GENETIC VARIABILITY STUDIES FOR SHOOT FLY RESISTANCE IN KHARIF SORGHUM

By

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DISSERTATION

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Affectionately Dedicated
Architect of my life
My Beloved
Joint Family &
Late Brother

CANDIDATE'S DECLARATION

I hereby declare that the entire work embodied in this thesis or a part thereof has not been previously submitted by me for a Degree of any University.

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CERTIFICATE I

This is to certify that **Shri RAVTE RAJENDRA JAIRAM** has satisfactorily prosecuted his course of research work for the period of not less than four semesters and that the dissertation entitled **"GENETIC VARIABILITY STUDIES FOR SHOOT FLY RESISTNACE IN KHARIF SORGHUM"** submitted by him is the result of original research work and is of sufficiently high standard to warrant its presentation to the examination. I also certify that the dissertation or a part thereof has not been previously submitted by him for a degree of any university.

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Research Guide

CERTIFICATE -II

This is to certify that the dissertation entitled **"GENETIC VARIABILITY STUDIES FOR SHOOT FLY RESISTNACE IN KHARIF SORGHUM"** submitted by **Shri. RAVTE RAJENDRA JAIRAM** to the Marathwada Agricultural University, Parbhani in partial fulfilment of the requirements for the degree of **MASTER OF SCIENCE (Agriculture)** in the subject of **AGRICULTURAL BOTANY (GENETICS AND PLANT BREEDING)** has been approved by the student's Advisory Committee after viva-voce examination in collaboration with the External Examiner.

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(R.J. Ravte)

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CD	-	Critical difference
cm	-	centimetres
df	-	degree of freedom
EMS	-	error mean sum of squares
et al.	-	And associates
etc	-	etceteras
GA	-	genetic advance
H2(b.s.)	-	heritability (broad sense)
MSS	-	Mean sum of squares
r	-	Correlation coefficients
SE	-	Standard error
Viz.	-	Namely
Σ	-	Summation value
$\overline{X}$	-	mean
%	-	per cent
/	-	per

INTRODUTION

CHAPTER-I

INTRODUCTION

Sorghum (*Sorghum bicolour* (L.) Moench) is the fifth most important cereal crop globally after rice, maize, wheat and barley. It is grown in about 86 countries covering an area of about 47 million ha with gain production of 69 million tons and average productivity of 1.45 t ha^{-1} (FAO, 2004). India is major producer of sorghum with the crops occupying an area of 8.67 million ha and yielding an annual production 7.24 million tons, during 2006 (FAOSTAT, 2006). Sorghum is one of the most important cereal crop in the semi arid and tropics and a major food source to both man and animal in several countries. It is an essential component in the caloric requirement of several peoples.

Sorghum is mainly grown in the states of Maharashtra, Andhra Pradesh, Tamil Nadu, Madhya Pradesh, Gujarat and Rajasthan. Maharashtra is the largest sorghum growing state in India. In Maharashtra sorghum is cultivated in both kharif and rabi season. In Maharashtra total area under sorghum was 48.04 lakh hectares and the 17.18 and 30.86 lakh hectares were grown in kharif and rabi seasons with an average productivity of 1413 and 417 kg/ha respectively (Anonymous, 2003).

Area and production of kharif sorghum is decreasing day by day due to biotic and abiotic stresses. Out of which insect pests is one of the major factor limiting sorghum production. Green revolution attempts in other crops including sorghum have failed due to number of insect pests as reported by Jotwani and Young, 1971. About 32 per cent of the actual crop produce is lost due to insect pests.

About 150 insect species have been recorded on sorghum out of which 31 species are economically important. In India about 20 pest species have been recorded to infest sorghum. (Reddy and Davies, 1979).

Out of these insect species, sorghum shoot fly assumed a major pest status in the state in general and rabi in particular. Among several species of shoot fly recorded in India, the sorghum shoot fly *Atherigona soccata* Randani has gained the importance with the introduction of high yielding hybrids and varieties. First commercial hybrid CSH-1 and the variety CSV-1 (Swarna) were heavily damaged by this pest on the farmer's field (Jotwani *et al.*, 1970). The annual lost of sorghum production due to shoot fly in India is estimated as nearly US $ 200 million (ICRISAT, 1982).

Favourable temperature and higher relative humidity are responsible for shoot fly density build-up in rainy season. This results in severe reduction of plant population and consequently the yield. In India up to 90 per cent infestation of sorghum seedlings has been recorded (Chundurwar and Karanjkar, 1978). The severity of incidence of shoot fly is mainly confined to late sowing kharif crop and early rabi sowing. The fly incidence is much less in areas where a single crop of sorghum is grown per year and sowing is timely i.e. at the beginning of rainy season. The fly incidence is fairly low on early planted crop (Jotwani *et al.*, 1970).

Large sources for resistance to the shoot fly have been identified and some of them have been utilized in the breeding programme (Singh, *et al.*, 1968, Pradhan, 1971 and Jotwani, 1978). The shoot fly infestation usually varies over locations and seasons but some varieties show constantly less susceptibility (Chundurwar and Borikar, 1983).

Work at various centres has established the existence of three general mechanisms of resistance to shoot fly, viz; non preference of oviposition, antibiosis and recovery resistance (Blum, 1972b). The oviposition non preference has been shown as major mechanism of resistance (Singh and Jotwani, 1980b; Davies and Reddy, 1981). Non-preference for oviposition operates at all levels of infestation over different environments. However, under no choice conditions, the non-preference mechanism is suppressed under heavy infestation conditions (Rana *et al.*, 1984).

Some morphological characters such as toughness of leaf sheath (Singh and Jotwani, 1980b), presence of irregularly shaped silica bodies in leaves (Ponnaiya, 1951a and Narayana, 1977), the glossiness of leaves and presence of trichomes on lower surface of leaves (Maiti *et al.*, 1980; Omari *et al.*, 1988) also contributed for resistance.

An initial survey of the leaf epidermal morphology indicated that many of the resistant lines were trichomed (Maiti, 1977). The presence or absence of trichomes is a stable varietal characteristics, its frequency on the leaf surface is variable (Maiti *et al.*, 1980).

Shoot fly resistance is quantitative trait and is governed by additive genes (Rao *et al.*, 1974). The habitability for resistance varies with the shoot fly pressure (Agarwal and House, 1982). The shoot fly resistance is reported to be due to gradual accumulation of resistance genes. Resistance shows partial dominance under moderate infestation and partial recessiveness under high infestation (Rana *et al.*, 1984).

Keeping in a view the importance of these aspects of shoot fly the present investigations were undertaken elite group of germplasms with following main objectives.

1. To study genetic variability for shoot fly resistance components.
2. To asses the correlation and path analysis for shoot fly resistance components.
3. To select useful and diverse genotypes for shoot fly resistance components trait.

REVIEW OF LITERATURE

CHAPTER-II

REVIEW OF LITERATURE

Sorghum is grown predominantly in different parts of world like Asia, Africa and Europe. Generally sorghum yield are low because of insect pest attack. In India among more than 120 pest species have been recorded, most of them being of minor or local importance (Reddy and Davies, 1977). The major pests of sorghum on global basis are the shoot fly, stem borer, green bugs, mites, midge, ear head bugs and worms.

Sorghum shoot fly is more destructive and poses greatest problem for control. Losses cause by this pest vary with pest population, season of sowing and nature of cultivars. The damage caused is reported to vary from 0 to 90 per cent (Jotwani *et al.*, 1970; Raodoe *et al.*, 1972; Mate *et al.*, 1979 and Khurana, 1980). In India, shoot fly was reported as early as in 1914 by Fletcher (Young, 1972).

Developing resistant varieties for such serious pest has, therefore, been considered to be of most priority. Dahmas (1943) has correctly emphasized the importance in pest management programme in sorghum

Shoot fly attacks the crop in early seedling stage on first to seventh leaf and lays cigar (rod) shaped eggs singly on the underside of leaves. The larvae after hatching move towards the base of the plant, ultimately cutting through the growing point forming "deadheart" symptoms.

Under Parbhani conditions, indicated only one peak period of incidence, which ranged from July to September plantings, at the average temperature of 20 – 30 ^{O}C relative humidity about 80

– 90 per cent (Chopde, 1977; Chundurwar and Karanjkar, 1978). The observations, under Parbhani conditions, indicated, up to first week of July as rather safe period for sowing of kharif sorghum and second fortnight of October for rabi sorghum.

As such literature on resistance in crop is increasing by heaps and bounds. However literature on host plant resistance and associated parameters has been restricted with special reference to sorghum shoot fly, *Atherigona soccata* Rondani.

The available literature is reviewed under the following sub headings.

2.1. Host plant resistance
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2.1.2.3 Recovery of resistance
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2.1.4. Biochemical factors in resistance
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2.3. Breeding for shoot fly resistance

2.1. Host plant resistance

Even at the initial stage of improvement of sorghum, it was felt that most practicable, long range solution for pest control

lies in developing insect resistant, high yielding varieties and hybrids. Accordingly, the methodology for screening and identifying the sources of resistance were developed and standardized (Jotwani, 1977).

2.1.1. Sources of resistance

Number of sorghum lines have been reported to be resistant to shoot fly by Ghode (1971), Rao (1972), Ramnath *et al.* (1974), Kundu and Sharma (1975); Singh *et al.* (1978); Mote *et al.*, (1981); Bapat and Mote (1982a, 1982b) and Sharma *et al.* (1983).

Ponnaiya (1951a) first screened 219 sorghum lines at Siruguppa. He reported 15 tolerant types, which were mostly from south India. Rao and Rao (1956) isolated 14 resistant varieties, which were primarily from Bombay and Madras. Large collection was screened under All India Co-ordinated sorghum improvement project after 1960, while the resistant varieties in trial in India, have by no means exhibited immunity to shoot fly attack.

Blum (1969) developed some tolerant derivatives by utilizing Indian source of resistance, in Israel. Certain varieties have constantly lower level of injury as compared to susceptible check (Young, 1972). He listed 35 such promising lines, which were in general agronomically undesirable types, being late in maturity, tall, susceptible to lodging usually photosensitive and low yielding. These lines were representatives of four sorghum groups viz. durra, cernum, durra/membranaceum and durra/caudatum and as such should represent sources of resistance with some genetic diversity (Young, 1972).

Bapat *et al.* (1977) tested forty-eight entries and found relatively less susceptible to shoot fly, in which the damage ranged

between 18.33 to 29.83 per cent as compared to 55.55 per cent in susceptible check CSH-1.

Screening of the world sorghum collections under All India Co-ordinated Sorghum Improvement Project helped to identify 38 resistant lines (Rana *et al.*, 1978). Almost all the identified resistant lines were belonging to Indian winter (Rabi) sorghums of shallu (pop sorghum) types.

Singh and Narayana (1978) reported that CSH-1 and Swarna were highly susceptible, whereas IS-2312 and IS-5604 were moderately resistant on the basis of egg laid. Mohlkar (1981) screened 38 entries with two susceptible checks. The overall results infestation and damage showed that six varieties viz., IS-2122, IS-2162, IS-5469, IS-5604, IS-5613 and IS-5648 posses moderately high level of resistance to shoot fly. Solunke *et al.* (1982) reported very less percentage of dead hearts in improved Saoner GM-2-3-1 and 3922 (405).

Some of the improved lines for shoot fly resistance such as ICSV-700, ICSV-705 and ICSV-717 developed at ICRISAT, Patancheru, have better yield potential than landraces (Agrawal and Abraham, 1985).

Naik and Bhuti (1985) screened 28 entries for resistance to Atherigona soccata in kharif season. Dead heart percentage was least (17 %) in IS 2312 but selected varieties SPV-351 and SPV-475 were having below 30 per cent dead hearts and in hybrids it ranged from 27.8 to 84.3 per cent.

At ICRISAT Patnacheru out of 1400 lines screened, 42 lines have less susceptibility to shoot fly (Taneja and Leuschner, 1985). Improved varieties CSV-5, CSV-6, CSV-7R, Swati (SPV-504)

and CSV-8R have been developed using landraces and posses moderate levels of resistance to shoot fly (Singh and Rana, 1986).

Nineteen entries were evaluated for relative susceptibility of sorghum hybrids to shoot fly (Anonymous, 1995). Most of the sources for resistance to shoot fly originate from post rainy season sorghums grown in India under residual soil moisture conditions (Sharma and Nwanze, 1997). Cultivars M-35-1, IS-1057, IS-2123, IS-2146, IS-4664, IS-2205, IS-5604 and IS-18551 have been widely tested and posses moderate levels of resistance to shoot fly.

Singh and Grewal (1997) screened 26 advanced sorghum genotypes from ICRISAT against shoot fly. Pooled data revealed that dead hearts formed by shoot fly varied from 8.5 to 76.5 per cent. IS-18551 and ICSV-93091 had less than 10 per cent dead hearts due to shoot fly. Dead hearts formation due to shoot fly was 15 to 20 per cent in ICSV-700, ICSV-99093, PB-15438 and IS-2312.

Balikai and Kullaisawamy (1999) tested 14 F2 populations of sorghum for resistance to sorghum shoot fly during rabi 1990-91 and found crosses of M-35-1 x SPV-488, M-35-1 x IS 8, M-35-1 x Afzalpur local and M-35-1 x IS-2312 to be promising on the basis of percentage dead hearts.

Singh and Kripashankar (2000) screened 25 entries against shoot fly and reported that dead heart of shoot fly varied from 3.10 – 74.30 per cent. The minimum damage was observed in IS-2205 (3.10 %) closely followed by MASV-3319, ICSV-93091 (3.40 % in each entry) and ICSV-700 (4.00 %).

Premkishore (2001) screened 39 sorghum entries against shoot fly and found that shoot fly incidence ranged from

3.25 per cent (PGN-64) to 40.80 per cent (SU-658), nine entries viz., PGN-1, KC-1, PGN-8, PGN-19, PGN-20, SEH-2, PFGS-57 and PFGS-8 showed less than 10 per cent dead hearts formation due to shoot fly while check CSV-15 recorded 20.60 per cent shoot fly dead heart. However, these entries were significantly different from susceptible entry SU-658.

Deshmukh (2003) screened 54 sorghum breeding lines for shoot fly resistance and observed valuable worth and utility of PMS-9B, PMS-19B and IB-12 (R) lines for shoot fly resistance breeding programme. These lines are showing high shoot fly tolerance comparable with resistant check IS-18551.

2.1.2. Mechanism of resistance

Resistance to shoot fly in sorghum can be classified in the following four components (Blum, 1972a).

1. Non-preference for oviposition
2. Antibiosis
3. Recovery resistance

All the three mechanisms non-preference for oviposition, antibiosis and tolerance suggested by Painter (1951) are known to exist in sorghum for shoot fly resistance.

2.1.2.1. Non-preference for oviposition

Jain and Bhatnagar (1962) reported significantly less oviposition on resistant varieties as compared with susceptible ones (Blum, 1967), Jotwani *et al.*, (1971), Rana *et al.* (1975) and Borikar and Chopde (1982a), Unnithan and Reddy (1985), Dhillon (2004), Deshpande (2005), Mehtre (2006) and Gomashe (2007), suggested

that resistance to shoot fly in sorghum was primarily due to non preference for oviposition.

Observations on non preference for oviposition showed that 1.33 to 6.00 eggs/10 plants were deposited on resistant varieties as against 12.00 egg/10 plant on susceptible varieties (Jotwani, 1978). However, no direct correlation was observed between number of eggs and dead heart percentage. But Maiti *et al.* (1982); Mote and Bapat (1982a) reported that the average number of eggs per plant was positively correlated with dead heart percentage. It was therefore suggested that non preference mechanism can be effectively utilized for developing resistant varieties.

Taneja and Leuschner (1985) reported that the susceptible cultivars are preferred for egg laying in terms of higher number of eggs per plant and plants with eggs. Under no choice condition more eggs were laid on resistance cultivars than under multiple choice condition.

Patel and Sukhani (1990a) screened 20 sorghum genotypes and observed that eleven genotypes showed less than 1.93 eggs per plant. Minimum eggs (0.78 eggs/plant) were observed on IS-2205. Therefore, these genotypes were considered to be less preferred for oviposition and the remaining nine genotypes were more preferred by shoot fly for oviposition. Maximum oviposition (3.94 eggs/plant) was observed on CSV-1, thus it was concluded that ovipositional non-preference was responsible for resistance to shoot fly. Positive and highly significant correlation was observed between shoot fly eggs per plant and per cent dead hearts.

2.1.2.2. Antibiosis

Although ovipositional non-preference seems to be the primary mechanisms for shoot fly resistance in sorghum, evidence of some degree of antibiosis is also available (Jotwni and Shrivastava, 1970, Blum, 1972a, Young, 1973, Soto, 1974, Sharama *et al.*, 1977). Blum (1972b) indicated that antibiosis might be an additional operative factor of resistance. He observed that significantly fewer larvae were found in an infested resistant than in an infested susceptible variety. He also observed that in an infested susceptible variety the larva was established at the base of seedling. In the resistance variety, the larva was usually found in the higher region.

Jotwani (1978) observed that larval and pupal periods were significantly longer on the resistant varieties. The survival and development was found to be adversely affected when the pest was reared on resistant varieties (Singh and Narayana, 1978). The larval and pupal periods were extended by 8 – 15 days on resistant varieties. The cultivars which possessed strong antibiosis showed lower survival of larvae. The longevity of female was also reduced.

