CROP LOSS ESTIMATION AND MANAGEMENT OF SHOOT BUG, *Peregrinus maidis* (Ashmead) IN *RABI* SORGHUM

RAJU ANAJI

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

AUGUST, 2005

CROP LOSS ESTIMATION AND MANAGEMENT OF SHOOT BUG, *Peregrinus maidis* (Ashmead) IN *RABI* SORGHUM

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

MASTER OF SCIENCE (AGRICULTURE)

in

AGRICULTURAL ENTOMOLOGY

By

RAJU ANAJI

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

AUGUST, 2005
DEPARTMENT OF AGRICULTURAL ENTOMOLOGY
COLLEGE OF AGRICULTURE, DHARWAD

UNIVERSITY OF AGRICULTURAL SCIENCES, DHARWAD

CERTIFICATE

This is to certify that the thesis entitled "**CROP LOSS ESTIMATION AND MANAGEMENT OF SHOOT BUG, *Peregrinus maidis* (Ashmead) IN *RABI* SORGHUM**" submitted by **Mr. RAJU ANAJI** for the degree of **MASTER OF SCIENCE (AGRICULTURE)** in **AGRICULTURAL ENTOMOLOGY**, to the University of Agricultural Sciences, Dharwad, is a record of research work done by him during the period of his study in this University under my guidance and supervision, and the thesis has not formed the basis of the award of any degree, diploma, associateship, fellowship or other similar titles.

DHARWAD

AUGUST, 2005

(R. A. BALIKAI)
Major Advisor

Approved by :

Chairman : ______________________
(R. A. BALIKAI)

Members : 1.______________________
(SHEKARAPPA)

2. ______________________
(B. D. BIRADAR)

3. ______________________
(B. M. CHITTAPUR)

Affectionately Dedicated to

My Beloved Parents

Smt. SHAKUNTALAMMA and Sri. VEERABHADRAPPA

ACKNOWLEDGEMENT

.... Gratitudes are the Memories of Heart"

No scientific endeavour is a result of individual efforts and so comes the time to look back the path which I traversed during this endeavour and to remember the faces and spirits behind the action with due respect. I take this opportunity to acknowledge the persons who inspired me to fulfill the goal.

No words would sustain to express my heartfelt gratitude and reverence to **Dr. R. A. BALIKAI,** *Entomologist, AICSIP & Professor and Head, Department of Agricultural Entomology, College of Agriculture and Regional Agricultural Research Station, Bijapur and Chairman of my advisory committee, for his inspiring guidance, constant, everlasting patience, encouragement, constructive criticism and intellectual suggestions which fueled my efforts to achieve the endeavour. I acknowledge this personality with deep sense of gratitude.*

The unflagging inspiration and insightful critiques and ideas of **Dr. SHEKARAPPA,** *Junior Entomologist AICSIP. Main Agricultural Research Station,* **Dr. B. D. BIRADAR,** *Senior Sorghum Breeder, Regional Agricultural Research Station, Bijapur and* **Dr. B. M. CHITTAPUR,** *Associate Professor, Department of Agronomy, College of Agriculture, Dharwad, University of Agricultural Sciences, Dharwad, members of my advisory committee, who sparked and spiked me top more on the right path in the persuit of this degree. I remain immensely indebted to them.*

I avail this opportunity to express my sincere gratitude and indebtedness to the staff members Dr. J. S. Awaknawar, Professor and Head, Dr. B. S. Nandihalli, Dr. S. A. Virakthamath, Dr. R. S. Giraddi, Dr. H. N. Sattigi, Dr. K. Basavanagoud, Dr. R. K. Patil, Dr. R. H. Patil, Dr. C. P. Mallapur, and all non-teaching staff of Department of Agricultural Entomology.

I lack in words to express my deep sense of gratitude to Dr. Manjunath M., Professor and Head, Department of Agril. Entomology, College of Agriculture, Shimoga, for his sustained encouragement for higher studies.

No words in this mortal world can suffice to express my feelings towards my beloved parents. My way in this world paves through the path carved by my parents ***Shri. Veerabhadrappa*** *and* ***Smt. Shakuntalamma****, whom I wish to idolize throughout my life. My words are inadequate to express my deepest sense of gratitude and profound indebtedness to brother* ***Lingaraj****, and sister* ***Shobha****.*

Words won't sustain my feelings for the intangible encouragement and unfailing companionship of ***B. C. Suresh****, for joining M. Sc. (Agri.) in Entomology.*

I extend my deep sense of gratitude to my friends Vijay, Adarsha, Ganapathi, Mohan, Ravi, Imran, Ashoka, Sai, Ramesh, Shashi, NOP, Ratikanth, Manja, Shivanand, Seema, Raji, Poovi, Uma, Roohi, Shobha, Kiran, Megeri, Girish, Sandesh, Swamy, Ujji, Veerendra and Satti.

My diction do not seem to be rich enough to translate gratitude into words, the timely help extended by my seniors, colleagues and juniors, without which I would not had this much of ease in completing this task under taken.

Finally I must acknowledge Nadaf, Arjun and Kalmesh (Arjun Computers), for recording this manuscript in the form of thesis. I also acknowledge Kumbar Binders, Dharwad for their timely service.

Any omission in this brief acknowledgement does not indicate lack of gratitude.

DHARWAD

AUGUST, 2005 **(RAJU ANAJI)**

CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

LIST OF APPENDICES

I. INTRODUCTION

Sorghum [*Sorghum bicolor* (L.) Moench] is one of the important cereal crops of the world. Sorghum ranks fourth among the world cereals in the order of wheat, maize and rice. It is the major source of food and fodder for millions of people in tropics and semi-arid tropics. The stem and foliage are used as green fodder, hay silage and pasture apart from using as fuel and building material. Sweet sorghum is used in the preparation of jaggery, syrup, ethanol (vehical fuel) and biscuits. Beer is prepared from sweet sorghum in many parts of Africa. Besides theses products, popped and sweet sorghum are also very popular all over the world (House, 1980).

Sorghum is widely grown in the world with an area of 42.07 million hectares with an annual production of 58.50 million tonnes. India is the largest sorghum growing country in the world with an area, production and productivity of 9.69 million hectares, 7.0 million tonnes and 733 kg per hectare, respectively (Anon., 2004). In India, sorghum ranks third in area and production after rice and wheat (Hosamani and Chittapur, 1997), grown in the states like Maharashtra, Karnataka, Tamil Nadu, Andhra Pradesh, Madhya Pradesh, Rajasthan and Gujarat. The crop is grown in all the three seasons either under irrigated or rainfed conditions.

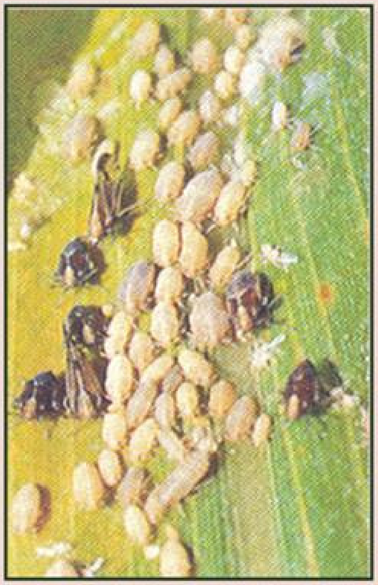
Karnataka is one of the leading states in sorghum cultivation after Maharashtra with an area of 18.91 lakh hectares and production of 12.38 lakh tonnes of grain (Anon., 2004). In the state, sorghum is grown both in monsoon and post-monsoon seasons. Pre-monsoon crop area in the state accounts to 3.90 lakh hectares with 5.16 lakh tonnes production. During post-monsoon season, the total area under sorghum is 15.01 lakh hectares with a production of 7.22 lakh tonnes. Nearly, 65 per cent of the total area in the state is covered by sorghum during *rabi* season, which accounts for44 per cent of the total sorghum production. The cultivation of sorghum is concentrated more in northern districts of Karnataka *viz.,* Bijapur, Bagalkot, Gulbarga, Dharwad, Gadag, Haveri, Raichur, Koppal, and Bellary.

