.8	64.2	355.5
13	DSV-4	144.9	158.8	8.2	16.9	64.2	314.1
14	IS 2312 (R)	163.5	165.0	8.3	16.2	60.0	335.5
15	DJ 6514 (S)	110.7	157.1	8.0	14.5	55.9	264.1

Appendix 6: Morphological characters of AVHT-II genotypes conferring to shoot bug and aphid resistance

Sl. No	Entry	Plant height (cm)		No. of leaves/ plant	Distance between two leaves	Leaf angle (º)	Leaf area (cm^2)
		45 DAE	Milky stage				
1	SPV 1626	140.5	193.3	9.3	16.3	65.3	323.4
2	SPV 1704	155.6	183.8	9.5	18.0	6745	347.6
3	SPH 1449	128.8	182.6	8.7	15.5	55.8	333.1
4	SPH 1501	150.5	186.3	8.4	16.7	54.3	259.7
5	SPH 1582	143.5	171.8	10.3	15.9	56.1	268.1
6	SPH 1579	148.7	174.6	9.6	18.6	57.3	333.0
7	SPV 1761	127.0	162.4	10.4	17.2	55.2	323.6
8	SPV 1762	143.5	179.0	9.5	16.3	54.3	325.6
9	SPV 1757	135.7	169.0	9.7	16.9	61.8	328.5
10	CSH 15R	148.0	170.3	8.4	16.2	60.2	274.4
11	CSV 216R	145.2	176.8	9.8	16.1	64.1	345.5
12	Maulee	142.0	175.6	9.3	16.3	64.2	312.1
13	M 35-1	143.7	163.7	8.3	16.2	60.4	338.5
14	CSV 18	128.5	184.0	8.7	16.5	61.8	336.4
15	Local check	144.9	158.8	8.4	16.5	64.6	312.1
16	IS 2312 (R)	143.5	165.0	8.1	16.3	60.8	337.5
17	DJ 6514 (S)	112.7	158.1	8.0	14.8	56.5	265.1

Appendix 7: Morphological characters of IVHT genotypes conferring to shoot bug and aphid resistance

Sl. No	Entry	Plant height (cm)		No. of leaves/ plant	Distance between two leaves	Leaf angle (º)	Leaf area (cm^2)
		45 DAE	Milky stage				
1	SPV 1805	207.5	341.8	8.3	20.8	55.0	341.8
2	SPV 1806	163.8	242.0	7.3	13.3	58.3	242.0
3	SPV 1794	187.2	257.3	8.5	17.3	57.5	257.3
4	SPV 1795	184.4	332.4	8.2	19.0	63.3	332.4
5	SPV 1796	184.9	280.0	8.5	19.3	63.3	280.0
6	SPV 1797	182.1	334.9	9.8	18.7	63.3	334.9
7	SPV 1798	161.5	198.5	7.2	18.5	58.3	198.5
8	SPV 1799	165.9	305.9	8.0	17.3	56.7	305.9
9	SPV 1800	181.3	289.1	8.3	17.0	60.0	289.1
10	SPH 1601	176.3	266.1	8.3	16.7	64.2	266.1
11	SPV 1801	174.3	274.9	8.0	22.7	60.8	274.9
12	SPV 1802	150.4	413.5	9.2	13.0	53.3	413.5
13	CSH 15R	193.2	314.6	7.0	15.7	47.5	314.6
14	CSV 216R	192.7	217.1	8.0	13.4	56.7	217.1
15	Maulee	184.2	227.5	8.2	19.8	60.0	227.5
16	M 35-1	192.6	273.2	7.0	16.3	51.7	273.2
17	CSV 18	197.8	264.4	7.8	19.0	60.0	264.4
18	SPV 1803	192.1	239.6	8.3	15.3	53.8	239.6
19	SPV 1804	175.7	340.8	9.8	16.0	61.7	340.8
20	DSV 4	171.2	279.3	8.8	18.3	57.5	279.3
21	IS 2312 (R)	163.6	346.4	10.0	16.5	59.2	346.4
22	DJ 6514 (S)	158.54	316.5	7.0	15.0	49.2	316.5

Appendix 8: Morphological characters of SPN genotypes conferring to shoot bug and aphid resistance