2.1.2.3. Recovery resistance

Many cultivars have ability to produce side tillers after the main shoot is killed by shoot fly, which in turn can produce a reasonable yield if the plant is not attacked further (Doggett and Majisu, 1966, Starks *et al.*, 1970).

Blum (1969) observed that in resistant varieties the walls of cells enclosed vascular bundles in central leaf whorl were lignified and that tillers of these resistant varieties grow faster than susceptible ones. Therefore, it was concluded that tiller survival in shoot fly

resistant sorghum is associated with lignified tissue in central whorl of leaves and fast growth rate of tillers.

Tillers of resistant cultivars are less preferred by shoot fly for egg laying, Doggett (1970) observed high heritability for recovery resistance and high correlation between recovered plants and yields. It was established as a secondary mechanism of resistance. Doggett (1972) identified "Namatera" and "Serese" as recovery resistant lines.

Sharma (1975) showed that percentage of dead hearts was negatively correlation with plant recovery and yield per plant, The number of tillers per 100 plants, the number of effective tillers, plant recovery and yield were positively associated with each others, indicating that tillering character contributed to yield rather than to shoot fly resistance.

Reddy and Davies (1977) reported existence of tolerance in some of the lines screened at ICRISAT, Patancheru. The more recovery was observed in the resistant varieties but clear-cut correlation was not observed between percentage of dead hearts and recovery resistance.

Kadam and Mote (1983) observed that some advance hybrids SPH-196, SPH-225, CSH-1, CSH-5, CSH-9, SPV-115, SPV-126, SPV-251, SPV-386 and SPV-472 showed high susceptibility to shoot fly in the initial stage, but possessed high recovery resistance which was reflected in grain yield. Mote *et al.* (1985) observed more recovery of damanged plants in the resistant varieties with low recovery in the susceptible varieties. The correlation between percentage of dead hearts and recovered plants was not observed probably due to independent genetic control.

2.1.3. Factors associated with resistance

The glossy appearance of seedling is also reported to be important characters for shoot fly resistance (Blum, 1972a; Bapat *et al.*, 1975, Maiti and Bidinger, 1979; Bapat and Mote, 1982b). The glossiness factor is reported to be more reliable during post rainy season (Taneja and Leuschner, 1985). Sukhani (1987) reviewed the literature on shoot fly resistance. Seedling vigour, glossiness, morphological characters and biochemical factors are reported to be associated with shoot fly resistance. Shoot fly resistance is dependent on parameters like seedling vigour, glossiness, non-preference for oviposition and trichome density (Sharma and Nwanze, 1997).

2.1.3.1 Morphological characters associated with shoot fly resistance

Ponnayia (1951b) and Narayana (1977) observed that shoot fly resistance and susceptible cultivars differed in the occurrence of irregularly shaped silica bodies in 4^{th} to 7^{th} leaf sheaths. The resistant cultivars were characterized by a distinct lignifications and thickness of cell wall, enclosing the vascular bundle sheaths within the central whorl of young leaves of the three leaf stage.

2.1.3.1.1 Seedling vigour

Shoot fly resistant lines have rapid initial growth, greater seedling height and hardness and have longer stems and internodes and short peduncles (Singh and Jotwani, 1980b). Earlier studies by Khurana and Verma (1985) and Jadhav *et al.* (1986) indicated positive correlation between plant height and shoot fly resistance. Rapid growth of seedling may retard the first instar larvae from reaching the growing point. In contrast slow growing due

to poor seedling vigour, low fertility and environmental stress increases shoot fly damage (Taneja and Leuschner, 1985).

Patel and Sukhani (1990) observed negative correlation of plant height with shoot fly oviposition and dead hearts formation. Resistant genotypes were taller and had higher growth rate than susceptible ones. Kishore (1994) reported that dual purpose sorghums, DS-1, DS-2, DS-3, DS-4, DS-5 and DS-6 showed resistance to both Atherigona soccata and Chilo portellus and Possessed desirable quality traits as plant height, stem girth and total number of leaves.

Shinde (2000) observed that susceptible checks and highly susceptible PMS entries had less plant height. The significant negative correlation of plant height was observed established with susceptibility and egg laying.

Sonone (2001) observed more plant height in the entries SPH-1248. SPH-1280, 19A x C-43 and resistant check IS-2312 indicating thereby that the taller entries exhibited the resistance to the shoot fly and the plant height was significantly less in susceptible check DJ-6514.

2.1.3.1.2. Glossiness

Mate *et al.* (1979) reported that CSH-1 having dark green colour of leaves were preferred by shoot fly for oviposition. However, fewer eggs were laid on resistant lines like IS-5469 and M-35-1 having leaves of light green colour. Moholkar (1981) observed that the resistant varieties were with lighter colour shaded as compared to the susceptible checks. The glossy (pale green thin leaves) trait in sorghum has been associated with shoot fly resistance (Bapat and Mote, 1982b and Omori *et al.*, 1988). Evaluation of all the glossy lines for their shoot fly reaction indicated

that shoot fly incidence was higher in non-glossy lines than in glossy ones in the post rainy season.

Patel and Sukhani (1990b) observed that there was positive correlation of dark green leaf colour with shoot fly oviposition and dead heart formations.

Correlations were studied between the shoot fly incidence in sorghum and the plant characters, days to flowering, number of leaves per plant, plant height and days to maturity (Rao *et al.*, 2000).

2.1.3.1.3. Trichomes

Maiti and Bidinger (1979) identified 32 lines from 8000 germplasm lines with trichomes on abaxial surface of the leaf blade. The relation between the non-preference for oviposition and presence of trichomes on the leaf lamina was reported by Maiti *et al.* (1980). The presence of trichomes on the leaf surface resulted in a lower frequency, both of oviposition by shoot fly and subsequent larval damage. The resistant cultivars IS-2146, IS-3962 and IS-5613 had high densities of trichomes on the abaxial surface while susceptible hybrid CSH-1 lacked these. Raina *et al.* (1981) suggested that the cultivars with trichomes would tend to make the downward journey of the larvae more difficult. Bapat and Mote (1982b) reported that three wild species of sorghum that were found to be immune to shoot fly had pubescence (Trichomes) on the lower surface of leaves, which might contribute to resistance.

Trichomes on sorghum leaves are non glandular hairs that are microscopic in size (Maiti and Gibson, 1983). The presence of high density trichomes is probably more important for increasing resistance to shoot fly

Highly significant negative correlation between shoot fly resistance and trichomes intensity were also reported by Omori *et al.* (1983). Agrawal and Abraham (1985) pointed out that the trichoms have high correlation with ovipositional non-preference found to be resistant to shoot fly.

2.1.4. Biochemical factors in resistance

The percentage of nitrogen, reducing sugars, total sugars, moisture and chlorophyll content of leaf in susceptible cultivars were higher than in resistant one. Lysine was present in the leaf sheaths of susceptible variety but absent in all the resistant cultivars he tested.

The resistant lines have more content of total amino acids, total phenol contents than susceptible lines. Susceptibility of sorghum to shoot fly was found to be positively correlated with phosphorous. Bapat *et al.* (1987) stated that the polyphenol oxidase activity was higher in resistant as well as moderately resistant varieties, as compared to susceptible varieties. Similarly chlorophyll content of susceptible and moderately resistant entries was slightly higher as compared to resistant entries.

2.2. Genetic basis of shoot fly resistance

A diallel set of crosses between sorghum varieties having high, intermediate and low levels of "recovery resistance" to sorghum shoot fly showed that the inheritance of this character is complex (Starks *et al.*, 1970). Genetic analysis of ovipositional non-preference underlying resistance to sorghum shoot fly indicated that hybrids are generally superior to parents and parental performance was good indicator of hybrid behaviour (Rao *et al.*, 1974). Further studies by Balakotaiah *et al.* (1974) using large F2 population

derived from a diallel mating system, revealed that the inheritance of shoot fly resistance is predominantly additive.

Additive gene action contributes most of the variation among entries in percentage of recovered plants but specific and epistatic effects were also significant. Sharma *et al.* (1977) studied shoot fly resistance with the help of diallel analysis and reported quantitative inheritance with the help of diallel analysis and reported qualitative inheritance of resistance. IS-5469 and IS-5490 were observed as good general combiners for shoot fly resistance. The resistance to shoot fly involved ovipositional non-preference.

Percentage dead hearts in resistant and susceptible varieties vary according to season, year and degree of infestation. Some lines are more resistant to attack among the resistant stock and could be chosen as preferential parental stocks in programme of incorporation of shoot fly resistance. Resistance was found to be partially dominant under low to moderate shoot fly pressures, but not under heavy infestation conditions. Resistance was also found to be polygenic in nature and governed by genes with predominantly additive effects. The non-preference mechanism is predominant one and it is quantitatively inherited with predominance of additive gene action.

Borikar and Chopde (1982b) indicated that both additive and non-additive components of gene action are important for shoot fly resistance under low shoot fly population pressure. However, dead heart percentage is predominantly controlled by additive gene action under moderate to heavy shoot fly pressure. In general, ovipositional preference was controlled by genetic factors. Dead heart percentage and egg laying was influenced by shoot fly populations. It therefore, appears that genetic studies and breeding for shoot fly resistance must be associated with the population

pressure. Selection for shoot fly resistance must be made in condition of high infestation.

Heterosis over the better parent for decreased egg laying, lower deadheart percentage and high trichome density was present only in few cases. Maiti and Gibson (1983) reported that genetic factors other than trichomes, seem to contribute to resistance.

Patel *et al.* (1985) stated that, additive as well as non-additive components for dead hearts were significant, indicating importance of both types of gene action in inheritance. Nimbalkar and Bapat (1987) reported that both the traits i.e. egg laying and per cent dead hearts were under the control of non additive gene action. The GCA variances for all characters were studied, had higher magnitude than SCA variances indicating the importance of additive and additive x additive gene interaction. The resistant parents IS-5604, IS-2146 and IS-5490 were good general combiners for shoot fly resistance.

2.3 Breeding for shoot fly resistance

Breeding for resistance to shoot fly was initiated in 1968 (Jotwani, 1977). The resistant varieties M-35-1 was crossed with CK-60B, 2219B, 3675B and IS-3691. Since recovery of dwarf plants in F_2 was very low, the F_1 plants from the back cross progeny were selfed for two generations. The selections when tested under heavy shoot fly infestation, proved to be highly susceptible to shoot fly. The programme was later modified using a number of other sources of resistance in crosses with improved agronomic material. A large number of derivatives from these crosses were screened and a few promising lines were selected for further intensive

screening. The entry E-303 was selected as multiple resistance to shoot fly and stem borer.

It has been established that the shoot fly resistance can be transferred from the donor parents and maintained in the successive segregating generations. Rao *et al.*, (1977) stated that due to the superiority of hybrids over parents and the additive nature of inheritance of the shoot fly resistance, it can be advantageously utilized in hybrids breeding as well as in the line development. They have also concluded that the resistance is due to a gradual accumulation of desirable genes rather than due to the presence of one or more genes.

Sharma and Rana (1983) reported that there were significant differences among the parents, F1 and F2 progenies. The response to oviposition in high yielding and susceptible varieties (5) was similar. The oviposition on resistant lines (R) was relatively low than that of high yielding varieties. Similar pattern was noted for percentage dead hearts. When S x S, S x R and R x R groups of hybrids were compared, both intra and inter group differences were significant.

Rana *et al.* (1984) concluded that the resistance shows partial dominance under moderate infestation and partial recessiveness under high infestation. Therefore, incorporation of resistance in both the parents of a hybrid is essential for late plantings. The quantitative nature indicated that the resistance is due to gradual accumulation of resistance genes. While resistant crosses can be identified in F2, genetic differences among progenies emerge in F3. Selection of the progenies 1.0 standard deviation below the population mean enables to pickup relatively resistant progenies. The offspring parental regression in F1, F2 and F3 are significant. Therefore, performance of selected progenies

would be reflected in the next generation by adopting such selection criteria, it is possible to gradually improve the level of resistance and develop number of varieties with adequate level of resistance.

Considering the genetic complexity of shoot fly resistance, both population and pedigree method of breeding are being used. A number of reasonably strong and stable sources of resistance, representing different genotypic areas and taxonomic races, had been identified earlier, but none of them possessed absolute resistance.

Bapat *et al.* (1987) reported that in their breeding program the combinations of IS-5604 x IS-2146, IS-5604 x CK-6013, IS-5604 x CS-3541 and IS-2146 x IS-5490 were resistant to shoot fly. There was upgrading for grain yield in IS-5604 x CK-60B, over it's parental mean yield. The resistance in these crosses might be due to incorporation of seedling characters from resistant parents. The upgrading both for shoot fly resistance and agronomic traits. In case of derived lines could be attributed to polygenic inheritance, involving additive gene action.

CHAPTER III

MATERIALS AND METHODS

The research work on "Study Of Genetic Variability Studies For Shoot Fly Resistance In Kharif Sorghum" was conducted at Sorghum Research Station, Marathwada Agricultural University, Parbhani, Maharashtra during Kharif 2006-07. The details of materials used and methods adopted for conduct of the experiment and statistical procedures of analysis followed are described in this chapter.

3.1 Experimental material

The experimental material comprised 101 genotypes were evaluated (Table no.1). This set consisted of 65 newly developed lines at ICRISAT, 10 selected elite restorer lines developed at Sorghum Research Station, Parbhani, 16 elite seed parents 'B' lines developed at Sorghum Research Station, M.A.U., Parbhani and 8 selected RIL's developed from two shoot fly resistance mapping population, currently using as donor sources in marker assisted selection for shoot fly resistance programme.

3.2 Experimental methods

3.2.1 Design of experiment

Experimental material was sown in shoot fly screening nursery on the experimental farm of Sorghum Research Station, M.A.U., Parbhani in 3rd week of July during Kharif 2006-07. The experiment was laid in a Randomized Block Design (R.B.D.) with two replications. Four rows of shoot fly susceptible genotype PVK-801 were sown as border row ten days before planting of experiment for increasing shoot fly population. Each breeding line

was presented by a single row of 4 m in length with 45 and 15 cm inter and intra row spacing, respectively.

Table 1. List of lines/ genotypes

Sr. No	Genotype	Sr. No.	Genotype
ICRISAT Lines			
1	IS-2122	34	ICSV-705
2	IS-2123	35	ICSV-707
3	IS-2146	36	ICSV-713
4	IS-2195	37	ICSV-714
5	IS-2265	38	ICSV-708
6	IS-2269	39	ICSV-711
7	IS-2312	40	ICSV-25151
8	IS-3962	41	ICSV-25131
9	IS-5470	42	ICSV-25117
10	IS-5480	43	ICSV-250
11	IS-5490	44	ICSV-804
12	IS-5571	45	ICSV-745
13	IS-18366	46	ICSV-93057
14	IS-13674	47	ICSV-93046
15	IS-5622	48	ICSV-25123
16	IS-5619	49	ICSV-1
17	IS-5613	50	ICSV-702
18	IS-5604	51	ICSV-711
19	IS-5566	52	ICSV-25001
20	IS-5538	53	ICSV-25003
21	IS-5511	54	ICSV-25004
22	IS-5484	55	ICSV-25005
23	IS-5088	56	ICSV-25006
24	IS-4646	57	ICSV-25007
25	IS-5076	58	ICSV-25010
26	ICSB-121	59	ICSV-25041
27	ICSB-15	60	ICSV-25039
28	ICSB-17	61	ICSV-25027
29	ICSB-19	62	ICSV-25026
30	ICSB-21	63	ICSV-25022
31	ICSB-23	64	ICSV-25019
32	ICSB-89002	65	ICSV-25018
33	ICSV-700		

Sr. No	Genotype	Sr. No.	Genotype
'B' Lines			
66	305B	74	296B
67	1002B	75	7B
68	6913B	76	452B
69	6938B	77	DMS-29B
70	55301B	78	20B
71	29B	79	9B
72	6924B	80	6937B
73	8B	81	PMS-28B
'R' Lines			
82	91011R	87	KR-191
83	ICSV-574	88	KR-196
84	AKR-354	89	M-11
85	C-43	90	KR-192
86	KR-199	91	KR-201
'RIL' Lines (296B x IS-18551)			
92	RIL-153	96	RIL-168
93	RIL-166	97	RIL-174
94	RIL-252	98	RIL-222
95	RIL-97	99	RIL-189
Check			
1	PVK-801	2	IS-18551

All other agronomic practices except plant protection were followed as per the requirement of crop and shoot fly screening nursery. Inter land fish meal technique were used to increase population of shoot fly

3.2.2 Observations

The data were recorded on randomly selected five plants of each breeding line for shoot fly resistance traits.

1) Glossy score

The glossy score is recorded on 1 to 5 grade scale. Glossy score 1 indicates high glossiness with pale green, shiny narrow leaves pointed upward. The glossy 5 indicates low glossiness with broad, dull green and dropping leaves. High

glossiness is desirable attribute for shoot fly resistance. In the same manner low glossiness is undesirable contribute for shoot fly resistance.

After emergence, 8 to 10 days, the glossy score was recorded on a 1 to 5 scale.