The demand for sorghum as a staple food has been growing in recent years (Anon., 1996). Though, sorghum is known for its versatile use, hardiness dependability, stability of yield and adaptability over a wide range of cultures and climates, the adverse edopo climatic conditions, pests and diseases prevailing in sorghum growing areas of the world limit the crop production (Swindle, 1980).

Sorghum is vulnerable to over 150 insect species from sowing to the final crop harvest (Sharma, 1985). Among the different insect pests of sorghum the shoot bug, *Peregrinus maidis* (Ashmead) (Homoptera : Delphacidae) previously considered to be of minor importance, but now with the introduction of new sorghum genotypes of different maturity periods in certain parts of Maharashtra, Andhra Pradesh, Karnataka and Tamil Nadu has become a serious pest. According to Hosamani and Chittapur (1997), shoot bug can cause a crop loss to an extent of 41 per cent.

Both macropterous and brachypterous nymphs and adults suck the sap from the leaves by congregation in the plant whorl and inner sides of the leaf sheath. Severe attack of shoot bug results in leaf chlorosis, stunted growth, shriveled and chaffy grains (Prabhakar *et al*., 1981). The top leaves start drying first, but leaf death gradually extends to older leaves and some times, death of the whole plant occurs (Teetes *et al*. 1983). Severe infestation at boot leaf stage results in twisting of top leaves thus preventing the emergence of panicles (Agarwal *et al*., 1978). Further, the honey dew excreted by nymphs and adults favours the growth of sooty mould fungus (*Capnodium* sp.) which inhibits the photosynthetic activity. It was also reported as a vector of sorghum stripe disease (SStD) and the other hosts of shoot bug include maize, bajra, sugarcane, ragi and other grasses (Peterschmitt *et al*., 1991) (Plate 1).

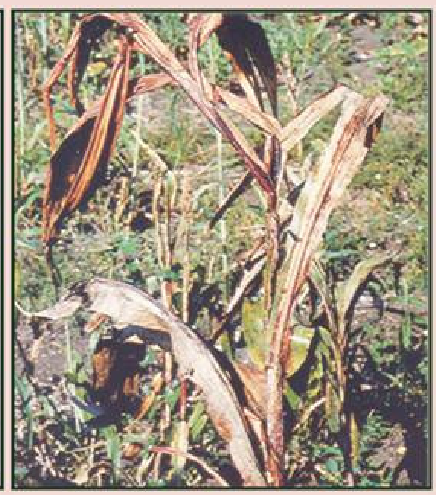
In recent years, pest problems have tremendously changed due to several factors and cause enormous economic losses in grain yields. Insect pests affect the quality and productivity of newly developed genotypes (Prem Kishore, 1990 and 1996). However, insecticidal hazards to many targeted and non-targeted species, disturbance in crop ecosystem led scientists to find out newer, safer, cost effective alternatives as components of integrated pest management (Pawar and Kadam, 1995). In this context and due to the fact that insecticides are inevitable components of IPM, research on loss estimation, screening for resistance and management of pest was envisaged in *rabi* sorghum during 2004-05 at the Regional Agricultural Research Station, Bijapur, Karnataka with the following objectives.



a) Shoot bug colony

b) Shoot bug adult

c) Sorghum stripe disease



d) Severely affected plant

Plate 1: Sorghum Shoot bug, *Peregrinus maidis* and its damage

1. To estimate and quantify extent of loss due to *P. maidis*
2. To evaluate *rabi* sorghum genotypes for resistance against shoot bug and
3. Management of *P. maidis* through seed dressers

II. REVIEW OF LITERATURE

The review of literature with respect to alternative hosts, loss estimation, screening of sorghum genotypes against shoot bug, virus vector relationship and management of sorghum shoot bug, *P. maidis* is presented below.

2.1 TAXONOMY AND SYNONYMY

The shoot bug, *P. maidis* was first reported as *Delphax maidis* by Ashmead (1890) from USA. Muir (1917) confirmed the identity of *Pundaluoya simplicia* Distant with *Delphax maidis* Ashmead, the latter having the priority. Based on the description and figure, Muir (1917) concluded that the *Delphax psylloides* Leth. was same as *D. maidis.*He examined the specimens from North America, Hawaii, Fiji, Australia, Ambo Riva, Java, the Philippines, Formosa, Malay Peninsula and India. It was also recorded from Ceylon, Seychelles Islands, West Africa, Cuba, Nicarugua and Brazil. Further Kirkaldy's genus *Peregrinus* was recognized and therefore considered the *Peregrinus maidis* (Ashmead) Kirkaldy as the correct synonym.

2.2 HISTORY OF SHOOT BUG (*P. maidis*)

2.2.1 Geographical distribution

The corn planthopper, *P. maidis* is a native of United States of America. It was reported for the first time on maize (Ashmead, 1890). Subsequently, it spread to Jamaica (Ritchie, 1917), the Philippines (Muir, 1917) and Hawaii (Fullaway, 1919) and devastated the maize field and moved towards cotton and cucumber fields in Puerto Rica(Fullaway, 1919). It later migrated towards Trinidad (Williams, 1921) and Florida(Watson, 1939). It was also distributed in maize fields of Mexico, El Salvador, Nicarugua, Panama, Argentina, Brazil, Colombia and Venezuela (Watson, 1939). Then, it spread to most of the countries in Africa *viz.,* Nigeria, Ethiopia, Egypt, Sudan, Morocco, Uganda, Zimbabwe, Zambia and Kenya (Westgate, 1918). Later, it migrated towards the Asian countries and was reported on bajra, sorghum, maize and other grasses (Fletcher, 1914; Lefroy, 1915 and Ayyar, 1940).

2.2.2 Intrusion into India

It is probable that shoot bug has entered into India along with forages (Lefroy, 1909 and 1915). Many workers reported on *Sorghum halepense* (Linn.) Pers., *Setaria italica* (Linn.) Bear, sorghum and maize in south India particularly in Maharashtra, North Karnataka, Andhra Pradesh and Tamil Nadu (Ayyar, 1940).

2.3 HOST RANGE

Shoot bug, *P. maidis* was reported for the first time on maize from America (Ashmead, 1890).In India, it was found on grasses and green plants (Lefroy, 1909 and 1915).Many workers from South India have reported the insect as a pest of sorghum, maize and bajra (Fletcher, 1914; Lefroy, 1915; and Ayyar, 1940). Chelliah and Basheer (1965) reported the incidence of shoot bug on *S. halepense*, S*. italica*, *Echinochloa colona* var. *frumantacea* Linn., *Paspalum scrobiculatum* Linn., and they mentioned that sorghum appeared to be the most favourable host plant and suffered heavily from the damage due to shoot bug.

It was also reported on cocoa from Seychelles Islands (Distant, 1914);on cucumber from Puerto Rica (Jones, 1915); on maize, *Zea mays* Linn. from the Philippines (Muir, 1917), Jamaica (Ritchie, 1917) and Puerto Rica (Cotton, 1919).