Sl. No	Entry	Plant height (cm)		No. of leaves/ plant	Distance between two leaves	Leaf angle (º)	Leaf area (cm^2)
		45 DAE	Milky stage				
1	RSV 639	132.0	172.8	8.5	19.0	57.5	291.8
2	RSV 836	138.2	181.8	9.2	20.2	60.0	280.0
3	RSV 834	145.2	203.1	8.0	19.0	57.5	359.7
4	RSV 768	139.3	192.1	8.0	18.0	54.2	282.1
5	RSV 823	119.2	189.6	10.5	17.0	55.0	314.7
6	RSV 842	110.0	187.4	8.3	18.5	55.8	228.7
7	RSV 790	126.8	204.0	10.3	17.5	60.0	379.0
8	RSV 458	136.3	161.7	8.8	19.7	49.2	213.4
9	RSV 744	127.8	170.0	9.7	19.7	50.8	244.2
10	RSV 471	113.0	185.2	8.0	16.5	55.8	225.0
11	RSV 824	147.2	190.2	10.2	19.8	58.3	379.3
12	RSPENT -1	95.8	154.9	5.8	16.0	49.2	280.8
13	RSPENT -2	131.0	173.8	10.0	16.7	56.7	261.2
14	RSPENT-3	168.5	187.3	12.5	18.5	69.2	270.2
15	RSPENT-4	179.8	224.0	11.5	19.7	54.2	318.0
16	RSPENT-5	179.7	201.1	11.0	19.3	55.0	337.7
17	IS 2312 (R)	157.0	166.9	12.0	20.0	63.3	324.9
18	IS 2205 (R)	121.5	187.1	11.2	16.3	52.5	223.9
19	DJ 6514	66.3	129.9	8.8	10.7	52.5	97.6
20	IS 18551	135.8	179.5	10.7	18.0	52.5	261.4
21	CS 3541	80.3	95.2	8.8	11.2	53.3	290.3
22	RSE 03	127.2	182.0	9.8	16.8	56.7	253.9
23	M 35-1	148.0	186.2	10.2	17.5	55.0	189.1
24	DSV 4 (LC)	128.7	172.2	10.5	19.0	51.7	266.7
25	BRJ-356	153.2	151.4	10.8	16.5	58.3	279.7
26	BRJ-367	150.3	176.6	10.5	15.5	59.2	263.1
27	BRJ 376	141.0	162.0	9.7	17.3	49.2	305.2
28	DSV 5 (LC)	119.5	169.5	10.0	16.7	50.8	321.3

Appendix 9: Morphological characters of ASBN genotypes conferring to shoot bug and aphid resistance

Sl. No	Entry	Plant height (cm)		No. of leaves/plant	Distance between two leaves	Leaf angle (º)	Leaf area (cm^2)
		45 DAE	Milky stage				
1	SLR 1	148.3	165.0	8.0	18.5	67.5	212.2
2	SLR 5	152.8	173.9	8.5	19.0	69.2	180.6
3	SLR 8	128.0	163.8	9.0	17.8	69.2	152.1
4	SLR 10	149.0	156.8	8.8	16.2	59.2	143.2
5	SLR 13	140.7	172.4	10.3	14.7	65.8	155.9
6	SLR 17	135.2	166.4	9.8	15.0	72.5	137.6
7	SLR 24	158.2	166.5	10.7	17.2	65.8	197.8
8	SLR 25	155.0	176.7	11.2	12.0	65.8	171.6
9	SLR 27	136.8	178.9	10.8	15.8	70.8	151.7
10	SLR 28	147.3	175.8	10.7	12.3	58.3	173.2
11	SLR 29	144.0	172.1	11.3	14.8	64.2	268.0
12	SLR 31	134.8	168.1	18.0	12.7	60.8	176.1
13	SLR 32	135.8	172.3	9.7	15.2	73.3	153.4
14	SLR 34	141.0	155.6	10.3	14.8	66.7	238.5
15	SLR 35	136.3	164.6	10.3	13.5	65.8	239.8
16	SLR 37	146.7	169.6	10.0	17.0	52.5	314.9
17	SLR 38	123.8	165.2	10.5	14.5	62.5	209.6
18	SLR 39	136.2	172.1	11.5	16.8	68.3	201.2
19	SLR 40	140.2	161.5	10.3	14.0	65.8	220.7
20	SLR 41	120.3	160.4	10.7	15.2	60.8	216.3
21	SLR 43	143.3	158.1	8.3	15.2	68.3	268.5
22	SLR 45	149.3	149.9	11.8	15.2	63.3	188.1
23	SLR 46	144.0	130.8	10.7	13.3	67.5	179.6
24	SLR 47	115.7	142.2	9.7	13.0	68.3	182.5
25	SLV 25	136.5	144.2	11.2	15.8	62.5	219.9
26	SLV 27	166.0	172.0	9.8	17.7	63.3	181.2
27	SLV 29	148.3	166.9	9.5	14.7	62.5	193.2
28	SLV 31	144.8	171.1	8.5	14.7	64.2	179.7
29	SLV 35	134.7	145.1	9.0	14.0	63.3	240.4
30	CRS 10	153.3	159.8	10.3	16.0	66.7	198.2
31	CRS 11	149.7	165.6	9.2	19.2	65.0	250.4
32	CRS 2	145.0	169.3	9.5	16.5	61.7	185.7
33	EP 56	146.0	164.7	10.8	14.2	57.5	177.5
34	IS 33722	140.5	177.9	10.2	11.5	67.5	202.8
35	IS 3420	133.3	168.1	10.5	13.0	64.2	190.5
36	EC 8-2	137.2	196.2	10.8	12.2	61.7	236.6
37	IS 33844-1	150.2	187.4	11.3	12.7	67.5	319.9
38	EP 65	154.5	187.9	10.5	13.3	69.2	212.4
39	PEC 10-1	133.2	175.3	9.8	12.5	70.8	237.5
40	PU 10-1	154.2	172.7	10.2	13.0	67.5	204.1
41	M 35-1	158.8	174.8	10.3	15.0	66.7	239.4
42	Maulee	138.7	167.9	9.7	14.0	67.5	268.5
43	CSV 216R	144.8	165.1	10.3	13.5	68.3	283.1
44	Aphid (R)	80.2	108.8	12.2	6.2	71.7	236.4
45	Aphid (S)	78.2	95.5	10.0	6.0	65.0	194.4
46	Shoot bug (R)	130.2	140.6	10.9	16.3	62.5	135.7
47	Shoot bug (S)	116.3	138.2	6.5	13.2	62.5	119.0
48	Local check	121.8	189.9	10.5	12.3	67.5	261.1
49	Local check	115.8	170.1	10.5	12.3	60.0	209.5