1) = > 75 % glossy

2) = 55-75% glossy

3) = 26 – 50 % glossy

4) = 1 – 25 % glossy

5) = No glossy

2) Seedling vigour score

Seedling vigour is graded as high and desirable grade (Grade 1) to low undesirable grade 5. Quick growth of seedling help to avoid oviposition and dead heart damage (%). In present result seedling vigour is recorded on 1 to 5 grade score. The scale (1) indicates high vigour with maximum height, leaf expansion and robustness. The scale (5) indicates low vigour with poor growth, low leaf expansion and poor adaptation.

After emergence on 14^{th} (14 DAE) days, the vigour score was recorded on 1 to 5 scale.

1) = > 90% of the seedling growth

2) = 75 – 90 % of the seedling growth

3) = 51 – 75 % of the seedling growth

4) = 25-50% of the seedling growth

5) = < 25% of the seedling growth

3) Plant Stand

Soon after the vigour and glossy scores taken, the total number of the plants in each row was recorded.

4) Oviposition (%)

The numbers of plants with eggs of each genotype were recorded separately on 14^{th} (14 DAE) and 21^{st} day (21 DAE) after emergence and oviposition per centage were calculated

Oviposition (%) = (number of plant with eggs) / (total number of plants) x 100

5) Deadheart count 1

In every row total shoot fly affected plants with deadheart symptoms were recorded after 21 days (21 DAE) of the germination.

Deadheart (%) = (number of plants with deadheart) / (total number of plants) x 100

6) Deadheart count 2

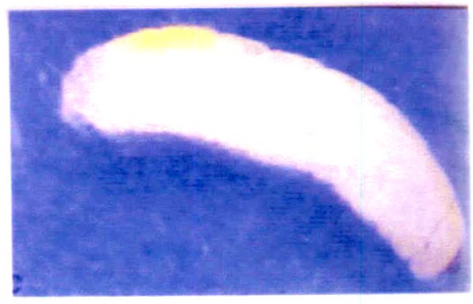
In every row total shoot fly affected plants were recorded separately after 28 days (28 DAE) of the germination.

Deadheart (%) = (number of plants with deadheart) / (total number of plants) x 100

7) Trichome density

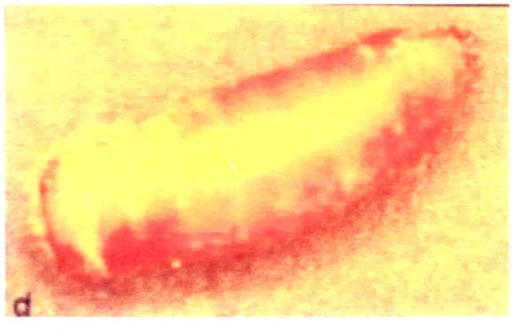
Fifth leaf blades from bottom of three plants in each genotype were randomly selected for trichome density observation at plot. Selected plants of each genotype were 17-21 DAE. Small piece of (1-2 cm^2) of the leaf samples from three plants each were collected from field separately stored them in vials with 20 ml solution of acetic acid and ethyl alcohol (2:1) for dechlorophication,

White cigar – shaped egg



Larva

Deadheart formation due to shoot fly



Pupa

Adult fly

Fig 1: Life cycle of shoot fly.

for the period of 24 hours. Then above solution mixture was removed from vials and added lactic acid to preserve the dechlorophied leaves, for further observation.

The number of trichomes present on both, lower and upper side of each leaf piece were counted and recorded them individually under microscope

8) Days to 50 per cent flowering

The number of days required from sowing to flowering of 50 per cent plants were recorded in all two replications.

9) Plant height (cm)

Plant height was measured for randomly selected five plants in centimeters from ground level to the tip of the last fully opened leaf and average height per plant was calculated at each stage. The data collected were statistically analyzed.

3.3 Statistical methods of analysis

3.3.1 Analysis of the design of experiment

The data available of mean values of plants selected in each replication were used for statistical analysis. For testing significance of results, the data were subjected to the methods of analysis of variance, commonly applicable to the randomized block design (Panse and Sukhatme, 1967). The whole data were subjected to the following statistical analysis.

Statistical analysis list

3.3.2 Analysis of variance

3.3.3 Estimation of means and range

3.3.4 Estimation of Standard Error (SE) of mean

3.3.5 Estimation of genetic variability parameters

3.3.5.1 Estimation of components of variance

3.3.5.2 Estimation of coefficients of variation

3.3.6 Estimation of heritability (b.s.), genetic advance

3.3.7 Correlation co-efficient

3.3.8 Path co-efficient analysis

3.3.9 D^2 statistical analysis

3.3.9.1 Wilk's criterion

3.3.9.2 Computation of D^2 values

3.3.9.3 Analysis of dispersion

3.3.9.4 Group constellation (cluster-formation) by Toucher's scheme

3.3.9.5 Computation of cluster means

3.3.9.6 Computation of inter and intra cluster distances.

3.3.2 Analysis of variance

The data collected on individual characters were subjected to the method of analysis of variance commonly applicable to the randomized block design (Fisher and Yates, 1975).

Sr. No.	Source of variation	Degree of freedom (d.f.)	Mean square	Expectations
1.	Replication	(r-1)	RMS	$\sigma^2e+r\,\sigma^2R$
2.	Genotype	(g-1)	GMS	$\sigma^2e+r\,\sigma^2g$
3.	Error	(r-1) (g-1)	EMS	σ^2e
	Total	(rg-1)		

The genotypic mean squares (GMS) were tested for their significance against error mean squares (EMS) by "F" test for $n_1 = (g-1)$ and $n_2 = (r-1)(g-1)$ degrees of freedom.

Where,

g = Number of genotypes

r = Number of replications

The characters showing significant differences were only subjected to further analysis.

3.3.3 Estimation of mean and range

The mean values for each character were worked out by dividing the total by corresponding number of observations.

$$\text{Mean } (\overline{X}) = 1/n \left[\sum_{i=1}^{N} Xi \right]$$

Where,

$\overline{X}$ = Mean of character

Xi = Total of all the observations for character

n = Number of observations

The lowest and highest values of mean of each character represented by range.

3.3.4 Estimation of standard error (SE) of mean, SE of difference and critical difference.

a) The S.E. of mean difference was calculated as

SE of mean (SEm) = $\sqrt{6^2 e/r}$

Where,

$\sigma^2 e$ = EMSS = Error mean sum of square

r = Number of replications

b) The standard error of difference SE(d) between to mean was calculated as:

SE of difference [SE (d)] =SEm̤ x$\sqrt{2}$

c) The critical difference (CD) or least significance difference (LSD) between any two mean was calculated as:

C.D.= SE(d) x t value at error d.f.

Where,

t= table value at error d.f. at 5% level of significance

3.3.5 Genetic variability

Various parameters of genetic variability were estimated using appropriate equation.

3.3.5.1 Estimation of components of variances

The phenotypic variances were calculated by using the respective mean squares from variance table (Johnson *et al.*, 1955).

Environmental variance = σ^2e = EMS

Genotypic variance (σ^2g)

$$\sigma^2g = \frac{GMS - EMS}{r}$$

Phenotypic variance (σ^2p) = $\sigma^2g + \sigma^2e$

Where,

GMS = Genotypic mean sum of squares

EMS = Error mean sum of squares

r = Number of replication

3.3.5.2 Estimation of coefficient of variation

The genotypic and phenotypic coefficient of variation (GCV and PCV) were calculated according to method suggested by Burton (1952).

i) Phenotypic coefficient of variation (PCV)

$$PCV\ (\%) = \frac{\sqrt{\sigma^2 p}}{\bar{X}} \times 100$$

ii) Genotypic coefficient of variation (GCV)

$$GCV\ (\%) = \frac{\sqrt{\sigma^2 g}}{\bar{X}} \times 100$$

Where,

$\sigma^2 g$ = Genotypic variance

$\sigma^2 p$ = Phenotypic variance

$\bar{X}$ = Mean of character

The high, medium and low GCV and PCV estimates were classified as

Low = 0 to 10

Moderate = 10 to 20

High = 20 and above

3.3.6 Estimation of heritability (b.s.), Genetic advance (GA).

3.3.6. a) Heritability (h^2)

Broad sense heritability was estimated for various characters as suggested by Hanson *et al.* (1956).

$$\text{Heritability } (h^2)\ (b.s)\ (\%) = \frac{\sigma^2 g}{\sigma^2 p} \times 100$$

$\sigma^2 g$ = Genotypic variance

$\sigma^2 p$ = Phenotypic variance

The high, medium and low heritability estimates were classified according to Robinson (1955) as below

Low = 0% to 30%

Moderate = 30% to 60%

High = 60% and above

b) Genetic advance (GA)

Genetic advance (at 5% selection intensity) was calculated using formula cited by Allard (1960).

$$GA = K \times \frac{\sigma^2 g}{\sigma^2 p} \times \sqrt{\sigma^2 p}$$

Where,

K = Selection difference (at 5 per cent selection intensity, the value of K = 2.06)

$\sigma^2 p$ = Phenotypic variance

$\sigma^2 g$ = Genotypic variance

The expected genetic advance (EGA) in percentage of mean is calculated as

$$EGA = \frac{GA}{\overline{X}} \times 100$$

Where,

GA = Genetic advance

$\overline{X}$ = General or grand mean of character

The high, medium and low GA as percentage of mean estimates were classified

Low = 0% to 10%

Moderate = 10% to 20%

High = 20% and above

3.3.7 Correlation co-efficients

Analysis of covariance was carried out by taking two characters at a time. The genotypic and phenotypic covariances were calculated as per the formula described by Johnson *et al.* (1955) below.

Environmental covariance (Cov. $e_{1.2}$) = EMP

Genotypic covariance: $(Cov.g_{1.2}) = \frac{GMP - EMP}{r}$

Phenotypic covariance: $(Cov.\ P_{1.2}) = (Cov.\ g_{.1.2}) + (Cov.\ e_{1.2})$

Where,

EMP = Error mean sum of product

GMP = Genotypic mean sum of product

r = Number of replications

The appropriate variances and covariances were used for calculating phenotypic and genotypic correlation coefficients (Johnson *et al.*, 1955)

a) Genotypic correlation coefficient (r_g)

$$(rg_{1.2}) = \frac{Cov.\ g_{1.2}}{\sqrt{(\sigma^2 g_1).\ \sigma^2 g_2)}}$$

Where,

$rg_{1.2}$ = Genotypic correlation coefficient between character 1 and 2

$Cov.g_{1.2}$ = Genotypic co-variance of character 1 and 2, respectively.

$\sigma^2 g_1$ and $\sigma^2 g_2$ = Genotypic variance of character 1 and 2, respectively.

The significance of the genotypic correlation coefficient was tested by referring Fisher and Yates, (1975) table.

b) Phenotypic correlation co-efficients (rp)

$$rp_{1.2} = \frac{Cov.p_{1.2}}{\sqrt{(6^2p_1)(6^2p_{1.2})}}$$

Where,

$rp_{1.2}$ = Phenotypic correlation co-efficient between the character 1& 2

Cov. $p_{1.2}$ = Phenotypic co-variance between character 1 & 2

6^2p_1 and 6^2p_2 = Phenotypic variance of characters 1 and 2 respectively.

The significance of genotypic and phenotypic correlation co-efficient were tested by 't' test.

$$t = \frac{r}{\sqrt{(1-r^2)/(n-2)}}$$

Where,

r = Correlation coefficients

n = Total number of observation

The calculated 't' value was tested with tabulated 't' value for respective (n-2) degree of freedom for significance.

3.3.8 Path coefficient analysis

To establish a cause and effect relationship the first step used was to partition genotypic and phenotypic correlation coefficient into direct and indirect effects by path analysis suggested by Dewey and Lu (1959) and developed by Sewall Wright (1921).

Seven characters related to shoot fly resistance were selected (causes) and deadheart count (28 DAE) was selected as effect for path analysis and all possible genotypic correlation co-efficient among them were worked out.

The concept behind path analysis is that, the dead heart percentage (28 DAE) is the function of various components like x_1, x_2, x_3, x_4, etc. A path diagram is constructed using simple correlation co-efficients among various characters under study and it is constructed before the estimation of direct and indirect effects. It helps in setting up simultaneous equations as follows, which in turn are used for estimation of direct effects.

It is obvious that shoot fly resistance/deadheart percentage (28 DAE) is the result of x_1, x_2 and x_3 and some other undefined factors which are deisngated by RC = residual effect.

Path co-efficients were obtained by solving a set of simultaneous equation of the form.

$$m_y = pn_y + rn_2 + rn_2py + rn_3 + \ldots.$$

where,

m_y = Correlation between one component and resistance to shoot fly (deadheart 28 DAE)

pn_y= Path co-efficient between that character and each of the other yield components in turn

Matrix – A Martrix-B

$$\begin{pmatrix} r_1y \\ r_2y \\ r_ny \end{pmatrix} = \begin{pmatrix} r_{11} & r_{12} & r_{13} \ldots\ldots r_{1n} \\ r_{21} & r_{22} & r_{23} \ldots\ldots r_{2n} \\ r_{n1} & r_{n2} & r_{n3} \ldots\ldots 1 \end{pmatrix}$$

Where,

$r_{n2} = r_{21}$ and so on and r_{ny} correlation between one component character and dead heart (28DAE). The B matrix was inverted (B^{-1}) and path coefficient (p_{ij}) were obtained as

$P_{ij} = A \times (B^{-1})$

The indirect effects of a particular character through other characters were obtained by multiplication of direct paths and particular correlation between these characters separately.

Indirect effects = $r_{ij} \times p_{ij}$

Where,

i = 1 to 7

j = 1 to 7

P_{ij} = $P_{1y} P_{2y} \ldots\ldots\ldots P_{ny}$

The path coefficient (pij), correlation coefficient (rij) and residual factor (R) were diagrammatically presented. The residual factor i.e. variation in resistance or dead heart count (28DAE) uncounted by these associations was calculated from the following formula.

Residual factor (R) = $\sqrt{1 - R^2}$

Where,

R^2 = $(p_{1y}, r_{1y} + p_{2y}, r_{2y} + \ldots\ldots\ldots + p_{ny}, r_{ny})$

Where,

$p_{1y}, p_{2y}, \ldots\ldots p_{ny}$, = Path values

$r_{1y}, r_{2y}, \ldots\ldots r_{ny}$, = Correlation coefficient

3.3.9 D^2 statistical analysis

The analysis of divergence was carried out by D^2 statistics of Mahalanobis (1928, 1936) as described by Rao (1952).

Analysis of variance for the individual characters studied was worked out as per RBD to test the significance of differences among the genotypes as described under section 3.4.1. The characters exhibiting significant differences were only used for further analysis

of D^2 statistics. The analysis of co-variance for character pairs, based on plot averages were carried out (Chocharan and Cox, 1957).

3.3.9.1 Wilk's criterion

After testing the difference between the populations for the seven characters, a simultaneous test of significance of differences in the mean values of a number of correlated variables with regard to pooled effect of the seven characters considered together was carried out using. Wilk's criterion (Wilks, 1931) which was estimated using the relationship that,

$$\Lambda = \frac{|E|}{|E+V|}$$

Where,

| E | was the determinant of the experimental error sum of squares and sum of products matrix and | E + V|, the determinant of experimental error of sum of squares and product matrix.

Significance of Wilks Λ criteria was estimated X^2 as.

$$X^2 pq = V = -m\log_e^{A}$$

Where,

$$m = \frac{n - (p + q + 1)}{2}$$

Where,

n = $N_1 + \ldots\ldots\ldots N_K - 1$

m = Total number of observations –1

p = Number of characters

q = k-1 (q is the degrees of freedom for varieties)

k = Number of genotypes

e = 2.7183, a constant

The calculated V - (Stat) was tested at [(cpq) d.f.] at 5% and 1 % level of significance.

3.3.9.2. Analysis of dispersion and contribution of different traits towards diversity

The v-statistic value at a large degrees of freedom (pq= 7 x 100, where p is the number of traits and q is the total number of varieties -1) is calculated. The V statistic value is distributed as X^2 and it is tested against the tabulated value at desired level for the test of significance of difference.

On the basis of analysis of dispersion, the relative contribution of different quantitative characters towards genetic diversity is calculated

3.3.9.3 Computation of D^2 values

Inverse the common dispersion matrix used to device a set of equations by which the original correlated variables ($x_1 - x_6$) were transformed to an uncorrelated ($y_1 - y_6$) set of variables. The D^2 values between any two varieties is the sum of suquares of difference (di^2) of their corresponding y values.

$$D^2 = \sum_{i}^{y} (y_i^1 - y_i^2)^2 = \sum_{i}^{y} di^2$$

Where,

i = 1 to y and superscripts 1 and 2 over y are the variety 1 and 2 respectively

For each combination, the mean deviation i.e. $y_i^1 - y_i^2$ with, i= 1,2,.....,p is computed and the D^2 is calculated as the sum of squares of these deviations i.e. $\Sigma(y_i^1 - y_i^2)^2$, similarly the

D^2 values for all combinations are calculated. The average D^2 values for each variety D^2 (last row) is calculated by averaging all D^2 for i^{th} variety occurring in n-1 i.e. 101-1 =100 pairs.

Significance of D^2 values

Each D^2 value is analogous to calculated χ^2 at d.f.(p). The D^2 value obtained for a pair of population is taken as the calculated value of χ^2 and is tested against the tabulated value of χ^2 for p degrees of freedom, where, p is the number of characters considered.