Fullaway (1919) from Hawaii recorded infestation on maize and further reported that the bugs in containment oviposit in stem of sugarcane and *Coix lachryma* Jobi, however, the nymphs apparently could not develop on these food plants. The insect was reported on sugarcane from Trinidad also (Williams, 1921) and on beans from Florida (Watson, 1939).

It was also reported on Napier grass, *Pennisetum purpureum* Shum.Bugs feed on it when the maize is too mature for them during June to July as this grass grows throughout the summer (Watson, 1939).Similarly, Tsai (1996) reported on itch grass (*Rottboellia exaltata* (L.)), gamma grass (*Tripsacum dactyloides* (L.)), oats, rye and barn yard grass (*Echinochloa crusgalli* (L.)).Likewise, Remes Lenicov *et al.* (2001) reported on *Cynodon dactylon* (L.)*, Paspalum* spp. *Bromus unioloides*

(Willd.) HBK and *Zea perennis* (Hitche) in Buenos Aires Province, Argentina and they also reported that *C. dactylon* was predominant host for survival and multiplication.

Catindig and Barrion (1995) reported that the bug, *P. maidis* effectively feeds on rice, maize and as many as 56 rice field weeds in Manila, Philippines. Among them *Rottboellia cochinchinensis* (Lour.), *Pannicum maximum* (Jacg) and *Leptochloa chinensis* (L.) recorded more number of eggs whereas, maize and rice recorded higher percentage of hatching and nymphal survivability.

2.4 LOSS ESTIMATION

2.4.1 Direct damage

When the population of *P. maidis* was less, the damage to the crop was not marked. Due to the attack of large number of nymphs and adults, the attacked plant showed an unhealthy yellow appearance combined with stunted growth. The honeydew excreted by the nymphs and adults favoured *Capnodium* sp. fungal growth causing sooty mould (Chelliah and Basheer, 1965).The pest was found to infest up to 12 to 35 per cent sorghum and maize plants at Jabalpur and about 45 to 60 per cent plants in Indore, Madhya Pradesh (Rawat and Sexena, 1967).

Delphacid is the main pest of *rabi* sorghum and reported to cause 30 per cent of loss in grain yield.The leaf sugary exudation (chikta), a serious menace to the cultivation of *rabi* sorghum in Maharashtra state was produced due to injury by delphacid under certain climatic conditions (Naik, 1965 and Mote *et al*., 1985).

Yield losses of sorghum due to the delphacid, *P. maidis* were estimated in Karnataka, India, during 1982-83.Three methods were used: caging plants with white nylon bags; mechanical removal of *P. maidis* and application of carbofuran 3G.Yield increases of 46.27, 37.24 and 47.86 per cent were recorded for these treatments, respectively in comparison to an untreated control, thus recording 25.46, 28.11 and 41.61 per cent loss in grain yield.Yield loss due to artificial infestation with 5, 10, 15, 20 and 25 first instar nymphs were also studied in a greenhouse. There were no significant differences between the height of un-infested plants and plants infested with 5 nymphs (112.50 and 101.25 cm, respectively) but with release of 10, 15, 20 and 25 first instar nymphs per plant, the height of plants were reduced (96.25, 83.25, 68.25 and 30.50 cm, respectively). The grain weight of un-infested plants was more (43.25 g) than those of infested plants (34.96, 18.08, 14.72, 12.74 and 3.93 g for plants with 5, 10, 15, 20 and 25 first instar nymphs, respectively) (Shivamurthappa *et al*., 1989).

Borade *et al.* (1993) conducted field experiments in Maharashtra during 1986 to investigate the effects of sowing date on leaf sugary malady on *rabi* sorghum. The crop was sown at weekly intervals from the last week of September until the 2nd week of November. Heavy infestation of *P. maidis* was observed on earlier sown sorghum, with a maximum on the crop sown in the 2nd week of October. Leaf sugary exudate began earlier on late sown sorghum. The least percentage of infected leaves (15.3%) was on the sorghum sown in the last week of September. It was concluded that *rabi* sorghum should be sown in the last week of September to minimize leaf sugary malady.

The grain loss and economic injury level were determined for *P. maidis* on sorghum in Andhra Pradesh, India, during September-October 1988-89.In both months, the correlation coefficient between incidence and grain yield was negative and significant.In September, when 15 nymphs fed throughout the crop period, 7.8 per cent loss was recorded, which increased to 74.8 per cent for 40 nymphs.In October, an avoidable loss of 14.1per cent was recorded with 15 nymphs which increased to 71.7 per cent for40 nymphs.Three insecticidal sprays were required to keep the crop completely free from *P. maidis*, with a cost of Rs. 457/ha.On the basis of the cost of sorghum grain and fodder being Rs 200 and Rs 40/quintal, respectively, the economic injury level was calculated to be 3.70 nymphs/plant (Raja sekhar, 1996).According to Hosamani and Chittapur (1997) the shoot bug on sorghum can cause loss to the extent of 41 per cent in grain yield.

2.4.2 As vector

The delphacid, *P. maidis* is a serious sap feeder, and it is the only known vector of maize stripe virus (MStV), sorghum stripe virus (SStV) and maize mosaic virus (MMV) of tropical and sub-tropical areas. Among them, MMV cause dwarf diseases and MStV and SStV cause leaf stripe or streak disease in maize and sorghum (Naidu *et al*., 1989). However, SStV is an isolate of MStV and it is transmitted in a persistent, propagative manner by the delphacid planthopper, *P. maidis* (Tsai and Zitter, 1982; Zitter, 1982; Gingery, 1988 and Nault and Ammar, 1989).

A disease characterized by chlorotic stripes and bands, named sorghum stripe disease (SStD), was observed on sorghum in India with an incidence of less than 0.5 per cent to nearly 10 per cent. The affected plants were dwarfed and had poor or no panicle formation. This disease could be transmitted by the delphacid planthopper, *P. maidis* to sorghum (Peterschmitt *et al*. 1991).The sorghum stripe disease (SStD) was severe in India particularly in South India, with presence of continuous chlorotic stripes and bands along the veins. The symptoms initially consisted of stippling and overlapping circles aligned in rows parallel to the veins progressing from the base towards the tip of the leaves in early stage.In advanced stage, the stippling/circles coalesce to form clear stripes. The leaves, which emerged later, were completely devoid of chlorophyll. The affected plants in early stage started with short internodes and produced poor panicle with few grains.The SStD infected plants, at advanced stages of crop growth, showed characteristic apical bending of ear head with short peduncle, compared to healthy sorghum plants (Narayana and Muniyappa, 1995a).

Even though, the disease was characterized by discontinuous chlorotic streaks between the veins, stunted growth and severe yield loss were reported on sorghum in India by several workers (Capoor *et al.*, 1968; Cherian and Kylasam, 1937 and Mali and Bhagawat, 1975). The causal agents of this disease were first time reported as rhabdo viruses by Naidu *et al.* (1989) in Peninsular India.Later, transmission efficiency, evaluation techniques, purification and characterization was made by Ammar *et al.* (1995) and Narayana and Muniyappa (1996).

Chao *et al.* (1988) reported that 21 per cent of *P. maidis* were active transmitters and transovarial transmission was detected in 34 per cent of the offsprings of viruliferous female and the causal agent transmitted a virus 15.7 days after hatching and the insect remained infective until death. Similarly, Jyothi *et al.* (1995) reported that nymphs were found to be efficient transmitters of virus (30%) than adults (13.3%) and between both forms macropterous forms were more efficient vectors (33.3%) than the brachypterous ones (23%). In both the cases the females showed a higher rate of transmission.