Appendix 10: Details of materials used and market rates of produce to workout cost economics in IPM trial

Sl. No.	Inputs	Rate (Rs)
I	**Plant protection materials**	
1	Chlorpyriphos 20 EC	180/l
2	Thiamethoxam 70 WS	40/5 g
3	Imidacloprid 70 WS	30/g
4	Endosulfan 35 EC	150/l
5	Carbofuran 3G	75/kg
6	Neem seed kernels	10/kg
7	Neem seeds (pods)	5/kg
8	*Verticillium lecanii*	30/kg
9	$CaCl_2$	60/500 g
II	**Services**	
1	Spraying operation	50/ha
2	Soil application of carbofuran/ crushed neem seeds	50/ha
III	**Rate of produce**	
1	Sorghum grains	800/q
2	Sorghum fodder	500/t

STUDIES ON MULTIPLE RESISTANCE AND MANAGEMENT OF SORGHUM PESTS IN *RABI*

NAGESH CHIKKARUGI **2007** **DR. R. A. BALIKAI**
MAJOR ADVISOR

ABSTRACT

The present investigations were under taken at the All India Coordinated Sorghum Improvement Project, Regional Agricultural Research Station, Bijapur, Karnataka during *rabi* 2006-07 on screening of sorghum genotypes for identifying multiple pest resistance and management of sorghum pests.

The genotype SLR 37 exhibited multiple resistances to shoot fly, shoot bug and aphid. The genotypes, CSH 15R, CSV 216R, BRJ 356 and RSV 824 were multiple resistance to shoot fly and shoot bug and the line x 428 was multiple resistance to aphid and shoot bug.

Highly significant and positive correlation existed between shoot fly incidence and leaf glossiness and seedling vigour and there was a highly significant negative correlation with trichome density. Non-significant positive correlation was observed in respect of plant height, distance between two leaves and leaf angle with aphid density, whereas, with increase in number of leaves there was reduction in aphid population. Total leaf area of the plant had a direct significant positive relationship with aphid density. A significant and positive correlation in respect of plant height and total leaf area, a non-significant positive correlation in respect of distance between two leaves and leaf angle, a significant negative correlation of numbers of leaves per plant was observed with sorghum stripe disease caused by shoot bug.

There was non-significant correlation between shoot fly, aphid and shoot bug incidence with biochemical constituents like nitrogen, phosphorous, potash and chlorophyll index of *rabi* sorghum genotypes.

Seed treatment with Imidacloprid 70 WS @ 5 g/kg seeds + Two sprays with *Verticillium lecanii* @ 2g/l at 30 and 60 DAE and seed treatment with thiamethoxam 70WS @ 3 g/kg seeds + One spray each with NSKE @ 5% at 30 DAE and *Verticillium lecanii* at 60 DAE were the most economic treatments as they recorded highest net profit and incremental cost benefit ratio.