3.3.9.4. Group constellation (Cluster formation)

No specific rules laid down for finding two clusters, because a cluster is not a well defined term. Based on the degree of divergence (D^2 value) between any two genotypes, a logical grouping of genotypes with low D^2 values can be arrived at. Since the range D^2 values vary enormously from one set of genotypes to any other, clustering is purely arbitrary. The start clustering the range of the D^2 values were found out. Then an appropriate (D^2) value was fixed with the lowest D^2 value between the genotype (or genotypes number) the starting group was determined.

Then find out the third variety having the lowest average D^2 value from the previous two genotypes and add it to them. Similarly the fourth genotypes with the lowest divergence from the first three and the procedure were continued.

At any stage when there is an abrupt increase in the average D^2 value of the genotypes for that cluster, than that genotype was taken outside the former cluster and was included in the next cluster. This procedure was continued till all the genotypes

were included in one or the other cluster. This is followed by Touchers scheme of cluster formation.

3.3.9.5. Computation of cluster means

The average intra and inter -cluster distances within and between the cluster along with their means in respect of each character are also calculated.

3.3.9.6. Computation of intra- and inter-cluster distances

The intra-cluster divergence has been computed for each cluster. The average intra cluster distance was obtained by using following formula.

$$\text{Average intra-cluster distance } (D^2) = \frac{\sum_{i=1}^{n} Di^2}{n}$$

Where,

ΣDi^2 = the sum of the distance(s) between all possible combinations of the genotypes involved in a cluster.

The inter-cluster divergence is calculated by averaging all possible D^2 values among all genotypes belonging to different clusters concerned, divider being the number of pairs involved.

RESULTS

CHAPTER-IV

EXPERIMENTAL RESULTS

The present investigation was undertaken with 101 genotypes which consisted 65 newly developed genotypes at ICRISAT, 10 selected elite restorer lines developed at SRS (Sorghum Research Station), Parbhani, 16 elite seed parents 'B' lines developed at SRS (Sorghum Research Station) Parbhani and 8 selected RIL's (Random Inbreed Lines) currently using as donor source in marker Assisted Selection (MAS) for shoot fly resistance programme (Table 3.1). The objectives of experimental study were, to study genetic variability for shoot fly resistance parameters and to evaluate the role of parameters in relation to shoot fly resistance in sorghum.

The character studies were as glossy score (8 DAE), seedling vigour (14 DAE), oviposition (%)(14 DAE), oviposition (%) (21 DAE), oviposition (%) (21 DAE), dead heart damage (%) (21 DAE), dead heart damage (%) (28 DAE), days to 50 per cent flowering, plant height (cm).

The result obtained from the statistical and biometrical analyses for various quantitative characters are presented under the following sub heads.

4.1. Analysis of variance

4.2. Estimation of means and range for parameters

4.3. Estimation of genetic variability heritability (b.s.) and genetic advance (GA)

4.4. Character association

4.4.1 Correlation coefficients

4.4.2 Path coefficients analysis

4.5. Assessment of genetic variability and clustering of germplasms

4.5.1 Multivariate analysis using Mahalanobi's D^2 statistics

4.5.1.1. Analysis of dispersion

4.5.1.2. Computation of D^2 values and their significance

4.5.1.3 Contribution of different characters towards diversity

4.5.1.4 Clustering of germplasm in to different clusters

4.5.1.5 Toucher's scheme for cluster formation

4.1 Analysis of variance

The data were subjected to analysis to study the genetic difference among 101 breeding lines for shoot fly resistance parameters under study. The variation among the genotypes was highly significant for all the characters indicating substantial genetic variability for the entire attribute were presenting selected genotypes (Table 4.1).

4.2. Estimation of means and range for parameters of shoot fly resistance

The mean performance of 99 and two checks for nine different characters along with range of mean for each attribute is given in Table 4.2.

4.2.1. Glossy score

The glossy score for in screened genotypes ranged from 1 to 5 with general mean 2.78 (Table 4.2). Out of screened genotypes 65 ICRISAT lines ranged from 1 to 5.Among ICRISAT lines IS-5470, IS-5604, IS-5484, ICSV-702, ICSV-25003, ICSV-25005, ICSV-25039, ICSV -25027, ICSV-25019 recorded desirable glossy score (1).

Table 4.1. Analysis of variance (MSS) for shoot fly resistance parameters

Source of variation	D.F..	Glossy score (1-5)	Seedling vigour score (1-5) (DAE)	Ovipo-sition (%) (14 DAE)	Ovipo-sition (%) (21 DAE)	No. of trichomes (10x field)	Dead heart damange % (21 DAE)	Dead heart damage % (28 DAE)	Days to 50 % flowering (days)	Plant height (cm)
Replications	1	0.01	0.27	67.5	76.4	1151.82	54.34	21.47	2.99	95.47
Genotypes	100	2.63**	1.07**	335.73**	317.70**	13136.12**	606.51**	413.97**	155.21**	8524.3**
Error	100	0.33	0.2	131.39	101.73	1680.95	134.97	127.23	3.88	207.86

*,** = Significance 5 % and 1% level respectively.

Table 4.2. Mean performance of shoot fly resistance parameters

Sr. No.	Genotypes	Glossy score (1-5)	Seedling vigour score (1-5) (DAE)	Ovipos-ition (%) (14 DAE)	Ovipos-ition (%) (21 DAE)	No. of trichomes (10x field)	Dead heart damange % (21 DAE)	Dead heart damage % (28 DAE)	Days to 50 % flowering (days)	Plant height (cm)
1	IS-2122	2.00	2.00	52.27	78.18	79.66	38.63	75.00	79.00	223.33
2	IS-2123	1.50	1.50	54.76	72.62	93.17	46.42	60.71	78.50	265.00
3	IS-2146	1.50	2.00	75.44	74.34	178.00	53.94	72.81	76.50	254.00
4	IS-2195	1.50	1.75	74.24	91.06	87.83	67.42	83.18	77.00	231.66
5	IS-2265	1.50	1.75	70.17	80.11	180.00	50.85	73.86	84.00	317.50
6	IS-2269	2.00	1.50	81.43	82.38	233.16	68.57	75.23	77.50	270.83
7	IS-2312	2.25	2.00	70.87	77.54	120.33	67.54	80.17	82.50	285.00
8	IS-3962	2.75	2.50	79.56	79.56	156.16	65.73	74.56	84.00	246.33
9	IS-5470	1.00	1.50	52.47	63.31	104.00	30.18	58.05	80.00	289.16
10	IS-5480	2.00	1.25	75.70	83.90	102.50	61.30	83.59	81.00	245.83
11	IS-5490	2.75	2.50	70.61	81.02	207.83	65.05	73.10	78.00	276.66
12	IS-5571	2.50	1.50	73.06	80.79	98.33	68.12	73.67	87.00	282.50
13	IS-18366	1.50	1.00	70.53	83.93	56.83	60.27	77.23	81.50	244.16
14	IS-13674	2.25	1.75	82.59	83.03	55.50	63.39	83.48	79.50	238.33
15	IS-5622	3.50	3.50	74.51	81.65	136.33	64.42	94.68	84.00	277.50
16	IS-5619	2.50	2.00	78.25	67.33	95.16	40.83	63.16	73.00	225.83
17	IS-5613	3.00	1.00	68.18	72.72	212.16	61.36	68.18	81.00	234.16
18	IS-5604	1.00	1.25	64.09	60.06	117.83	27.86	51.13	83.00	295.83
19	IS-5566	2.50	1.25	49.12	62.72	127.16	38.16	54.39	83.50	286.33
20	IS-5538	1.50	2.00	72.72	77.27	76.66	45.45	77.27	83.50	281.66
21	IS-5511	1.50	1.25	68.12	78.80	194.33	57.52	76.54	88.50	291.66
22	IS-5484	1.00	1.75	49.09	65.43	129.83	43.40	61.59	78.50	242.50
23	IS-5088	2.00	1.50	70.84	85.42	188.33	52.68	78.13	83.00	273.33
24	IS-4646	2.25	2.00	72.67	77.22	157.33	54.45	74.84	83.50	351.33
25	IS-5076	2.00	1.75	79.22	65.37	188.00	41.88	65.15	87.00	295.83
26	ICSB-121	2.75	2.50	92.62	97.50	0.00	82.74	95.00	78.00	94.16
27	ICSB-15	5.00	2.75	90.00	100.00	0.00	81.97	100.00	81.50	65.00
28	ICSB-17	3.50	2.75	86.53	91.17	0.00	80.65	88.23	73.50	88.33
29	ICSB-19	2.75	3.50	92.86	98.09	0.00	78.57	95.24	78.00	105.00
30	ICSB-21	3.00	3.00	71.05	98.10	0.00	73.68	97.37	86.50	85.00
31	ICSB-23	2.25	2.75	81.60	100.00	0.00	79.44	97.72	77.50	115.33
32	ICSB-89002	4.50	3.75	88.33	97.22	0.00	77.22	97.22	82.00	129.17
33	ICSV-700	2.00	2.00	72.55	81.29	81.67	50.87	67.31	85.50	262.00
34	ICSV-705	2.50	2.25	65.11	95.00	162.67	53.58	73.80	78.00	87.00
35	ICSV-707	3.25	2.25	53.01	75.55	186.17	47.49	75.41	78.50	160.33
36	ICSV-713	1.00	1.25	70.99	74.60	208.66	32.22	53.07	84.50	139.83
37	ICSV-714	2.75	2.50	75.59	86.60	151.33	52.08	78.87	84.50	164.50
38	ICSV-708	3.00	2.50	60.43	88.98	222.50	51.08	83.48	80.00	164.83
39	ICSV-711	3.00	2.25	70.17	91.66	256.66	56.03	79.16	81.00	185.00
40	ICSV-25151	2.50	2.25	65.26	91.86	31.33	55.84	83.87	77.00	147.33
41	ICSV-25131	2.50	2.00	73.86	83.80	0.00	69.88	77.55	79.00	230.83
42	ICSV-25117	2.00	2.75	78.63	90.91	0.00	71.82	80.75	78.00	215.00
43	ICSV-250	3.00	2.00	63.27	71.16	177.00	54.57	63.27	77.00	228.33

Sr. No.	Genotypes	Glossy score (1-5)	Seedling vigour score (1-5) (DAE)	Ovipos-ition (%) (14 DAE)	Ovipos-ition (%) (21 DAE)	No. of trichomes (10x field)	Dead heart damange % (21 DAE)	Dead heart damage % (28 DAE)	Days to 50 % flowering (days)	Plant height (cm)
44	ICSV-804	4.00	3.50	88.48	97.82	0.00	84.13	95.32	81.50	272.50
45	ICSV-745	5.00	2.00	89.03	100.37	0.00	91.81	100.00	83.50	130.00
46	ICSV-93057	3.00	2.50	66.82	78.60	142.50	57.20	61.10	83.50	187.16
47	ICSV-93046	2.75	2.50	78.59	84.47	161.66	77.65	86.36	85.00	257.83
48	ICSV-25123	1.75	1.75	65.73	58.53	135.83	30.59	55.73	74.50	141.83
49	ICSV-1	2.75	1.75	81.60	84.09	0.00	65.47	72.29	77.00	162.00
50	ICSV-702	1.00	1.75	63.97	73.29	66.50	50.31	54.65	84.00	179.66
51	ICSV-711	2.75	1.50	83.48	74.45	191.83	50.76	71.95	85.00	204.16
52	ICSV-25001	2.25	1.75	81.62	83.67	29.33	67.79	78.23	74.00	208.00
53	ICSV-25003	1.00	1.00	56.86	57.02	107.16	28.27	48.53	81.00	104.50
54	ICSV-25004	2.50	2.75	47.50	68.61	48.17	44.72	60.28	81.50	164.66
55	ICSV-25005	1.00	1.00	64.62	70.47	157.00	43.27	51.46	90.00	250.83
56	ICSV-25006	3.50	1.50	70.87	72.81	30.67	56.31	71.58	69.50	176.33
57	ICSV-25007	3.75	1.50	63.78	63.78	114.33	45.59	63.60	72.50	235.50
58	ICSV-25010	1.50	2.00	56.06	72.08	50.67	48.81	60.49	78.50	108.66
59	ICSV-25041	2.50	1.50	56.63	82.76	110.83	71.59	78.03	81.00	210.00
60	ICSV-25039	1.00	1.00	45.24	45.23	216.33	21.43	40.48	84.50	232.66
61	ICSV-25027	1.00	1.50	51.60	51.14	60.16	34.55	45.88	80.00	205.00
62	ICSV-25026	3.00	2.25	73.09	78.09	90.66	58.45	72.97	84.00	195.50
63	ICSV-25022	4.00	1.75	53.59	56.93	57.83	53.94	69.02	84.50	182.33
64	ICSV-25019	1.00	1.50	68.86	78.41	98.33	54.77	64.32	77.50	109.17
65	ICSV-25018	2.00	2.50	72.40	86.03	336.33	56.06	67.64	72.50	110.50
66	305B	4.00	4.00	92.85	95.24	0.00	92.85	90.47	78.50	157.50
67	1002B	2.00	2.50	75.00	87.50	0.00	77.50	85.00	78.00	149.00
68	6913B	4.00	2.75	87.48	91.48	0.00	87.30	93.95	80.50	167.17
69	**6938B**	4.00	4.50	92.06	92.85	0.00	87.30	100.00	78.50	152.00
70	55301B	5.00	2.25	89.57	97.06	0.00	80.75	97.72	81.50	137.50
71	29B	1.00	1.00	49.30	73.26	0.00	32.29	58.68	77.50	115.50
72	6924B	1.50	1.50	60.85	89.47	105.33	50.33	75.87	77.50	150.00
73	8B	4.50	2.75	76.62	95.34	0.00	81.38	92.96	85.00	77.50
74	296B	3.00	3.00	72.05	91.30	0.00	76.86	88.50	84.50	156.66
75	7B	4.50	2.25	92.82	97.72	131.00	86.36	88.63	78.00	181.66
76	452B	2.25	1.75	74.09	89.18	110.50	51.00	61.00	77.00	169.50
77	DMS-29B	3.00	1.25	69.21	69.21	0.00	53.81	66.58	78.00	160.00
78	20B	3.00	2.25	72.27	90.91	143.50	65.00	81.36	79.00	234.16
79	9B	2.00	2.50	66.84	77.37	0.00	60.17	91.40	82.00	175.83
80	6937B	5.00	3.00	93.66	95.74	0.00	85.14	95.74	85.00	177.00
81	PMS-28B	5.00	3.25	75.12	92.46	0.67	81.93	95.09	85.50	124.17
82	91011R	2.00	1.75	57.33	87.91	0.00	75.91	85.91	83.50	206.66
83	ICSV-574	4.75	3.00	91.72	97.71	0.00	89.45	93.45	80.00	160.33
84	AKR-354	4.50	3.00	88.00	91.65	0.00	87.30	91.65	83.50	226.67
85	C-43	4.00	1.25	89.00	87.13	0.00	78.95	85.30	81.00	145.00
86	KR-199	3.75	1.75	83.01	90.19	0.00	85.28	87.91	79.00	180.00
87	KR-191	4.00	1.75	85.82	83.82	0.00	79.48	85.82	82.00	143.33
88	KR-196	4.50	1.75	92.96	100.00	0.00	88.42	92.85	79.50	163.33
89	M-11	3.25	1.75	88.65	92.50	0.00	81.15	83.65	83.50	171.00

Sr. No.	Genotypes	Glossy score (1-5)	Seedling vigour score (1-5) (DAE)	Oviposition (%) (14 DAE)	Oviposition (%) (21 DAE)	No. of trichomes (10x field)	Dead heart damange % (21 DAE)	Dead heart damage % (28 DAE)	Days to 50 % flowering (days)	Plant height (cm)
90	KR-192	3.50	1.50	88.69	86.90	0.00	78.27	84.22	78.50	188.33
91	KR-201	5.00	3.50	79.97	97.91	0.00	77.56	95.99	82.50	217.83
92	RIL-153	3.00	1.75	81.57	95.44	78.66	70.08	81.78	81.00	139.83
93	RIL-166	2.50	1.75	67.39	89.13	253.83	65.22	84.78	79.00	225.00
94	RIL-252	2.50	1.50	72.67	86.75	168.33	70.70	84.37	75.00	213.00
95	RIL-97	2.50	1.25	50.91	66.82	84.00	43.18	61.36	78.00	288.33
96	RIL-168	2.75	2.00	81.14	79.06	2.00	56.58	80.15	78.50	178.33
97	RIL-174	3.00	1.75	83.30	89.48	109.83	85.13	89.13	83.00	226.67
98	RIL-222	3.00	2.75	77.64	84.37	108.00	54.24	83.95	84.00	178.33
99	RIL-189	3.00	1.25	85.71	95.24	0.16	78.57	92.86	85.00	231.66
100	PVK-801*	5.00	3.25	92.10	100.00	0.00	92.10	97.37	79.50	152.50
101	IS-18551**	1.00	1.00	52.08	56.63	147.00	45.83	50.00	85.00	291.67
	Range	1-5	1-4.50	40.91-93.66	45.23-100	0.00-336.33	21.43-92.85	40.48-100.00	69.50-90.00	351.33-65.00
	$\bar{X}$	2.78	2.08	73.09	81.35	84.19	62.49	77.45	79.87	194.46
	S.E. ±	0.57	0.44	11.46	10.08	40.99	11.61	11.28	1.97	14.41
	C.D.	1.14	0.88	22.74	20.01	81.34	23.05	22.37	3.91	28.6

*-suceptible check

**-resistance check

Among 'B' lines, glossy score ranged from 1 to 5, lines 29B (1), 6924B (1.5) shown desirable glossy score white, 55301B(5), 6937B (5), PMS-28B (5), recorded undesirable glossy score.