With respect to disease incidence, Naidu *et al.* (1989) reported SStD during November to April. Narayana and Muniyappa (1995b) reported 13.5 per cent SStD in Karnataka. Similarly, Garud *et al.* (2000) reported 9 to 21 per cent incidence during *rabi* season in Maharashtra. This disease was also reported in severe form in Mexico (70%) on maize (Rocha-Pena *et al*., 1984), in Africa (Reynaud *et al*., 1987) and Taiwan, Asia (Yang, 1990).

Tsai (1996) reported that the virus was found in severe form on itch grass, grass (*E. crusgalli*), maize and sorghum. Sdoodee *et al.* (1997) reported that 200 genotypes of sorghum were susceptible to the disease.Similarly, Remes Lenicov *et al.* (2001) reported the disease incidence on maize, sorghum, *C. dactylon*, *Paspalum* spp. and *B. unioloides* in Buenos Aires, Argentina.Further, they also reported that increase in population of*P. maidis* led to the increase in disease incidence.

2.5 SCREENING OF SORGHUM GENOTYPES AGAINST SHOOT BUG

Chavan *et al.* (1959) screened about 254 Indian and 106 exotic sorghum types to the leaf sugary disease in order to get the resistant breeding material.But, none of the types screened were found to be free from the malady. It was observed that M 35-1, a resistant variety in *rabi* tracts of Karnataka suffered to the tune of 32.26 per cent, whereas the incidence on GJ-960 (Guntur Madras) was highest (76.92%) and was lowest on honey sorghum (6.45%).

Subbarao and Lakshminarayana (1975) studied the relative susceptibility of66 sorghum lines in an advanced yield trial to major pests including shoot bug at Rajendranagar, Hyderabad. The results revealed that varieties 148, SPH-4, CSH-1, 604, 3660A × IS 84, 22E, 269, SB-1066, 171, 36A × 148 and 168 showed the least damage (below 25%) by shoot bug while varieties CS-3541, 746, 563, 914, SB-411 and 141 were severely affected.Like-wise Agarwal *et al.* (1978) reported that resistant varieties of sorghum *viz*., I753, H 109, GIB, 3677B and BP-53 had leaves that were very tightly wrapped around the stem while susceptible varieties had more loosely attached leaves.

Mote and Shahane (1993) screened 78 sorghum varieties in field condition for their reaction to delphacids, aphid and leaf sugary exudates (LSE) and reported the varieties IS-105, IS-192, IS-716, IS-656-177, IS-1122-226, IS-2117, IS-2291,IS-2932-118, IS-3021, IS-2572-A, IS-3804, IS-4482, IS-6446, IS-7441, BTP-28,PVT-1-1-2, M 35-1, IC/CI-7,IC/CI-15, ICSV-148, ICSV-151, ICSCTV-2 and ICSCTV-12 as free from LSE at 53 days crop growth stage when LSE ranged from 1.0 to 1.9.At 61 days crop growth stage, the LSE grade ranged from 1.0 to 3.3. The varieties *viz.,* IS-1063, IS-6446, IS-8893, SPV-504, ICSV-150 and ICSCTV-12 were free from LSE. The varieties IS-105, IS-2228, IS-

3582, IS-3801, IS-3962, IS-5242, IS-9838 and M 35-1 were observed to be highly susceptible to LSE by recording more than 2 grade of LSE.The entries IS-105, IS-1056, IS-1122-226, IS-1122-228, IS-2228, IS-2294, IS-2391, IS-2932-93,IS-3021, IS-4495, IS-5755, IS-9338, CSH-8R and ICSV-151 were observed to be highly susceptible to LSE by recording more than 3.0 LSE grade.The varieties IS 9338 and SPV 86 were highly susceptible to LSE and showed higher LSE grades of 4.3 and 4.0, respectively.The variety IS 2587 was found to be least susceptible to delphacids. The variety, IS 2932-118 was totally free from LSE while IS 2288 was highly susceptible.In general, IS 1840, BTP-28, ICSCTV-9, ICSV-148 and SPV 504 were promising against delphacids, aphid and LSE. The intensity of LSE was found to be increased with the increase in the population of delphacids.

Mote and Shahane (1994) conducted investigations on cultivar reaction to delphacid (*P. maidis*), aphid (*Melanaphis sacchari* (Zehntner)) and leaf sugary exudation (LSE) to determine the important cultivar morphological characters and biochemical constituents associated with resistance. The results revealed that (a) Sorghum cultivarIS-2587 was found to be the least susceptible to delphacid, (0.2 delphacid/plant). The highly susceptible cultivar IS-2288 harbored 5.2 delphacids/plant. (b) IS-2932-118 was totally free from LSE.LSE grades for IS 4482, BTP-28, and IC/CI-7 were lower (1.4) than those found in highly susceptible cultivars *viz.*, IS Nos. 105, 1056, 1122-226, 1122-228, 2228, 2291, 2391, 2932-93, 3021, 4495, 5755, 9338, CSH-8R and ICSC-151 (3.0) (c). The intensity of LSE was found to increase with the population of delphacid.Moreover, such intensity was higher at 61 days crop growth stage as compared to 51 days. (d) The development of the insect population and LSE were more pronounced in cultivars having higher nitrogen, sugar and total leaf chlorophyll contents (IS-105, IS-2217, IS-1063, and IS-453).(e) Cultivars with higher contents of phosphorous, potash and polyphenols and biophysical characters *viz.,* light green and non-glossiness leaves, leaves with more trichomes and waxyness were less preferred by delphacids and also showed the least development of LSE (ICSCTV-9, BTP-28, IS-1840, ICSV-148 and SPV 504).Whereas, the genotypes with higher nitrogen, sugar and chlorophyll and varieties with greater plant height, greater distance between two leaves and smaller leaf angle were more preferred by the shoot bugs. (f) The cultivars IS-1840, BTP-28, ICSCTV-9, ICSV-148, and SPV-504 were promising against delphacid, aphid, and leaf sugary exudation.

Stability of resistance of corn planthopper, *P. maidis* was studied over three plant growth stages in 56 sorghum germplasm accessions.Genotypes x stage interactions were significant.Plant age exerted a profound influence on the rate of oviposition, establishment of nymph, macropterous and brachypterous adult populations and plant damage.Resistance to corn planthopper was stable over three growth stages inIS 18557, IS 18677 and PJ 8K(R), which also supported low colonization of nymph and adult population; IS 2308 was unstable due to high deviation.Significantly low rate of oviposition on resistant as compared to susceptible genotypes and the positive and significant correlation between oviposition and plant damage illustrated that antixenosis for oviposition was the primary mechanism of resistance.As a consequence the genotypes preferred for oviposition showed susceptibility due to higher plant damage.Establishment of nymphs was affected on the genotypes, IS 1054, IS 1082, IS 2194, IS 3992, IS 12308, IS 18676 and IS 19349 which may be due to the factors involved either in reduced hatchability of eggs and /or deterrence or poor feeding preference of nymphs (Singh and Rana, 1992).