Among 'R' lines, glossy score ranged from 2 to 5. The single line 91011R (2) shown desirable glossy score and line KR-201 (5) recorded undesirable glossy score.

Among RIL's (Random Inbred lines) glossy score ranged from 2 to 3. Most of the RIL recorded moderate glossy score.

Among all screened genotypes, 27 genotypes recorded glossy score or equal less than two (2) indicating desirable glossy score and high resistance research against shoot fly infestation. These lines also indicating less dead heart per centage. Fifty six lines recorded glossy score in between 2 and 4 and likely to show intermediate reaction.

4.2.2. Seedling vigour score (1-5)

Seedling vigour score ranged from 1 to 4.5 with general mean 2.08 (Table 4.2). In all screened genotypes ICRISAT lines ranged from 1 to 3.75. The IS-18366, 5613, ICSV-25003, 25005, 25039 recorded desirable seedling vigour one (1), closely followed by IS-2123 (1.50), IS-2269 (1.50), IS-5470 (1.50), IS-5480 (1.25), IS-5571 (1.50), IS-5604, 5566, 5511 (1.25), IS-5088 (1.50), ICSV-711, 25006, 25007, 25041, 25027 and 25010 (1.50).

Among 'B' lines seedling vigour score ranged from 1 to 4.5. The 29B (1) with high seedling vigour closely followed by DMS-29B (1.25), 6924B (1.50) and 452B (1.75). In case of 'R' lines seedling vigour ranged from 1.25 to 3.50. The lines C-43 (1.25),

seedling vigour ranged from 1.25 to 2.75. The RIL-97 (1.25), RIL-189 (1.25) recorded high seedling vigour.

Among tested genotypes, 60 genotypes recorded seedling vigour score equal or less than 2 indicating high vigour and two lines with low seedling vigour more or equal to 4, which indicate poor vigour and are likely to susceptible to shoot fly damage other lines showed intermediate reaction to shoot fly.

4.2.3. Oviposition (%)(14 DAE)

Oviposition (%)(14 DAE) ranged from 40.91 to 93.66 per cent with general mean 73.09 per cent in screened genotypes.

Among ICRISTAT's lines the oviposition (%) (14 DAE) ranged from 45.24 to 92.86. The lines ICSV-25039 showed minimum oviposition (%)closely followed by IS-5484 (49.09), IS-15566 (49.12) as compaired to resistance check IS-18551 (52.08) and high oviposition recorded in three genotypes ICSB- 19 (92.86), ICSB-121 (92.62), ICSB-15 (90) at par with susceptible check PVK-801. Among 'B' lines plant with eggs ranged from 49.30 to 93.66 per cent, plants with minimum oviposition (%) recorded in the lines 29B (49.30%), 9B (66.94%). Maximum number of plants with eggs recorded in lines 6937B (93.66 %), other 'B' lines recorded more than 70 per cent plants with eggs (14 DAE).

Among 'R' lines oviposition (%) (14 DAE) ranged from 57.33 to 92.96 per cent. 91011R recorded minimum plants with eggs 57.33 per cent and KR-196 recorded maximum 92.96 per cent. In case of RIL's oviposition (%) ranged from 40.91 to 85.71 per cent RIL lines, RIL-97 recorded minimum (40.91) per cent plants with eggs while RIL-189 (85.71 %) recorded maximum plant with eggs.

Among tested genotypes, only five lines recorded less or equals to 50 oviposition (%) (14 DAE). Due to low percentage of plant infestation with eggs, dead heart damage (%) is likely to be low. Other lines have more than 50 oviposition (%) (14 DAE).

4.2.4. Oviposition (%) (21 DAE)

Plant with eggs (21 DAE) ranged from 45.28 to 100 per cent with general mean 81.35 per cent in al 101 genotypes (Table 4.2).

Among all ICRISTAT lines plant with eggs ranged form 97.82 to 45.28 per cent. Lines ICSV-804 (97.82 %) recorded maximum plant with eggs (21 DAE) followed by ICSV-745 (97.37 %), ICSB-121 (97.50 %), ICSB-89002 (97.22 %). ICSV-25039 (45.28 %) recorded minimum plant with eggs (21 DAE) followed by ICSV-25027 (51.14%), ICSV-25123 (53.33 %).

Among 16 'B' lines plant with eggs (21 DAE) ranged from 97.72 to 69.21 per cent. DMS-29B (69.21 %) recorded minimum plant with eggs (21 DAE) and 7B (97.72 %) recorded maximum plant with eggs (21 DAE) followed by 55310B (97.06 %) and 6937B (95.24 %).

Among 10 'R' lines plant with eggs (21 DAE) ranged from 82.82 to 100 per cent, KR-191 (82.82 %) minimum and KR-196 (100 %) maximum plant with eggs (21 DAE). In case of RIL's range found between 56.82 to 95.44 per cent. RIL-97 shown minimum (56.82 %) and RIL-153 (94.44 %) maximum plant with eggs (21 DAE).

4.2.5 Number of trichomes on lower leaf surface (10x microscopic field)

Thichomes on the under surface of leaves is one of the important parameter for shoot fly resistance. Trichomes on sorghum leaves are non grandular hair that are microscopic in size.

In present study, numbers of trichomes on lower surface were counted under 10x microscopic field for all 101 genotypes and result are presented as follows. Number of trichomes in tested genotypes on lower side of leaf ranged from 0 to 336.33 with general mean of 84.19, among tested genotypes (Table 4.2).

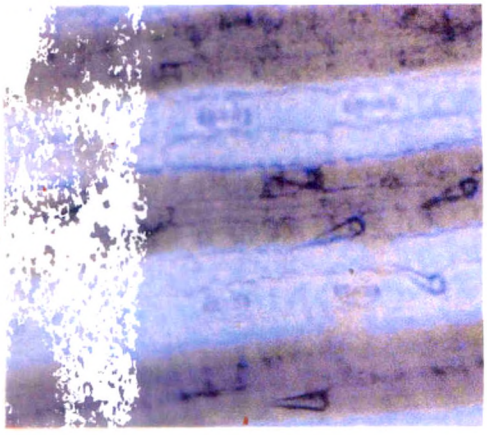
Among ICRISAT lines the line ICSV-25018 (336.33) recorded highest number of trichomes (10 x microscopic field), followed by ICSV-711 (256.60), RIL-166 (253.83), IS-2269 (233.16), ICSV-708 (222.50), IS-5613 (212.16), ICSV-713 (208.66), IS-5490 (207.83), ICSV-25039 (216.33), IS-5511 (194.33), ICSV-711 (191.83).

Among tested genotype 42 lines recorded high number of trichomes (10x microscopic field) more or equal of 100 which shown non preference lines for oviposition of shoot fly.

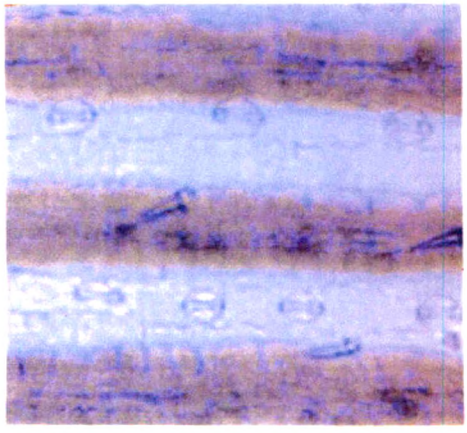
4.2.6 Deadheart damage (%) (21 DAE)

Dead heart damage (%) 21 DAE range from 21.43 to 92.85 per cent with general mean of 62.49 per cent, among all 46 genotypes (Table 4.2).

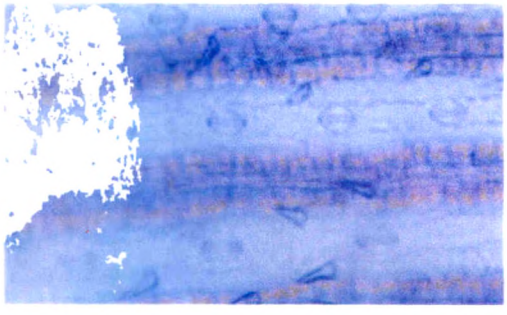
Among ICRISAT lines dead heart damage (%) 21 DAE ranged from 21.43 to 91.81 per cent, lines ICSV-25039 (21.43 %) recorded lowest dead heart damage (%) followed by IS-5604 (27.86 %), ICSV-25003 (28.27 %), IS-5470 (30.18 %), ICSV-25123 (30.59



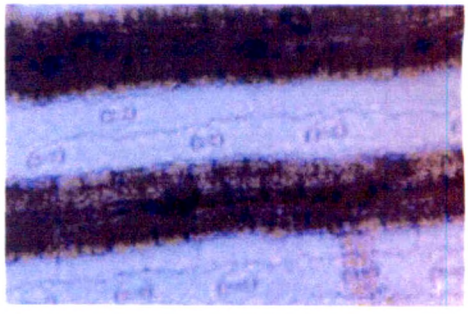
ICSV-25039



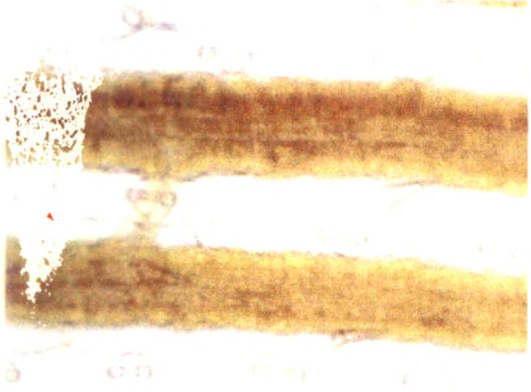
ICSV-25005



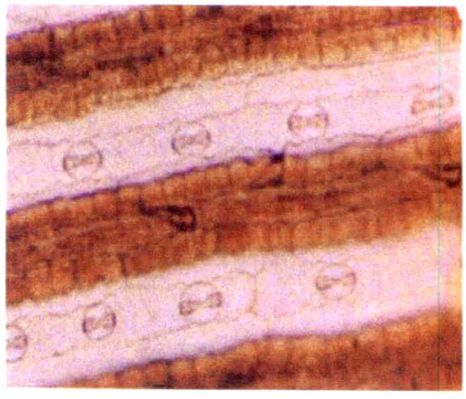
IS-18551



PVK-801



452B



RIL-97

Fig2 : Trichome density in promising lines along with resistant (IS 18551) and susceptible (PVK 801) checks

%). Line ICSV-745 (91.81 %) recorded highest dead heart percentage followed by ICSV-804 (84.32), ICSB-121 (82.74) ICSB-15 (81.97) ICSB-17 (80.65).

Among 'B' lines dead heart damage (%), 21 DAE ranged from 32.29 to 92.85 per cent 305B (92.85 %) recoded highest deadheart damage (%) and line 29B (32.29 %) recorded minimum dead heart followed by 6924B (50.33 %), 452B (51%), DMS-29B (53.81), 9B (60.17 %).

Among 'R' lines dead heart damage (%) 21 DAE ranged from 72.91 to 89.45 per cent. The lines 91011 R recorded least 75.91 per cent dead heart and line ICSV-574 (89.45 %) recorded maximum dead hearts.

Eight RIL's ranged dead heart (%) (21 DAE) between 43.18 to 85.13 per cent, RIL-97 recorded minimum (43.18 %) dead heart (%) 21 DAE followed by RIL-222 (54.24 %), RIL-168 (56.58 %) and RIL-166 (65.22%)..

Among tested genotypes 45 genotypes recorded dead heart damage (%) 21 DAE less or equal to 60.0 per cent. Which indicates resistance to shoot fly and less dead heart formation. These 45 genotypes also have high glossy score and high seedling vigour.

4.2.7 Dead heart damage (%) 28 DAE

Dead heart damage (28 DAE) ranged from 40.48 to 100 per cent with general mean of 77.45 per cent, among tested genotypes (Table 4.2)

Among ICRISAT lines the dead heart damage (28 DAE) range from 40.48 to 100 per cent. Lowest percentage of damage was found in line. ICSV-25039 (40.48 %), closely followed by ICSV-

25027 (45.88 %), ICSV-25003 (48.53 %), IS-5604 (51.13 %), ICSV-25005 (51.46 %), ICSV-713 (53.07 %), IS-5566 (54.39 %), ICSV-702 (54.65 %), ICSV-25123 (55.73 %), IS-5470 (58.04 %).

Among the 'B' lines dead heart damage (28 DAE) ranged from 58.68 to 100 per cent. 29B recorded minimum dead heart damage (58.68 %) followed by 452B (61 %), 6938B recorded maximum dead heart damage (100 %) closely followed by 55301B (97.72 %), 6037 B (95.74 %), PMS-28B (95.09), 6913B (93.95)

Among 'R' lines dead heart ranged from 83.65 to 95.99 per cent. M-11 recorded minimum dead heart damage (83.65%) while KR-201 (95.99 %) recorded maximum dead heart damage (28 DAE).

Among RIL's dead heart ranged from 61.36 to 92.86 per cent. RIL-97 recoded minimum dead heart damage (61.36 %) while RIL-189 (92.86 %) recorded maximum dead heart damage (28 DAE).

Among tested genotypes 11 lines recorded dead heart damage (%) (28 DAE) less or equal to 60 per cent. Twenty lines recorded above 90 per cent dead heart damage (28 DAE) and other genotypes shown intermediate reaction against the dead heart formation.

4.2.8 Day to 50 % flowering (days)

Early maturity is desirable character from breeding point of view. Days to 50 % flowering ranged from 69.50 to 90 days with general mean of 79.87 days (Table 4.2)

Among all ICRISAT lines the ICSV-25006 (69.50) found earlier in flowering followed by ICSV-25007 (72.50%), ICSV-25018

(72.50 %), IS-5619 (73 %), ICSB-17 (73.50) ad ICSV-25005 (90 %) found late in 50 % flowering.

Among 'B' lines day to 50 % flowering ranged from 77 to 85.50 days. Line 452B recorded minimum days to 50 % flowering (77 days) and line PMS-28B recorded late in days to 50 per cent flowering.

Among 10 'R' lines days to 50 per cent flowering ranged between 79 to 83.50 days. KR-199 recorded minimum days (79 days) for 50 per cent flowering and 91011R (83.50 %), AKR-354 (83.50), M-11 (83.50 %) recorded maximum days to 50 % flowering.

Among RIL's days to 50 per cent flowering ranged between 75 to 85 days RIL-252 (75) recorded minimum days to 50 per cent flowering and RIL-189 (85 %) recorded highest days for 50 per cent flowering.

4.2.9 Plant height (cm)

Plant height in tested genotypes ranged from 65 to 351.65 cm with general mean of 194.46 cm. Among ICRISAT selected lines plant height ranged from 351.65 to 65 cm. ICSB-15 (65 cm) recorded minimum height followed by ICSB-21 (85 cm), ICSV-705 (87 cm), ICSB-17 (88.33 cm), ICSB-121 (94.16 cm) and IS-4646 recorded heights plant height (351.33 cm) followed by IS-2265 (317.66 cm), IS-5076 (295.83 cm), IS-5604 (295.83 cm).

Among 16 'B' lines plant height (cm) ranged from 77.50 to 234.16 cm. 8 B recorded minimum height 77.50 cm followed by 452B (100.50 cm), 29B (115.50 cm) 55301B (137.50 cm), PMS-28B (124.17 cm) and 20B recorded maximum height 234.16 cm. In case of 'R' lines plant height ranged from 143.33 to 226.67 cm. KR-191 (143.33 cm) recorded maximum height followed by C-43 (145 cm),

ICSV-574 (160.33), KR-196 (163.33 cm) and AKR-354 recorded maximum height (226.67). Among the RIL's plant height ranged from 139.83 to 288.33 cm. RIL-97 recorded maximum height 288.33 cm and RIL-153 recorded less plant height (139.83 cm) followed by RIL-168 (178.33 cm) and RIL-222 (179.33 cm).

4.3 Genetic variability

The genetic components viz. range, mean, genotypic coefficients of variation (GCV), phenotypic coefficients of variation (PCV), heritability (broad sense) and genetic advance (GA) were worked out using a appropriate statistical method for shoot fly resistance characters in sorghum breeding lines (Table 4.3).

4.3.1 Glossy score (1-5)

The genotypic variance and phenotypic variance values for this parameters were found as 1.15 and 1.48 respectively (Table 4.3). The estimated genetic co-efficient of variation (GCV) and phenotypic co-efficient of variation (PCV) for this trait were 38.63 and 43.83 per cent, respectively. This character exhibited a high broad sense heritability 77.70 %) estimate coupled with expected genetic advance (1.95).

4.3.2. Seedling vigour (1-5)

The genotypic variance and phenotypic variance values for this parameter were found as 0.43 and and 0.63 respecively (Table 4.3). The estimated genetic coefficient of variation (GCV) and phenotypic coefficient of variantion (PCV) for this trait 31.67 and 38.29 per cent respectively. This character exhibited a high sense heritability (68.38 %) estimate coupled with expected genetic advance (1.12%).

Table 4.3. Genetic variability parameters for shootfly resistance in sorghum lines

Sr .No.	Characters	Range min max	Mean $\bar{X}$	Genotypic variance (σ^2g)	Phenotypic variance (σ^2p)	GCV (%)	PCV (%)	Heritability b.s (%)	Genetic advance (GA)	GA as % of mean
1	Glossy score (1-5)	1 - 5	2.78	1.15	1.48	38.63	43.83	77.70	1.95	70.15
2	Seedling vigour score (14-16 DAE)	1 - 4.5	2.08	0.43	0.63	31.67	38.29	68.38	1.12	53.95
3	Oviposition (%) (14 DAE)	40.91 - 92.86	73.09	102.16	233.56	13.82	20.90	43.74	13.77	18.84
4	Oviposition (%) (21 DAE)	45.23-100	81.35	107.98	209.72	12.77	17.80	51.49	15.35	18.88
5	No. of trichomes (10x microscopic field)	0.00-336.33	84.19	5727.58	7408.53	89.88	102.23	77.31	137.06	162.81
6	Dead heart damange (%) (21 DAE)	21.43-92.85	62.49	235.77	370.74	24.56	30.80	63.59	25.22	40.36
7	Dead heart damage (%) (28 DAE)	40.48-100	77.45	143.36	270.60	15.45	21.23	52.98	17.95	23.18
8	Days to 50 % flowering (days)	72.50-90.00	79.87	75.66	79.54	10.88	11.16	95.11	17.46	21.87
9	Plant height (cm)	317.50 - 65.00	194.46	4158.22	4366.08	33.16	33.97	95.24	129.62	66.66

4.3.3. Oviposition (%) (14 DAE)

The genotypic and phenotypic variance values for this parameter were found as 102.16 and 233.56 respectively (Table 4.3). The estimated genetic and phenotypic coefficients of variation for this traits were 13.82 and 20.90 per cent, respectively. This characters exhibited a broad sense heritability 43.74 per cent coupled with expected genetic advance (13.77).

4.3.4 Oviposition (%) (21 DAE)

The genotypic and phenotypic variance values for these parameters were found as 107.98 and 209.72 respectively (Table 4.3.) The estimated genetic and phenotypic coefficients of variation for this trait were 12.77 and 17.80 per cent, respectively. This character exhibited a high broad sense heritability (51.49 %) coupled with expected genetic advance (15.35).

4.3.5. Number of trichomes on dorsal leaf surface (10x microscopic field)

The genotypic and phenotypic variance values for this parameter were found as 5727.58 to 7408.53, respectively (Table 4.3). The estimated genotypic and phenotypic coefficients of variation for this trait were 89.88 and 102.23 per cent, respectively. This character exhibited a high broad sense heritability (77.31 %) coupled with high expected genetic advance (137.06).

4.3.6 Dead heart damage (%) (21 DAE)

The genotypic and phenotypic variance values for this parameter were found as 235.77 and 370.74, respectively (Table 4.3). The estimated genotypic and phenotypic coefficients of variation for this trait were 30.80 and 63.59 per cent, respectively.

-25039

ICSV-25005

IS-18551

PVK-801

452B

RIL-97

Fig 3: Promising line along with resistant (IS – 18551) and susceptible (PVK – 801) checks

This character exhibited a broad sense heritability (63.59 %). Coupled with high expected genetic advance (25.22).

4.3.7 Dead heart damage (%) (28 DAE)

The genotypic and phenotypic variance values for this parameter were found as 143.36 and 270.60, respectively (Table 4.3). The estimated genotypic and phenotypic coefficients of variation for this trait were 15.45 and 21.33 per cent, respectively. This character exhibited a broad sense heritability (52.98 %) coupled with genetic advance (17.95%).

4.3.8 Days to 50 % flowering

The genotypic and phenotypic variance values for this parameter were found as 75.66 and 79.54, respectively (Table 4.3). The estimated genotypic and phenotypic coefficients of variations for this trait were 10.88 and 11.16 per cent, respectively. This character exhibited high broad sense heritability (95.11 %) coupled with expected genetic advance (17.46).

4.3.9 Plant height (cm)

The genotypic and phenotypic variance values for this parameter were found as 4158.22 and 4366.08, respectively (Table 4.3). These estimated genotypic and phenotypic coefficients of variation for this trait were 33.16 and 33.97 per cent, respectively. This character exhibited as broad sense heritability (95.24 %) coupled with expected genetic advance (129.62).

4.4. Character association studies

Study of the association between various characters helps to establish the importance of each of the important component characters with dead heart damage (%) (28 DAE),

whereas the path co-efficient analysis is used to evaluate the direct and indirect contribution of each variable towards the dead heart damage (%). Thus these two analysis help to formulate a selection criteria during breeding programme.

4.4.1 Correlation coefficients

The correlation study was undertaken at genotypic and phenotypic level in order to find out the inter-relationship of different shoot fly resistance parameters. The estimated association among six important characters with dead heart damage (%) 28 DAE) is given in Table 4.4. It was found that the genotypic correlation values in general were greater than their corresponding phenotypic correlation values.

Seedling vigour (14-16 DAE) has significant positive correlation with dead heart damage (%) (28 DAE), while trichome density have positive correlation with glossy score and negative correlation with dead heart damage (%) 28 DAE and all other characters. Oviposition (%) at (14 DAE and 21 DAE) and dead heart damage (%) (21 DAE) have positive correlation with dead heart damage (%) (28DAE). Glossy score recorded positive correlation with trichome density and seedling vigour and negative correlation with dead heart damage (%)(21 & 28 DAE) &Oviposition (%)

Dead heart damage (%) 21 DAE recorded (0.989) significant positive correlation with dead heart percentage (28 DAE), oviposition (%) (21 DAE) also recorded (0.989) significant positive correlation with dead heart (%) (28 DAE) followed by percent oviposition (%) (14 DAE) (0.913) oviposition (%) (14 DAE) is also positively correlated with oviposition (%) (21 DAE) (0.972) (Table 4.4).

Table 4.4. Genotypic (g), Phenotypic (P) correlation cefficients of deadheart damage (%) (28 DAE) & other parameters

Sr.No.	Characters		Seedling vigour score (1-5) (DAE)	per cent plant with eggs (14 DAE)	Per cent plant with eggs (21 DAE)	No. of trichomes (10x field)	Dead heart damange % (21 DAE)	Dead heart damage % (28 DAE)
1	Glossy score (1-5)	G	0.687**	-0.834**	-0.724**	0.482**	-0.810**	-0.823**
		P	0.508**	-0.550**	-0.560**	0.386**	-0.674**	-0.622**
2	Seedling vigour score	G		0.702**	0.702**	-0.389**	0.710**	0.863**
	(14-16 DAE)	P		0.365**	0.439**	-0.276**	0.427**	0.488**
3	Oviposition (%)	G			0.972**	-0.469**	0.915**	0.913**
	(14 DAE)	P			0.680**	-0.360**	0.730**	0.657**
4	Oviposition (%)	G				-0.491**	0.964**	0.989**
	(21 DAE)	P				-0.310**	0.788**	0.774**
5	No. of trichomes	G					-0.601**	-0.578**
	(10x microscopic field)	P					-0.478**	-0.436**
6	Dead heart damange (%)	G						0.989**
	(21 DAE)	P						0.823**

*,** - Significance at 5 % and 1% level respectively

4.4.2 Path coefficient analysis

Path coefficient is an effective tool to analysis the direct and indirect influence of different characters on dead heart damage (%) (28 DAE) and permit a greater critical examination for effective factors that produce given correlation. This helps in giving due weightage to a particular character during selection.

Genotypic path analysis between dead heart damage (%) (28 DAE) and other shoot fly resistance parameters was carried out by using genotypic correlation coefficient (Table 4.5)

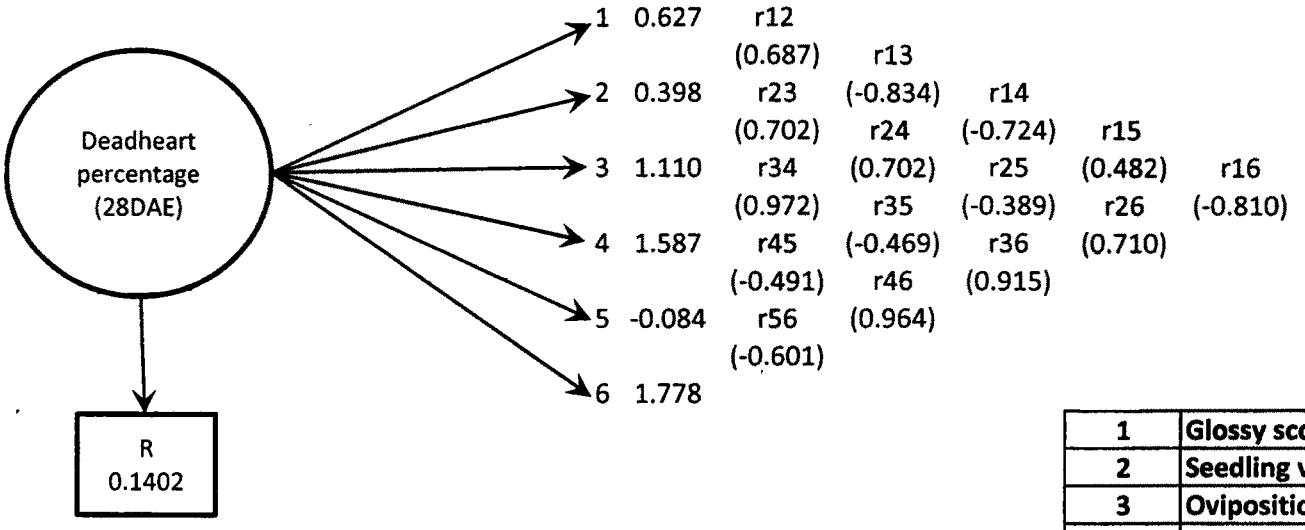
The results of path co-efficient analysis revealed that the highest positive direct effect (1.7784) of dead heart damage (%) (21 DAE) was observed, closely followed by Oviposition (%) (21 DAE) (1.5875),Oviposition (%)(14 DAE) (1.1102).

The parameter glossy score exhibited direct positive effect (0.627) on dead heart damage (%) (28 DAE). Glossy score exhibited indirect positive effect on dead heart damage (%) (28 DAE) via seedling vigour score (0.2740), number of trichomes (0.0405). and negative effect via. oviposition (%) (14 DAE), (-0.925), dead heart damage per cent (21 DAE) (-1.441) ,Oviposition (%) (21 DAE) (-1.1497),

The parameter seedling vigour has direct positive effect (0.3988) on dead heart damage (%) 28 DAE. It has positive indirect effect via oviposition (%) (14 DAE) (0.7797) dead heart damage (%) (21 DAE) (1.2631) and has negative indirect effect through oviposition (%) (21 DAE) (-1.1141), glossy score (-0.4315), number of trichomes (10 x field) (-0.0327).

Table 4.5. Direct (diagonal) and indirect (above half diagonal) effect of different characters on deadheart damage (%) (28 DAE) in sorghum

Sr.No.	Characters	Glossy score (1-5)	Seedling vigour score (1-5) (DAE)	per cent plant with eggs (14 DAE)	Per cent plant with eggs (21 DAE)	No. of trichomes (10x field)	Dead heart damange % (21 DAE)	Dead heart damage % (28 DAE)
1	Glossy score (1-5)	0.6279	0.2741	-0.9257	-1.1497	0.0406	-1.4411	-0.8230
2	Seedling vigour score (14-16 DAE)	-0.4315	0.3988	0.7797	-1.1141	-0.0327	1.2631	0.8630
3	Oviposition (%) (14 DAE)	-0.5236	0.2801	1.1102	-1.5428	-0.0395	1.6281	0.9130
4	Oviposition (%) (21 DAE)	-0.4548	0.2799	1.0790	1.5875	-0.0414	1.7139	0.9890
5	No. of trichomes (10x microscopic field)	0.3025	-0.1550	-0.5209	0.7801	-0.0842	-1.0691	-0.5780
6	Dead heart damange (%) (21 DAE)	-0.5088	0.2832	1.0164	-1.5298	-0.0506	1.7785	0.9890



1	Glossy score
2	Seedling vigour score
3	Oviposition (14 DAE)
4	Oviposition (21 DAE)
5	No. of trichomes (10x microscopic field)
6	Deadheart percentage (21 DAE)

Fig.4.Path diagram showing factors influencing shootfly resistance in sorghum

The parameter oviposition (%) (14 DAE) have direct positive effect (1.1102) on dead heart damage (%) (28 DAE) It has indirect positive effect via. dead heart damage (%) (21 DAE) (1.6280), seedling vigour score (0.2800) and indirect negative effect through oviposition (%) (21 DAE) (-1.5427), glossy score (-0.5235), trichome density (-0.0394).

Oviposition (%) (21 DAE) exhibited positive direct effect (1.5874) on dead heart damage per cent (28 DAE). It has positive indirect effect through dead heart damage (%) (21 DAE) (1.7139), oviposition (%) (14 DAE) (1.0789), seedling vigour (0.2798) and negative indirect effect through glossy score (-0.4547), number of trichomes (-0.0413).

Number of trichomes (10x field) exhibited negative direct effect (0.0841) on dead heart damage (%) (28 DAE). It has positive indirect effect through oviposition (%) (21 DAE) (0.7801), glossy score (0.3025) and negative indirect effect through dead heart damage (%) (21 DAE) (-1.0690), oviposition (%) (14 DAE) (-0.5208) and seedling vigour score (-0.1550).

Dead heart damage (%) (21 DAE) exhibited positive direct effect (1.7784) on dead heart damage (%) (28 DAE). It has positive indirect effect on deadheart damage (%) (28 DAE) through character oviposition (%) (14 DAE) (1.0163), seedling vigour score (0.2832) and negative indirect effect via character's oviposition (%) (21 DAE) (-1.5298), glossy score (-0.5088) and trichome density (-0.0506).

4.5. Assessment of genetic variability

An attempt has been made in the present study for assessing the genetic variability and for classifying 101 genotypes for shoot fly resistance in sorghum. Based on seven characters a

set of breeding lines was grouped in to different cluster, following D^2 statistic (using Toucher's scheme) method.

4.5.1. Multivariate analysis using D^2 statistic

D^2 statistic a concept, developed by Mahalanobis (1936) is an important tool to plant breeder. It is useful in quantifying the degree of divergence between the biological populations at genotypic level and to assess the relative contribution and different components to the total divergence at both intra and inter-cluster levels. Rao (1952) suggested the application of this technique for the assessment of genetic diversity in plant breeding.

4.5.1.1. Analysis of dispersion

The analysis of dispersion for the mean values is based on Wilk's criterion. The V-statistic value is distributed as (χ^2 = 762.9072) at a large degree of freedom (pqd.f. = 7 x 100 = 700) where, p= number of traits, q=total number of entries-1. The χ^2 value is tested against the tabulated value at desired level for the test of significance of differences. Therefore, pooled differences (aggregate of all genotypes are highly significant justifying there by the need to calculate D^2 values.

The original measurements of plot means were transformed in to standardized uncorrelated method as described by Rao (1952). The D^2 values corresponding to all possible pairs of combination were computed using uncorrelated means. The D^2 value corresponding to the pairs of combination between the genotypes, studies ranged between 0.384 and 140.26. The lowest D^2 value (0.384) was between the genotypes 6913B and AKR-354, while the highest D^2 values (140.26) was between the genotypes ICSV-25039 and 6938B.

As there were 101 breeding lines the presentation of all the D^2 values here in the matrix format is difficult. All except little the D^2 combination were found to be greater than the tabulated χ^2 values at 7 p.d.f. at 5 per cent (14.06) and 1 per cent (18.47) level of significant.

4.5.1.2. Relative contribution of different shoot fly resistance parameters towards diversity

The relative contribution of different traits towards genetic diversity is shown in Table 4.6. The contribution of parameters number of trichome density (numbers / microscopic field) was found maximum (34.83 %) followed by deadheart damage (%) at 28 DAE (28.63 %), seedling vigour score (10.61%), dead heart damage (%) at 21 DAE (8.43 %), glossy score (7.06 %), oviposition (%)(21 DAE) (5.82 %) and Oviposition (14 DAE) (4.05 %).

4.5.1.3 Clustering the germplasm in to different clusters

Genetic diversity is generally considered as an important criterion for choosing the parents for recombination breeding. Based on 7 shoot fly resistance parameters, the breeding lines were grouped in to different clusters following Mahalanobis D^2 analysis (Toucher's scheme of cluster formation).

4.5.1.3(a) Toucher's scheme of cluster formation

D^2 analysis and clustering of breeding lines has been done according to Toucher's method or described by Rao (1952). The distribution of 101 breeding lines into ten different clusters is presented in Table 4.7. The cluster II has largest with 35 genotypes. The cluster-I included 33 genotypes and cluster-X has17 genotypes, cluster IX included flour genotypes while III, IV, V, VI, VII, VIII included each two genotypes.