Chandra shekar *et al.* (1993) reported that antibiosis and antixenosis components involving in orientation, colonization of nymphs and adults corn planthopper *P. maidis* for oviposition and nymphal development. The genotypes IS-18676, IS 19349 and IS 18677 showed a high degree of antixenosis in settling fewer nymphs and adults consistently at 30, 45 and 60 DAG. This finding was supported with low colonization of nymphs and brachypterous and macropterous adults under field conditions.In addition, high degree of antixenosis for oviposition in both laboratory and field tests was evidenced on IS 18676 and IS 19349 at 30, 45 and 60 DAG, but on SPV 472 and SPV 475 only at specific plant growth stages.Similarly, Raja sekhar (1997) reported that the variability in the rate of *P. maidis* adults colonization, together with the suitability of plant growth stages for oviposition, contributed to variable degree of antixenosis for oviposition.

Raja sekhar *et al.* (1995) evaluated 38 genotypes for their relative susceptibility to the shoot bug. The varieties were sown during first week of July in a single line of 6 m. The trials were also repeated in October commencing from 30 days after plant emergence. The variety SPV 736 and hybrid MSH 65 were considered promising in harbouring the lowest bug population of 60.8 and 68.8 bugs per 10 plants, respectively. Hybrids PSYH 3 and SPH 430 also showed some resistance. The genotypes, which proved promising in rainy season, were also found to carry low bug population in post-rainy season.

Garud *et al*. (2000) reported that in rainy season crops raised on the experimental station at Parbhani, the disease incidence ranged from 2 per cent in CSH 13R to 9 per cent in M 35-1, and in the post-rainy season it ranged from 9 per cent in CSH 15R to 21 per cent in SPH 695 and SPV 1090.Prem Kishore (2000) provided viable options to contain insect pests and do away with insecticides due to their adverse effects to humans and environment and prohibitory costs. Further, he also reported varieties *viz.,* SPV 1413, SPV 1155, SPV 1359, SPV 1451, SPV 1461, SPV 1462, SPV 1463 and SPV 1464 and hybrids *viz.,* SPH 733, SPH 1010, SPH 1026, SPH 1075, SPH 1159, SPH 1164, SPH 1168 and SPH 1171 as resistant to delphacids.

Subbarayudu (2002) studied the incidence of shoot bugs (*Peregrinus maidis*) on 20 sorghum genotypes in a field trial during the rainy season (*kharif*) at the NRCS, Hyderabad, India in 1998.At 64 days after emergence, the maximum number of shoot bugs per plant was recorded on genotype M 35-1 (25.8) and the fewest on genotypeDJ 6514 (3.5).Ten days later, there were fewer shoot bugs per plant on all genotypes except on ICSV 700. Genotype CSV 15 had the maximum number of damaged plants (50.5%) while CSH 6 had the least (9.5%) although differences were not significant. The sorghum genotypes *viz.,* DJ-6514, ICSV-700, IS-2205 and CHS-6 were found to be tolerant to shoot bug and these genotypes have potential for incorporation in sorghum shoot bug resistant breeding programme.The genotypes *viz.,* Swati, M 35-1, CSH 9, SPV 462 and ICSV 745 were highly susceptible to the shoot bug damage.

Genotypes namely, CS 3541, DJ 6514, CSH 9 and ICSV 745 recorded less shoot bug nymphs in two monitorings.Of all the genotypes, CSV 15 was highly susceptible to shoot bug (Anon. 1999).

2.6 NATURAL ENEMIES

According to Guppy (1914) the hymenopteron parasite *Anagyrus flaveolus* Watern (Hymenoptera : Mymaridae) parasitised the eggs of *P. maidis* to the extent of 75 to 80 per cent. Muir (1917) from Philippines reported that the eggs of shoot bug were parasitised by *Paranagrus* sp. (Hymenoptera : Mymaridae). Westgate (1918) obtained effective control of *P. maidis* by the release of large number of parasitoids, *Ootetrastichus* sp. in maize field.

Ayyar (1919) reported two chalcidid egg parasitoids, *Paranagrus optabilis* Perkins and *Ootetrastichus indicus* Giraul on shoot bug. According to the investigations of Fullaway (1919) in Hawaii Island, two mymarids which parasitised the eggs of *P. maidis* were *Paranagrus osborni* (Fullaway & Anagrus) and *Anagrus frequens* Perkins to the extent of 50 per cent. A drynid parasitoid, *Haplogonatopus vitiensis* Perkins was found to develop on the nymphs of *P. maidis*. Apart from these, Pipenculid flies and stylopid beetles were also found parasitising. Predators on shoot bug includes an ant, *Pheidole megacephala* Fab., a Coccinellid, *Coleophora ineqalis* (Thunberg), a bug, *Zelus peregrinus* Kirk., and earwing, *Chelisoches morio* Fab. and spiders.

Loftin and Christenson (1934) recorded *Mesogramma subannulatum* (Loew) attaching *P. maidis* on sorghum. Pemberton (1937) reported that many beneficial species, which included a capsid, *Cyrtorhinus lividipennuis* Reut., feeding on the corn leafhopper*P. maidis*. Bagal and Trehan (1945) from Poona (Maharashtra) noticed the adults of *Menochilus sexmaculatus* Fab. and *Coccinella septempunctata* Linn. feeding on young nymphs of *P. maidis* on sorghum during hot weather.Verma (1955) reported that a mirid bug, *Cyrtorhinus mandulus* Bredd, an egg predator checked the population of *P. maidis* in Hawaii. Morin Acosta (1964) recorded an ant, *Doru lineare* (Esch.) and some undescribed red mites preying on the nymphs and adults of *P. maidis*.

A red mite, *Bochartia* sp. (Acari : Erythraeidae) was found feeding on the nymphs and adults of the *P. maidis* at Jabalpur during 1964-66. The number of mites per host nymph or adults ranged from 1 to 3 and the percentage of parasitization varied from 3.7 to 15.5 (Rawat and Sexena, 1967).

Carnegie and Harris (1969) reported two mirid bugs *Tytthus mandulus* Bredd. and*T. parviceps* (Reut.) (Hemiptera : Miridae) which were able to feed on the eggs of *P. maidis* in the laboratory at 25 to 30^{0}C and 80 to 100 per cent relative humidity. A predacious bug, *Geocoris tricolor* Feb. (Hemiptera : Lygaeidae) was found feeding on the *P. maidis* on sorghum at Jabalpur in Madhya Pradesh (Rawat and Modi, 1969).Like-wise Kulkarni *et al.* (1979) from Dharwad reported an identified predacious mite *Erythraeus* sp. (Trambidiformes : Erythraeidae) feeding on *P maidis.* The mite infestation ranged from 0 to 38.10 per cent and average was 9.12 per cent.The larvae of the mite found to adhere to the abdominal segment, whereas, adult moved freely on sorghum foliage.Singh *et al.* (1993) reported an egg parasitoid, *Anagrus haviolus* and general predator, *Cheilomenes sexmaculata* (Fab.) feeding on *P. maidis* in South India. Similarly, Catindig *et al.* (1994) reported two egg parasitoids on *P. maidis viz., Gonatocerus* and *Oligosita* from the Philippines.

2.7 MANAGEMENT OF*P. maidis*

Rathore *et al.* (1970) tested endosulfan (0.03%), malathion (0.05%), phosphamidon (0.025%), dimethoate (0.03%), endrin (0.025%), DDT (0.2%) and formothion (0.025%) against shoot bug and reported that endosulfan (0.03%) and malathion (0.05%) showed better knock down effect, while phosphamidon (0.025%) and endrin (0.025%) were effective up to two weeks.

Kulkarni *et al.* (1975) carried out a field experiment for the control of shoot bug using chemicals *viz.,* quinalphos (0.07%), endosulfan (0.08%), chlordimeform (0.05%), monocrotophos (0.05%) and dicrotophos (0.05) sprayed at 25 days after sowing.All these chemicals reduced the number of bugs even up to 10 days after spraying. Chlordimeform was the most effective as it recorded 0.1 bugs per shoot, compared to untreated control, which recorded 2.2 bugs per shoot.