Table 4.6. Relative contribution of different characters to diversity (D^2) in sorghum breeding lines

Sr.No.	Characters	Number of times appearing first in ranking	Per cent contribution towards diversity (%)
1	Glossy score (1-5)	384	7.6
2	Seedling vigour (%) (14-16 DAE)	536	10.61
3	Oviposition (%) (14 DAE)	205	4.05
4	Oviposition (%) (21 DAE)	294	5.82
5	No. of trichomes (10x microscopic field)	1759	34.83
6	Dead heart damage (%) (21 DAE)	426	8.43
7	Dead heart damage (%) (28 DAE)	1446	28.63
	Total	**5050**	**100**

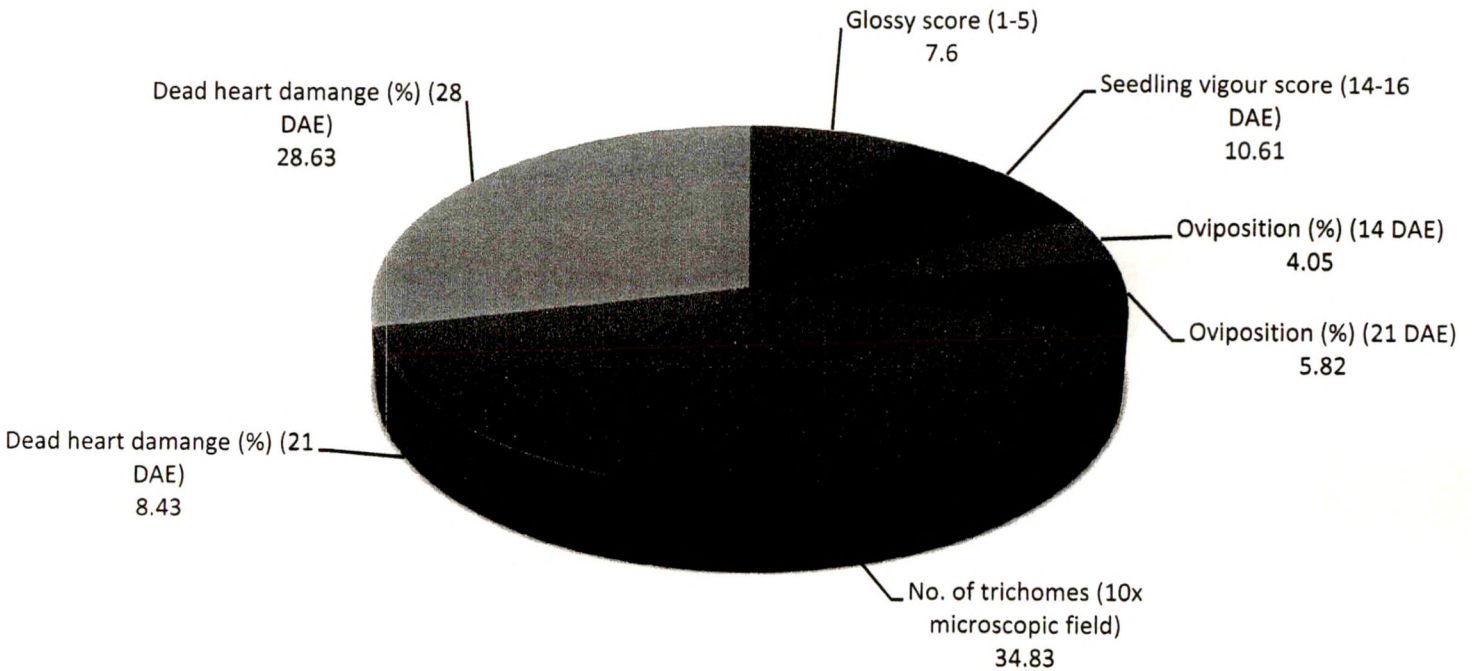


Fig.5. Per cent contribution towards diversity (%)

Table 4.7. Distribution of breeding lines, in to different clusters by Toucher's scheme

Cluster No.	No. of breeding lines included	Breeding lines
I	33	IS-2122, IS-2123, IS-2146, IS-2195, IS-2265, IS-2269, IS-2312, IS-3962, IS-5470, IS-5480, IS-5490, IS-5571, IS-18366, IS-13674, IS-5622, IS-5519, IS-5613, IS-5604, IS-5566, IS-5538, IS-5511, IS-5484, IS-5088, IS-4646, IS-5076, ICSB-121, ICSB-15, ICSB-17, ICSB-19, ICSB-21, ICSB-23, 6913B, AKR-354
II	35	ICSB-89002, ICSV-700, ICSV-705, ICSV-707, ICSV-713, ICSV-714, ICSV-708, ICSV-711, ICSV-25151,ICSV-25131 ICSV-25117, ICSV-250, ICSV-804,ICSV-745,ICSV-93057, ICSV-93046, ICSV-25123, ICSV-1, ICSV-702, ICSV-711, ICSV-25001, ICSV-25003, ICSV-25004, ICSV-25005, ICSV-25006, ICSV-25007, ICSV-25010, ICSV-25041, ICSV-25039, ICSV-25027, ICSV-25026, ICSV-25022, ICSV-25019, ICSV-574, PVK-801
III	2	C-43, KR-192
IV	2	PMJ-28B, KR-201
V	2	KR-199, KR-191
VI	2	M-11, RIL-189
VII	2	305B, 6938B
VIII	2	55301B, 6937B
IX	4	ICSV-25018, 1002B, RIL-252, RIL-174
X	17	29B, 6924B, 8B, 296B, 7B, 452B, DMS-29B, 20B, 9B, 91011R, KR-196, RIL-153, RIL-166, RIL-97, RIL-168, RIL-222 , IS-18551

Table 4.8 Cluster means in Toucher's scheme

Cluster	Character						
	Glossy score (1-5)	Seedling vigour score (1-5) (DAE)	Oviposition (%) (14 DAE)	Oviposition (%) (21 DAE)	No. of trichomes (10x field)	Dead heart damange % (21 DAE)	Dead heart damage % (28 DAE)
I	2.36	2.02	73.35	79.49	102.31	60.21	77.84
II	2.72	2.09	69.40	77.51	95.65	56.90	71.62
III	3.75	1.37	88.84	87.01	0.00	78.61	84.76
IV	5.00	3.37	77.54	95.18	0.33	79.35	95.54
V	3.87	1.75	84.42	87.00	0.00	82.38	86.87
VI	3.37	1.50	87.18	93.87	0.08	79.86	88.25
VII	4.50	4.25	92.46	94.04	0.00	90.07	95.23
VIII	5.00	2.62	91.61	96.40	0.00	82.94	96.73
IX	2.37	2.06	75.84	87.44	153.62	72.34	81.53
X	2.76	1.89	69.71	83.71	68.46	62.15	77.98

4.5.2 New cluster centers (mean of 10 clusters)

The performance of cluster mean values for seven characters is presented in Table 4.9. The result of table 4.8 indicates that there were much difference in the cluster mean for almost all characters.

The cluster means for almost all characters were highest in cluster VII closely followed by cluster VIII. The cluster means found highest in cluster IX (153.62) for character trichome density. Trichome density shown variable means among all characters.

4.5.2.1 Glossy score

For this character mean was highest in cluster IV and VIII (5) Indicating undesirable glossiness followed by cluster VII (4.50) and cluster-I has lowered mean (2.36), followed cluster-IX (2.37), cluster-II (2.72) indicating desirable glossiness.

4.5.2.2 Seedling vigour score

For this character genotypes of cluster VII recorded mean (4.25) and cluster III recorded minimum mean (1.37) indicating desirable seedling vigour.

4.5.2.3 Oviposition (%) (14 and 21 DAE)

For this character, the genotype for cluster-II recorded lowest mean (60.4 and 77.51 respectively) indicating lower plants with eggs. Cluster-VIII has highest (91.61 and 96.40) mean indicating highest plant with eggs. Cluster VII also has near about equal mean of cluster VIII (92.46 and 94.04 respectively) closely followed by cluster VI (87.18 and 93.87, respectively.

Table 4.9. Inter and intra cluster distance and D^2 values

Clusters	I	II	III	IV	V	VI	VII	VIII	IX	X
I	4.79 (22.96)	5.01 (25.16)	5.1 (26.02)	6.88 (47.43)	5.04 (25.47)	4.88 (23.85)	7.66 (58.81)	6.32 (39.96)	5.1 (26.01)	5.07 (25.73)
II		5.15 (26.55)	4.99 (24.90)	6.54 (42.88)	4.9 (24.10)	4.91 (24.13)	6.89 (47.47)	6.02 (36.34)	5.52 (30.50)	5.16 (26.65)
III			1.1 (1.23)	5.28 (27.97)	1.46 (2.15)	1.63 (2.68)	6.89 (47.47)	3.78 (14.29)	5.93 (35.20)	4.6 (21.22)
IV				1.22 (1.50)	4.38 (19.24)	5.37 (28.84)	3.28 (10.81)	2.46 (6.05)	7.48 (55.90)	6.41 (41.18)
V					1.24 (1.53)	1.92 (3.70)	5.95 (35.41)	319 (10.23)	3.77 (33.29)	4.54 (20.67)
VI						1.79 (3.21)	6.87 (47.30)	4.12 (17.00)	5.63 (31.72)	4.36 (19.07)
VII							1.94 (3.80)	4.43 (19.70)	7.95 (63.32)	7.61 (57.93)
VIII								1.95 (3.83)	6.99 (48.96)	5.85 (34.31)
IX									5.48 (30.03)	5.63 (31.76)
X										5.14 (26.45)

(Figures in parentheses indicates D^2 value)

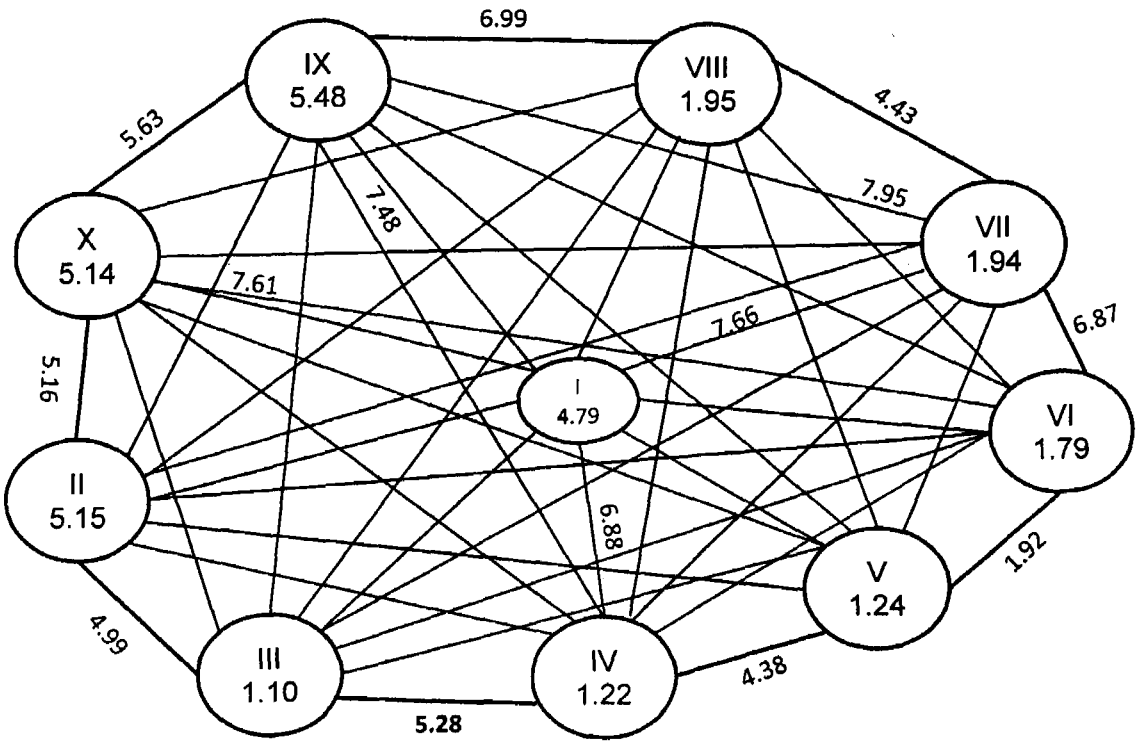


Fig.6. Intra and inter cluster distance (not to the scale)

4.5.2.4 Number of trichomes

Number of trichomes show highest mean value in cluster IX (153.62), followed by cluster –I (102.31), cluster-II (95.65). While cluster-III, V, VII, VIII recorded mean zero (0) cluster IV and VI recorded lowest mean (0.33 and 0.08 respectively). Indicating that genotypes accommodated in cluster III, IV, V, VI, VII, VIII were susceptible to shoot fly.

4.5.2.5 Dead heart damage (%) (21 and 28 DAE)

For the characters dead heart (%) at (21 & 28 DAE) the genotypes from cluster-II recorded lowest mean (56.90 and 71.62 respectively) indicating lower dead heart damage percentage cluster -VIII shown highest mean value (82.94 and 96.73 respectively) followed by cluster-VII (90.07 and 94.23 respectively).

Cluster-I had shown the better performance for all components characters including high glossy score, high seedling vigour score, less Oviposition (%), high number of trichomes, less dead heart formation.

Cluster-II recorded best performance for all character among the all cluster which recorded least mean for oviposition (%) (14 DAE), oviposition (%) (21 DAE), dead heart damage (%) (21 DAE), dead heart damage (%) (28 DAE) and better mean for trichome density also recorded better.

4.5.3 The inter and intra cluster values

The intra and inter cluster values were worked out using D^2 values from D^2 statistical analysis. On the basis of these distances, the variations in clusters were studied (Table 4.9).

The intra cluster distance was found maximum for cluster-IX (5.48) closely followed by cluster-X (5.14), cluster-II (5.15), cluster-I (4.79). The maximum, inter cluster distance was found between cluster-IV and cluster- IX closely followed by cluster-VII and IX, cluster- III and VII, cluster- VII and X. The minimum intra cluster distance found in cluster III (1.10) closely followed by cluster-IV (1.22), V (1.24), VI (1.79).

DISCUSSION

CHAPTER-V

DISCUSSION

Variability in the population, especially in respect of the characters in which improvement is sought for, is indispensable pre-requisite for successful plant selection. The genotypes under study were therefore, firstly examined to assess the variability present among different genotypes in respect of number of metrical traits. The correlation and path analysis provides information on genetic association of deadheart damage and other parameters, which in turn are useful in developing breeding strategies and selection criteria.

The genetic diversity which is the basis of plant breeding, is produced due to inherent genetic differences in plant species, it is of major interest to the plant breeders as their object is to isolate diverse genotypes for crop improvement. Several measures of genetic distance have been proposed over the past two decades to suit various objectives in which Mahalanobis's generalized distance (Mahalanobis, 1936 and Rao, 1952) occupied a unique place in plant breeding.

The clustering of germplasm lines into distinct groups or clusters is helpful in identifying the diverse genotypes for their use in hybridization programme. For clustering the large number of breeding lines D^2 statistic analysis method was used.

The present experimental material comprising a set of 101 breeding lines were evaluated to estimate the extent of genetic variability, heritability, genetic advance correlation and path analysis. Further these lines were subjected to D^2 - statistical analysis to group the genotypes based on variation mainly for shoot

fly resistance component. The results of present study are discussed in the following text.

Genetic variability for shoot fly resistance exists in sorghum germplasm. Many of the germplasm sources for resistance to this pest have poor agronomic features and sources with high level of resistance are not available in cultivated sorghum. The relation of resistant genotypes by utilizing one or few resistance parameters is efficient because several components are involved in resistance and one or more genes govern each of these components of resistance. Expression of many of these components are influenced by environmental factors. Shoot fly resistance is a polygenetic trait and show large genotype environment interaction.

5.1. Glossiness

The intensity of glossiness of leaves at seedling stage is positively associated with resistance to shoot fly (Sharma and Nwanze, 1997). Glossiness of leaves may possibly affect the quality of light reflected from leaves and influence the orientation of shoot flies towards their host plant. Expression of glossiness in seedling is an important trait for identifying shoot fly resistance in sorghum and it is easily identifiable. Agrawal and Abraham (1985) reported that glossiness is highly correlated with shoot fly resistance.

Most of glossy lines show that presence of trichomes (Maiti *et al.*, 1980). In present investigation, nine genotypes namely, IS-5470, IS-5604, ICSV-713, ICSV-702, ICSV-25003, ICSV-25005, ICSV-25039, ICSV-250027 and IS-18551 recorded highly desirable glossy score, which is comparable with resistant check IS-18551 (Table 5.1). However, these genotypes are showing shoot fly damage in the category of less susceptible.