Sharma *et al*. (1982) reported that all the insecticides tested (BHC 10% dust @ 20 kg/ha, carbaryl 5% dust @ 20 kg/ha, cythion 5% dust @ 2 kg/ha, endosulfan 4% dust @ 20 kg/ha, phenthoate 2% dust @ kg/ha, endosulfan 4% granules @ 10 kg/ha and endosulfan 35 EC @ 0.01% spray) were effective in reducing the *P. maidis* population and increasing the grain yield. Minimum population of shoot bug was recorded in cythion 5% dust followed by endosulfan 4% granules @ 10 kg/ha. Higher seed yield was recorded by cythion 5% dust followed by phenthoate 2% dust and BHC 10% dust applied @ 20 kg per ha.

Gandhale *et al.* (1986) reported that two sprays (as soon as infestation of pest and 15 days later) of insecticides with demeton-s-methyl (0.02%), monocrotophos (0.02%), dimethoate (0.03%) and formothion (0.02%) were most effective in controlling shoot bug. The plots treated with methyl demeton (0.02%) gave highest grain yield which was at par with monocrotophos (0.02%), quinalphos (0.03%), carbaryl 10% dust @ 20kg/ha, BHC 10% dust @ 20 kg/ha and endosulfan 4% dust @ 20 kg/ha.

Tsai *et al.* (1990) reported the effectiveness and persistence of seven insecticides *viz.,* methomyl, carbaryl, diazinon, oxydemeton methyl, acephate and dimethoate on*P. maidis* on maize crop. Among the chemicals, oxydemeton methyl, a systemic insecticide showed the greater effect on *P. maidis* causing cent per cent mortality at one day after treatment and its effect continued for three days thereafter.Carbaryl, a contact insecticide displayed the longest residual effect among all the insecticides tested with mortality continuing for up to 10 days after treatment.

Chaudhari *et al.* (1994) tested eleven chemicals against shoot bug and reported that all the chemicals *viz.,* carbaryl (0.02%), dimethoate (0.03%), quinalphos (0.05%), cypermethrin (0.01%), bromophos methyl (0.05%), endosulfan (0.05%), carbaryl (5%D), BHC (10%D), carbaryl + BHC (10%D) and Kaolin (3%) were effective in controlling shoot bug population except carbofuran (5%) seed treatment.Tallamy *et al.* (1997) reported Cucurbitacins, the bitter triterpenes common to all cucurbitaceae were potent feeding oviposition deterrents and also very good antifeedents against *P. maidis*.

Raja sekhar (1996) reported that, in field studies conducted in Andhra Pradesh, India, during the rainy and post-rainy season of 1988-89 on crop losses due to *Peregrinus maidis* on sorghum, the vulnerable stage was 60 days after seedling emergence and the avoidable loss was lowest when the crop was sprayed twice at 45 and 60 days after emergence with demeton-methyl. The cost-benefit ratio was highest for spraying 60 days after emergence.

Bheemanna *et al.* (2003) reported that imidacloprid 70 WS at 2 g per kg seed treatment was effective in reducing population of shoot bug, which was on par with its higher dose (5 g/kg seed). These two treatments recorded significantly lower population over endosulfan 35 EC spray at 30 days after sowing and endosulfan 35 EC (0.07%) seed soaking for eight hours. Imidacloprid 70 WS (2 g/kg) seed treatment also recorded low incidence of maize streak virus disease.

Effect of date of sowing on seasonal incidence and management practices of shoot bug were carried out at Karnataka, India during 2003-04.The incidence of shoot bug started from last week of

July (with a minimum population of 0.66 bugs/5 plants).There was steep increase in population of shoot bug from August last week to December first week recording maximum population of 67.33 bugs per five plants. With respect to actual dates, October 8th sown crop recorded maximum number of shoot bug population with the mean value of 45.71 shoot bugs per 5 plants.No incidence of shoot bug was recorded in the months of February and June. The management of shoot bug with seed treatment of thiamethoxam 70 WS @ 2g per kg or seed dressing with carbosulfan 25 DS (40g/kg) or whorl application of phorate 10 G (10kg/ha) resulted in higher profit than the other chemicals (Vijaykumar, 2004).

III. MATERIAL AND METHODS

Studies on various aspects of sorghum shoot bug, *P. maidis* were carried out at the All India Co-ordinated Sorghum Improvement Project, Regional Agricultural Research Station and College of Agriculture, Bijapur, Karnataka during *rabi* 2004-05. The details of location of the experimental site, weather conditions, soil characteristics, experimental materials used, experimental procedures adopted during the course of investigation and statistical methods employed are presented in this chapter.

3.1 LOCATION OF THE EXPERIMENTAL SITE

Bijapur is situated in the Northern Dry Zone (Region-II, Zone-3) of Karnataka between 16^0 49' N latitude and 77^0 20' E longitude and at 398.37 m above mean sea level.

3.2 WEATHER CONDITIONS

The average rainfall is 580 mm confined to monsoon period from June to November with occasional showers in pre-monsoon months of April and May. Mean maximum temperature is usually more than 28^0C throughout the year except in December. The relative humidity is high during monsoon months from July to September and uniformly low during summer months from March to May. The mean monthly, weekly and daily meteorological data such as rainfall, temperature, sunshine hours, relative humidity, wind speed and number of rainy days recorded during the crop growth period are presented in Appendices 1-3.

3.3 SOIL CHARACTERISTICS

The soil of the experimental site used for field studies *viz*., loss estimation, varietal screening and shoot bug management was deep black soil.

3.4 LOSS ESTIMATION DUE TO SHOOT BUG

The crop loss estimation due to sorghum shoot bug was studied by following two methods which are given below.

3.4.1 Loss estimation under protected and unprotected conditions with different sowing dates

This experiment was conducted with five dates of sowing taken up at weekly intervals commencing from the fourth week of September to the fourth week of October (28-09-2004, 04-10-2004, 11-10-2004, 18-10-2004 and 25-10-2004) in a Factorial Randomized Block Design having protected and unprotected plots with three replications, using M 35-1 variety in a plot size of 3.6 X 4.5m (6 rows each of 4.5 meter length). The crop was raised with a spacing of 60 X 15 cm by following all recommended package of practices (Anon., 2001) except the plant protection schedule. Two plants were maintained per spot till one month. After one month, only one plant was maintained at each spot by removing one plant (preferably the shoot fly attacked one if any). In the case of protected plots the shoot bug was kept under check by spraying endosulfan 35 EC @ 0.07 per cent twice at 25 and 40 days after germination. While in the unprotected plots, it was allowed for natural infestation of shoot bugs. The ear head caterpillars and other pests were hand-picked and destroyed. The incidence of shoot bug was regularly noted both in protected and un-protected plots at 20, 30, 40, 50 and 60 days after germination on five randomly selected plants. The average of all five observations was calculated and expressed as mean population per five plants.

3.4.1.1 Estimation of loss in grain and fodder yield

The data on grain and fodder yield was recorded from the net plot of each treatment separately. The per cent crop loss in terms of grain and fodder yield at different dates of sowing was calculated by using the modified Abbott's formula (Tejkumar, 1979) given below.

$$\text{Per cent crop loss} = \frac{\text{Yield in protected crop} - \text{Yield in un-protected crop}}{\text{Yield in protected crop}} \times 100$$

Plate 2: A view of caged sorghum plants for crop loss estimation

3.4.1.2 Estimation of loss in 1000 grain weight

The loss in the quality of sorghum grains (from the field experiment for estimation of yield loss) was determined in terms of seed weight. Weight of 1000 grains from each treatment was recorded. Weight of three such grain samples from three replications was taken and average was worked out.

3.4.1.3 Panicle emergence

Total number of plants in each net plot was recorded and plants with clear panicle emergence were also recorded at 80 days after sowing and per cent panicle emergence was worked out. The data were subjected to angular transformations before statistical analysis.

3.4.1.4 Shoot bug population

The shoot bug population (both nymphs and adults) was recorded on five randomly selected plants in each treatment. The average population per plant was worked out. The data were subjected to square root transformations before statistical analysis.

3.4.1.5 Disease incidence

Total number of plants in each net plot was recorded and plants showing the stripe disease were also recorded at 70 days after sowing and per cent disease incidence was worked out. The data were subjected to angular transformations before statistical analysis.

3.4.1.6 Leaf sugary exudates

Leaf sugary exudates intensity grade was recorded on 45th day after sowing on second leaf from the top. The intensity grades for leaf sugary malady were as given below. 1= No appearance of leaf sugary malady; 2= Exudates droplets up to 0.1 cm diameter; 3= Exudates droplets between 0.1 to 0.5 cm diameter; 4= Exudates droplets between 0.5 to 1.0 cm diameter; 5= Exudates droplets over more than 1 cm diameter (Chaudhari *et. al.* 1994).

3.4.1.7 Leaf sugary malady

Total number of plants in each net plot were recorded and plant showing the leaf sugary exudates malady were also recorded on 45th day after sowing and per cent plants affected by leaf sugary malady was worked out.

3.4.2 Loss estimation with graded infestation under caged conditions

This trial was conducted at the Regional Research Station, Bijapur during *rabi* season of 2004-05 using M 35-1 variety. The crop was raised with a spacing of 60 X 15 cm by following all recommended package of practices (Anon., 2001) except the plant protection schedule. The crop was sown on 28-09-2004. Each treatment consisted of five plants, which were covered by thin muslin cloth (1m width X 0.5m breadth X 2.5 m height) (Plate 2) at 25 days after emergence. Shoot bug releases were made at the rate of 0, 5, 10, 15, 20, 25 and 30 first instar nymphs per plant at 25 days after emergence on the caged plants. Release of no insects covered with muslin cloth served as control. Uniform aged first instar nymphs multiplied in the laboratory were used for this purpose. Three replications were maintained. Shoot bug population was recorded on all the five plants in each treatment at 40, 50 and 60 days after emergence. Throughout the vegetative phase shoot bugs were allowed to feed on the plants. At the time of harvest, observations were made in each treatment with respect to height of the plants, weight of the grains of individual ear and 1000-grain weight.

3.4.2.1 Height of the plants

The height of five caged plants at maturity was measured in centimeter from each replication using wooden ruler from the ground level to the tip of the panicle and was averaged.

3.4.2.2 Loss in grain yield

The grain weight of five caged plants in each replication was measured in grams using sensitive balance after threshing, cleaning and drying. The same was averaged and expressed in terms of grams per plant.

3.4.2.3 Loss in fodder yield

In each replication five caged plants were cut after panicle separation and dried plants were weighed using sensitive balance. Then it was averaged and expressed in terms of grams per plant.

3.4.2.4 1000-grain weight

The weight of 1000-grains from the grains harvested from five caged plants in each replication was recorded and averaged.

3.4.2.5 Shoot bug population

The number of shoot bug adults and nymphs were counted from all the five caged plants in each replication thrice at 40, 50 and 60 days after emergence. The average of all three observations was calculated and mean population per plant was worked out.

3.4.2.6 Economic Injury level

Based on the level of infestation, yield per plant, cost of insecticide, average market price of sorghum grain and fodder per quintal, the economic injury level (EIL) was computed by utilizing the procedure of Stone and Pedigo (1972) as modified by Ogunlana and Pedigo (1974). The EIL was computed by the following formula.

$$\text{Economic Injury Level} = \frac{\text{Gain threshold}}{\text{Yield reduction per bug}}$$

$$\text{where, Gain threshold (GT)} = \frac{\text{Cost of pest control}}{\text{Market price of grain and fodder (Rs/q)}}$$

3.5 SCREENING OF SORGHUM GENOTYPES FOR REACTION TO SHOOT BUG

This trial was carried out during *rabi* 2004-05. Sixty five entries received from National Research Centre for Sorghum, Hyderabad and fifteen entries from Senior Sorghum Breeder, RARAS, Bijapur were used for screening against shoot bug. Totally eighty lines were screened against shoot bug under field conditions. The list of entries is given in table1. The pedigree of entries received from NRCS, Hyderabad is given in Appendix-4. Each genotype was sown in two rows of 3.5 m length with a spacing of 60 x 15cm with two replications on 4-10-2004. All the recommended package of practices was followed except plant protection measures. Five plants in each genotype were selected randomly for observations. Varietal susceptibility to shoot bugs was assessed, by scoring number of shoot bugs (both adults and nymphs) per plant on these five plants at 45 days after emergence of the crop.

3.5.1 Causes of resistance

Based on preliminary screening results, twenty genotypes with varied level of shoot bug infestation were selected for ascertaining the probable cause of resistance. The test entries included 104B, M 31-2B, RS 29, SPV 1626, M 148-138, RS 615, IS 2312, IS 37190, JP 1-1-5, M 35-1, DSV 4, DSV 5, SFR 7, 61505, 61506, 61507, 61512, 61532, 61551 and Hathi kunta.

3.5.1.1 Biophysical basis of resistance

Plant morphological characters like plant height, distance between two leaves, number of leaves per plant and leaf angle were recorded at milky stage of the crop. These plant morphological characters were correlated with shoot bug population recorded at 45 days after emergence of the crop on twenty genotypes under study.

3.5.1.2 Biochemical basis of resistance

Leaf samples collected from field at 45 days after sowing were subjected to biochemical analysis. Biochemical constituents namely total sugar, reducing sugar and total phenols in leaves of sorghum genotypes were determined. These biochemical parameters were correlated with the shoot bug population recorded on different genotypes.

Table 1: List of sorghum lines used for screening against shoot bug

Sl. No.	Entry	Sl. No.	Entry	Sl. No.	Entry
1.	61504	28.	61548	55.	61605
2.	61505	29.	61551	56.	61606
3.	61506	30.	61556	57.	61607
4.	61507	31.	61557	58.	61608
5.	61508	32.	61558	59.	61610
6.	61510	33.	61559	60.	61611
7.	61511	34.	61562	61.	61612
8.	61512	35.	61566	62.	61613
9.	61515	36.	61567	63.	CK 60B
10.	61516	37.	61568	64.	296B
11.	61519	38.	61569	65.	104B
12.	61520	39.	61570	66.	M 31-2B
13.	61521	40.	61573	67.	SPV 1626
14.	61522	41.	61576	68.	M 148-138
15.	61523	42.	61578	69.	RS 615
16.	61524	43.	61579	70.	IS 37190
17.	61525	44.	61580	71.	JP 1-1-5
18.	61526	45.	61581	72.	Swati (SPV-504)
19.	61527	46.	61582	73.	DSV 4
20.	61528	47.	61587	74.	DSV 5
21.	61530	48.	61588	75.	SFR 7
22.	61532	49.	61589	76.	M 35-1
23.	61533	50.	61590	77.	Hathi Kunta (S)
24.	61540	51.	61592	78.	RS-29 (R)
25.	61543	52.	61595	79.	IS-2312
26.	61544	53.	61596	80	DJ-6514
27.	61547	54.	61602		

3.6 MANAGEMENT OF SHOOT BUG THROUGH SEED DRESSERS

To evaluate different seed dressers, spray and granules for the management of shoot bug, *P. maidis*, a field experiment was laid out in a Randomized Block Design at the Agricultural Research Station, Bijapur during *rabi* 2004-05. The experiment consisted of 11 treatments including an untreated check with three replications. The details of the treatments imposed are given in Table 2. The popular sorghum variety M 35-1 was raised in the plots measuring 4.5×3.6 m with 60 cm and 15 cm spacing between the rows and plants, respectively. All the agronomic practices were followed as per the Package of Practices for Higher Yields except plant protection schedule (Anon., 2001).