Table 5.1. Desirable breeding lines for shoot fly resistance

Sr. No.	Genotypes	Glossy score (1-5)	Seedling vigour score (1-5) (DAE)	per cent plant with eggs (14 DAE)	Per cent plant with eggs (21 DAE)	No. of trichomes (10x field)	Dead heart damange % (21 DAE)	Dead heart damage % (28 DAE)
1	IS-5470	1.00	1.50	52.47	63.31	104.00	30.18	58.05
2	IS-5604	1.00	1.25	64.09	60.06	117.83	27.86	51.13
3	IS-5566	2.50	1.25	49.12	62.72	127.16	38.16	54.39
4	IS-5511	1.50	1.25	68.12	78.80	194.33	57.52	76.54
5	IS-5076	2.00	1.75	79.22	65.37	188.00	41.88	65.15
6	ICSV-713	1.00	1.25	70.99	74.60	208.66	32.22	53.07
7	ICSV-25123	1.75	1.75	65.73	58.53	135.83	30.59	55.73
8	ICSV-702	1.00	1.75	63.97	73.29	66.50	50.31	54.65
9	ICSV-711	2.75	1.50	83.48	74.45	191.83	50.76	71.95
10	ICSV-25003	1.00	1.00	58.86	57.02	107.16	28.27	48.53
11	ICSV-25005	1.00	1.00	64.62	70.47	157.00	43.27	51.46
12	ISCV-25039	1.00	1.00	45.24	45.23	216.33	21.43	40.48
13	ICSV-25027	1.00	1.50	51.60	51.94	60.16	34.55	45.88
14	6924B	1.50	1.50	60.85	89.47	105.33	50.33	75.87
15	452B	2.25	1.75	74.09	89.18	110.50	51.00	61.00
16	RIL-97	2.50	1.25	50.91	66.82	84.00	43.18	61.36
17	IS-18551	1.00	1.00	52.08	56.63	147.00	45.83	50.00

Outstanding lines for shootfly resistance characters

Glossiness	IS-5470, IS-5604, ICSV-713, ICSV-702, ICSV-25003, ICSV-25005, ICSV-250039, ICSV-250027.
Seedling vigour	ICSV-25003, ICSV-25005, ICSV-250039
Oviposition %	IS-5470, IS-5566, ICSV-25039, ICSV-25027, RIL-97
Trichome density	IS-5511, IS-5076, ICSV-713, ICSV-711, ICSV-25005, ICSV-250039
Dead heart %	IS-5604, IS-5566, ICSV-713, ICSV-25123, ICSV-702, ICSV-25003, ICSV-25005, ICSV-250039, ICSV-25027

*- Common lines for all characters - ICSV-250039, ICSV-25005

5.2. Seedling vigour

Rapid growth of seedling may retard the first instar larvae from reaching the growth tip. In contrast slow growth due to poor seedling vigour, low fertility or environmental stress increases shoot fly damage (Taneja and Leuschner, 1985). Shoot fly resistant lines have rapid initial plant growth, greater seedling height and hardness. The relationship between vigour of the plant and its escape from fly attack was also reported by (Karanjkar *et al.*, 1992). Faster growing plant remain in the favourable height (Succeptible stage) for a relatively shorter period than the slower growing susceptible plants. In the present study four genotype viz. ICSV-25003, ICSV-25005, ICSV-25039, IS-18551 recorded desirable seedling vigour score which was comparable with resistant parent IS-18551. Sixteen genotype (Table 5.1) exhibited less shoot fly damage coupled with high seedling vigour, these result indicates that seedling vigour is one of the major component responsible for complex trait like shoot fly resistance.

5.3 Non - preference for oviposition

Ovipositional non preference by shoot fly in resistant cultivars is considered as primary mechanism for shoot fly resistance (Jotwani *et al.*, 1971 and Sharma and Rana, 1983). The ovipositional non preference is mainly observe under multi-choice condition. But under no choice condition in the field, it has tendency to be less effective so that the resistant and susceptible varieties are equally damaged. The efficiency of this mechanism in not stable and break down under no choice condition or under heavy shoot fly pressure in the field (Singh and Jotwani, 1980 and Borikar and Chopde 1982a).

Inheritance of ovipositional non preference has been recorded as additive however, both additive *and non* additive components of heritable variation core important for the triat, egg/plant (Borikar and Chopade, 1982). Although some amount of non additive gene action is involved, the trait is predominatly under the control of additive gene action for shoot fly resistance (Rao *et al.*, 1974 and Borikar and Chopade, 1982b).

In the present study six genotype namely IS-5470, IS-5566, ICSV-25039, ICSV-25027, ICSV-25003, RIL-97, IS-5604, IS-18551 have comparatively less egg laying by shoot flies. These genotypes have also indicated desirable seedling vigour and glossiness.

5.4 Trichomes density (Nos./microscopic field)

The association between trichomes and shoot fly resistance has been reported by many workers. Trichomes on sorghum leaves are non glandular hair that is microscopic in size, approximately 50 µm long (Gibson and Maiti, 1983). Many workers have established the association of prickle hairs (shoot pointed trichomes) present on the leaves and leaf sheaths with shoot fly resistance (Singh *et al.*, 1980).

The importance of trichome on the under surface of leaves has been reported by several workers (Gibson and Maiti, 1983 and Taneja and Leuschner, 1985). Trichomes were major factor, but not only factor involved in resistance, Density of trichomes per unit area of leaf lamina surface is genetically controlled but presence of trichomes probable is more important for increasing to shoot fly than intensity (Gibson and Maiti, 1983).

Lines possessing both high trichome and high glossy leaf character are more resistant than lines with only one of these

traits. Presence of trichomes on the lower surface of leaf and unknown antibiotic factors are likely to create hindrance for egg laying by shoot flies (Borikar *et al.*, 1985). In the present study six genotype recorded higher trichomes than resistance check IS-18551 viz. IS-5511, IS-5076, ICSV-713, ICSV-711, ICSV-25005 & ICSV-25039. These genotype also shown less ovipisition coupled with high seedling vigour, high glossiness and less dead heart (%).

Shoot fly damage is recorded in terms of dead heart damage on 21st and 28th days after seedling emergence. Dead heart damage (28 DAE) is final indication of genotype resistance to shoot fly in sorghum. Resistance to shoot fly in quantitatively inherited and polygenically controlled.

Most of 'B' and 'R' lines recorded zero trichome density with high dead heart (%), non glossy score and poor seedling vigour, indicate that high susceptible to shoot fly parameters.

5.5. Deadheart damage

The final indication of shoot fly damage is recorded as deadheart damage (28 DAE). The dead heart damage is more in the genotypes, which are poor seedling vigour, less glossiness and low trichome density coupled with high voiposition. In present investigation 17 genotypes recorded less dead heart percent. Nine genotypes viz. IS-5604, IS-5566, ICSV-713, ICSV-25123, ICSV-702, ICSV-25003, ICSV-25005, ICSV-25039, ICSV-25027 recorded less dead heart damage per cent at par with résistance check IS-18551. Two genotype ICSV-25039 and ICSV-25027 recorded comparable less deadheart damage than resistance check IS-18551.

In present investigation 17 genotypes have indicated less deadheart damage (28 DAE) (less than 75 %). Desirable

seedling vigour, glossy score and high trichome density are associated with the tolerance reaction of these genotypes.

5.6 Correlation between different resistant parameters

There is significant positive correlation of seedling vigour score with glossy score oviposition, dead heart. However, seedling vigour score indicated significant positive correlation with plants with eggs (14 and 21 DAE) and dead heart damage (21 and 28 DAE). Earlier studies by Khurana and Verma (1985) indicated positive correlation between plant height and shoot fly resistance. Faster growing plants remain at favourable height (susceptible stage) for a relatively shorter period than the slower growing susceptible plants. Glossy score indicated significant positive correlation, with trichome density. Agrawal and Abraham (1985) reported that glossiness is highly correlated with shoot fly resistance.

Trichome density indicated significant negatively correlation with plants with eggs (%) (14 and 21 DAE) and deadheart damage (21 and 28 DAE). Trichomes have high correlation with oviposition non preference (Agrawal and Abraham, 1985). Deadheart damage indicated significant positive correlation with oviposition and negative correlation with trichome density.

5.7 D^2 statistical analysis

The concept of genetic distance is very important while differentiating a well defined population. The importance of genetic variability in the crop improvement has been stressed in the past years by several workers. In order to assess the degree of variability and diversity in the breeding lines and set 101 genotypes were evaluated and D^2 statistics analysis developed by Mahalanobis's (1936) was carried out. The results indicated that present of

substantial genetic variability among the breeding lines and further on this basis, the genotypes were grouped in to 10 clusters. The practical significant of grouping the genotypes in to different clusters and computing statistical distance between them are discussed here.

5.7.1 Analysis of dispersion

The analysis of dispersion for the mean values based on Wilk's criterion showed highly significant (χ^2 = 3000.413 for 700 d.f.) value at large degrees of freedom. Also the significance of 'V' statistic indicates that the differences between the mean in respect of pooled effect of all the characters between different genotypes are significant. This suggests the necessity of calculating D^2.

The analysis for estimating the contributing of different characters towards genetic diversity (Table 4.6) indicated that seedling vigour score (10.61 %),oviposition (%) (21 DAE) (5.82 %), deadheart damage (28 DAE) (28.63%), number of trichomes (34.83%), contributed maximum to the total genetic divergence in this set of genotypes. These characters accounted for more than 75 per cent of the total divergence in the breeding material. It is clear from the results (Table 4.6) that all characters have contributed more or less similar towards the genetic diversity. The reason probably may be strong correlation between the shoot fly resistance parameters. This study in agreement with Biradar *et al.* (1996b) studied a representative group of 67 maintain lines of sorghum using Mahalanobis D2 statistic for grain yield and yield components. The 67 genotypes were grouped in to 20 clusters. Contribution of different characters towards genetic diversity was analysed. These were no indications of relationship between geographical diversity and genetic diversity.

5.7.2 Average D^2 values and their interpretation and implication

As the statistical distance represents the index a genetic diversity among clusters. The crosses should be attempted from widely separated clusters.

According to Bhatta (1970), the mean (D^2) statistical distance may be considered arbitrarily as a guideline and selection parents & crosses belonging to different clusters having same and higher inter cluster distance than the mean statistical distance may attempted. In the present study the range of D^2 value varies from 0.384 (between 6913B and AKR-354) to 140.26 (between ICSV-25039 and 6938B). This range of D^2 values indicate high degree of divergence among 101 genotypes. The total 101 genotypes were grouped in to 10 clusters (Table 4.7). The high degree of divergence present in between cluster I, II, IX & X. indicating possibility to develop shoot fly resistance genotypes. and hybrids.

5.7.3 Clustering of germplasm lines

The grouping of genotypes into various clusters was carried out following Toucher's scheme. All the germplasm lines were classified in to 10 clusters (Table 4.6). Cluster II comprised 35 genotypes closely followed by cluster I (33) and cluster X (17). Joshi and Vashi (1992) classified 89 sorghum genotypes including 70 hybrids. These genotypes were classified using D2 statistics and grouped in to nine clusters.

5.7.4 Cluster means

Cluster I consists of genotypes with the desirable mean of all characters indicating high glossiness, high vigour, less plants with eggs, high trichome density and low deadheart damage.

Cluster II consists of genotypes with desirable means of all characters studied

Cluster X comprises genotypes with moderate means for all characters as compared to other genotypes of I and II clusters and are having moderate reaction to shoot fly. Comparison of cluster means revealed that genotypes of cluster II gave desirable mean values of all characters closely followed by cluster X, I and IX.. Therefore, the genotypes from cluster II, I. IX & X can be involved in hybridization programme to get recombinants with desirable values for all the traits under study.

5.7.5 Inter and intra-cluster distances

The genotypes grouped together are less divergent than the ones which are placed in different clusters. The clusters which are separated by the greatest statistical distance show the maximum divergence.

The minimum inter-cluster distance between the various clusters suggested that the genetic contribution of the genotypes of all cluster were in the close proximity with those in other cluster of the pair.

The maximum inter-cluster distance was observed between the genotypes of cluster IV and IXI (Table 4.9), Intra cluster distance varied form 1.10 to 5.48 (Table 4.9), maximum being observed in cluster IX which consists of 4 genotypes with more variable..

In this investigation, D^2 statistics gave idea of most diverse parents. Accordingly almost all characters are highly variable in present study but deadheart damage (28 DAE) showed highest variability 6913B and AKR-354 (D2 = 0.384) and ICSV-

25039-6938B (D2 = 140.26) are the most divergent genotypes in the present study.

Genotypes from different clusters having desirable specific level of particular character are suggested for future breeding program.

Cluster I : Thirty three genotypes were grouped in this cluster out of which IS-5470, IS-5604, IS-5566, IS-5511, IS-5076 have desirable combination of shoot fly resistance parameters like high glossiness, high vigour, high trichome density, high non-preference to oviposition and low deadheart damage. These lines are very tolerance to shoot fly & identify resistance source for shoot fly.

Cluster II : Thirty five (35) genotypes were grouped in this cluster out of which ICSV-713, ICSV-745, ICSV-702, ICSV-711, ICSV-25003, ICSV-25005, ICSV-25039 and ICSV-25027 genotypes are desirable for all shoot fly resistance parameters. They are better tolerance to shoot fly coupled with good grain yield . All these lines developed at ICRISAT through sorghum shoot fly resistance breeding programme.

Cluster X : In this cluster 17 genotypes were grouped out of which 6924B, 452B, RIL-97, RIL-52, RIL-153 and IS-18551 desirable to all shoot fly resistance parameters . specially seed parents developed at ICRISAT have better shoot fly tolerance. RIL (recombinant inbreed lines) derived from shoot fly resistance mapping population presently using as donor source in marker assisted breeding programme.

SUMMARY AND CONCLUSION

CHAPTER-VI

SUMMARY

The present experimental material consisted 101 genotypes in which 45 newly developed lines at ICRISAT, 10 selected elite restorer lines developed at Sorghum Research Station, Parbhani. 16 elite seed parents 'B' lines developed at Sorghum Research Station, MAU, Parbhani and 8 selected RIL's currently using as donor sources in marker assisted selection for shoot fly resistance programme.

The result of present study are summarized as under

6.1 Glossiness

Eight genotypes namely IS-5470, IS-5604, ICSV-713, ICSV-702, ICSV-25003, ICSV-25005, ICSV-25039 and ICSV-25027 were recorded desirable glossy score with resistant parent IS-18551. Genotypes ICSV-25039 and ICSV-25027 were showing desirable combination of high seedling vigour, high glossiness coupled with less shoot fly damage than resistance check IS-18551.

6.2 Seedling vigour

In the present study seedling vigour score range from 1 to 4.5 in the genotypes. Four genotypes viz. ICSV-25003, ICSV-25005, ICSV-25039 and IS-18551 recorded desirable seedling vigour score. Genotype ICSV-25039 recorded lowest dead heart damage followed by ICSV-25005 than resistant check IS-18551.

6.3 Oviposition (%)

Six genotypes viz. IS-5470, IS-5566, ICSV-25039, ICSV-25027, RIL-97 recorded less preference for oviposition by shoot fly. Genotypes ICSV-25039, ICSV-25027 recorded less oviposition (%) than resistance check IS-18551.

6.4. Trichomes density (nos. / microscopic field)

Six genotype viz. IS-5511, IS-5076, ICSV-713, ICSV-711, ICSV-25005, ICSV-25039 recorded high trichome density (nos. / microscopic field) than resistance check IS-18551. None of restorer 'R' one recorded trochome numbers. Only four 'B' lines recorded trichomes at lower side of leaves.

6.5 Deadheart damage

The final indication of shoot fly damage is recorded as deadheart damage (28 DAE). The dead heart damage is more in the genotypes, which are poor seedling vigour, less glossiness and low trichome density coupled with high voiposition. In present investigation 17 genotypes recorded less dead heart percent. Nine genotypes viz. IS-5604, IS-5566, ICSV-713, ICSV-25123, ICSV-702, ICSV-25003, ICSV-25005, ICSV-25039, ICSV-25027 recorded less dead heart damage per cent at par with résistance check IS-18551. Two genotype ICSV-25039 and ICSV-25027 recorded comparable less deadheart damage than resistance check IS-18551.

6.6 Correlation between different resistance parameter

Glossy score is showing significant negative correlation with oviposition and deadheart damage, seedling vigour are positively correlated with glossy score, ovipostion and deadheart. Trichome density indicating significant negative correlation with dead heart damage and oviposition. However, dead heart damage

indicated significant positive correlation with oviposition and significant negative correlation with trichome density and glossiness.

6.7. D^2 Statistic

D^2 statistical analysis indicated considerable amount of genetic variation among the genotype with D^2 values corresponding to the pairs of combination between 101 genotypes which ranging from 0.384 to 140.26. The maximum D^2 value of 140.26 was observed in pair of lines ICSV-25039 and 6938B.While the lowest 0.384 was noted in pair of genotype 6913B and AKR-354.

All the genotypes were grouped into ten clusters by employing Toucher's scheme as described by Rao (1952), cluster-II has maximum (35) number of genotype followed by cluster-I (33), X (17), IX (4).

Among the characters studied seedling vigour score (10.61 %) deadheart damage (%) (28 DAE) (28.63 %) recorded high contribution towards diversity. Maximum contribution towards diversity recorded 34.83 per cent by trichome density (nos. / microscopic field).

On the basis of cluster means and inter cluster divergence, the desired genotypes were suggested for tentative breeding programme.

Cluster I : IS-5470, IS-5604, IS-5566, IS-5511, IS-5076

Cluster II :ICSV-713, ICSV-745, ICSV-702, ICSV-711, ICSV-25003, ICSV-25005, ICSV-25039 and ICSV-25027

Cluster X : 6924B, 452B, RIL-97 and IS-18551

Thus if the crosses were attempted from widely diverse clusters, they would throw desired recombination showing good shoot fly coupled with high level of shoot fly resistance.

In present research project, the most important and valuable observation is the worth and utility of genotype ICSV-25005, ISCSV-713, ICSV-5511 for shoot fly resistance breeding programme to ultimately our aim to develop shoot fly resistance cultivars.

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LITERATURE CITED

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