Seed treatment was done by taking the recommended quantity of chemical in a polythene cover and mixed with seeds thoroughly by adding few drops of water and gum. Seed coating was made by mixing recommended quantity of chemical and water in a polythene bag to which known quantity of seeds were mixed and then dried under shade before sowing.

In soil application treatment, chemical was applied in furrows and covered with soil before sowing. Whorl application was done by applying recommended quality of insecticides into leaf whorls at 25 days after germination. Spraying was done by using Knapsack sprayer at 25 days after germination. The population of nymphs and adults were recorded on five randomly selected plants in each replication at 30, 40, 50 and 60 days after germination.

3.6.1 Shoot bug population

The shoot bug population (both nymphs and adults) was recorded on five randomly selected plants in each treatment in all the replications. The average population per five plants was worked out.

Table 2: Details of treatments for the management of shoot bug in *rabi* sorghum

Sl. No.	Treatment	Method of Application	Dosage
1.	Imidacloprid 70 WS	Seed dressing	2 g/kg seeds
2.	Imidacloprid 70 WS	Seed dressing	5 g/kg seeds
3.	Thiamethoxam 70 WS	Seed dressing	2g/kg seeds
4.	Thiamethoxam 70 WS	Seed dressing	3g/kg seeds
5.	Carbosulfan 25DS	Seed dressing	20 g/kg seeds
6.	Chlorpyriphos 20 EC	Seed dressing	5 ml + 20 ml water/kg seeds
7.	Imidacloprid 17.8 SL	Seed dressing	2 ml + 20 ml water/kg seeds

8.	Phorate 10 G	Soil application	20 kg/ha
9.	Carbofuran 3G at 25 days after germination	Whorl application	8 kg/ha
10.	Endosulfan 35 EC at 25 days after germination	Spray	2 ml/lit
11.	Untreated Check	-	-

3.6.2 Panicle emergence

Total number of plants in each net plot was recorded and the plants with clear panicle emergence were also recorded at 80 days after sowing and per cent panicle emergence was worked out. The data were subjected to angular transformations before statistical analysis.

3.6.3 Disease incidence

Total number of plants and number of plants showing stripe disease symptoms were recorded from the net plot of each treatment. The data were subjected to angular transformations before statistical analysis.

3.6.4 Grain and fodder yield

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

3.6.5 Economics

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

IV. EXPERIMENTAL RESULTS

The results of the experiments conducted during *rabi* 2004-05 on the sorghum shoot bug, *P. maidis* are elucidated in this chapter.

4.1 CROP LOSS ESTIMATION DUE TO SORGHUM SHOOT BUGS

The results of crop loss estimation due to sorghum shoot bugs studied during *rabi* 2004-05 by following two methods are presented in the following pages.

4.1.1 Loss estimation under protected and unprotected conditions with different sowing dates

The results of the experiment conducted with five dates of sowing taken up at weekly intervals commencing from September fourth week to October fourth week with protected and unprotected conditions are presented below.

4.1.1.1Estimation of loss in grain and fodder yield

4.1.1.1.1 Grain yield

The data pertaining to the grain yield as influenced by different dates of sowing in the protected and unprotected conditions are presented in Table 3.Significant differences were observed between protection levels and sowing dates while their interaction effect was non significant.

The results revealed that there was significant difference between protected and unprotected plot with grain yield of 17.90 and 15.96 q ha^{-1}, respectively.The sowing taken up during September IV week recorded significantly highest grain yield of 20.52 q ha^{-1} as compared to the later sowing dates.The crop sown during October I week recorded grain yield of 18.58 q ha^{-1} and gradually decreased with delay in sowings and the lowest grain yield of 13.37 q ha^{-1} was recorded when the crop was sown during October IV week.However, the grain yield recorded in all the five weekly sowings differed significantly from each other. The interaction effect on grain yield was non-significant. The loss in grain yield was to the tune of 11.18, 9.10, 6.65, 12.24 and 16.03 per cent in the crops sown during September IV week, October I, II, III, and IV week, respectively due to shoot bug infestation (Fig 1).The overall loss of 11.16 per cent in the grain yield was recorded under unprotected conditions as compared to protected ones across five dates of sowings.

4.1.1.1.2 Fodder yield

The data pertaining to the fodder yield as influenced by different dates of sowing in the protected and unprotected conditions are presented in Table 3.Significant differences were noticed between protection levels and weekly sowing dates while their interaction effect was non significant.

The mean fodder yield obtained under protected and unprotected conditions was 5.42 and 4.29 t ha^{-1}, respectively which differed significantly from each other.The first sowing taken up during September IV week harvested highest fodder yield of 5.72 t ha^{-1} and was on par with crop sown during October I week (5.37 t ha^{-1}) while, it differed significantly from October II, III and IV week sown crop with 5.02, 4.57 and 3.62 t ha^{-1}, respectively.The loss in fodder yield was to the extent of 19.43, 21.16, 18.63, 18.49 and 27.86 per cent in the crops sown during September IV week, October I, II, III, and IV week, respectively due to shoot bug infestation (Fig 1).Thus, with natural infestation of shoot bug, the overall loss of 21.11 per cent in the fodder yield was recorded under unprotected conditions as compared to protected ones irrespective of dates of sowing.

4.1.1.2 Loss in 1000-grain weight and reduction in panicle emergence

4.1.1.2.1 1000-grain weight

The data recorded with respect to 1000-grain weight as influenced by different dates of sowing in the protected and unprotected conditions are presented in the Table 4. Significant differences were observed between the sowing dates only but significant differences were not noticed between protection levels as well as due to interaction effects.

Table 3: Influence of different dates of sowing and levels of protection on grain and fodder yield

Sowing week	Grain yield (q/ha)				Fodder yield (t/ha)			
	Protected	Unprotec-ted	Mean	% Loss	Protected	Unprotec-ted	Mean	% Loss
September IV	21.73	19.30	20.52	11.18	6.33	5.10	5.72	19.43
October I	19.47	17.70	18.58	9.10	6.00	4.73	5.37	21.16
October II	17.43	16.27	16.85	6.65	5.53	4.50	5.02	18.63
October III	16.33	14.33	15.33	12.24	5.03	4.10	4.57	18.49
October IV	14.53	12.20	13.37	16.03	4.20	3.03	3.62	27.86
Mean	17.90	15.96	16.93	11.16	5.42	4.29	4.86	21.11

For comparing	S. Em. ±	C. D. (0.05)	S. Em. ±	C. D. (0.05)
Protection	0.32	0.95	0.12	0.36
Sowing Dates	0.51	1.50	0.19	0.57
Interaction	0.72	N.S.	0.27	N.S.

N.S.= Non-significant

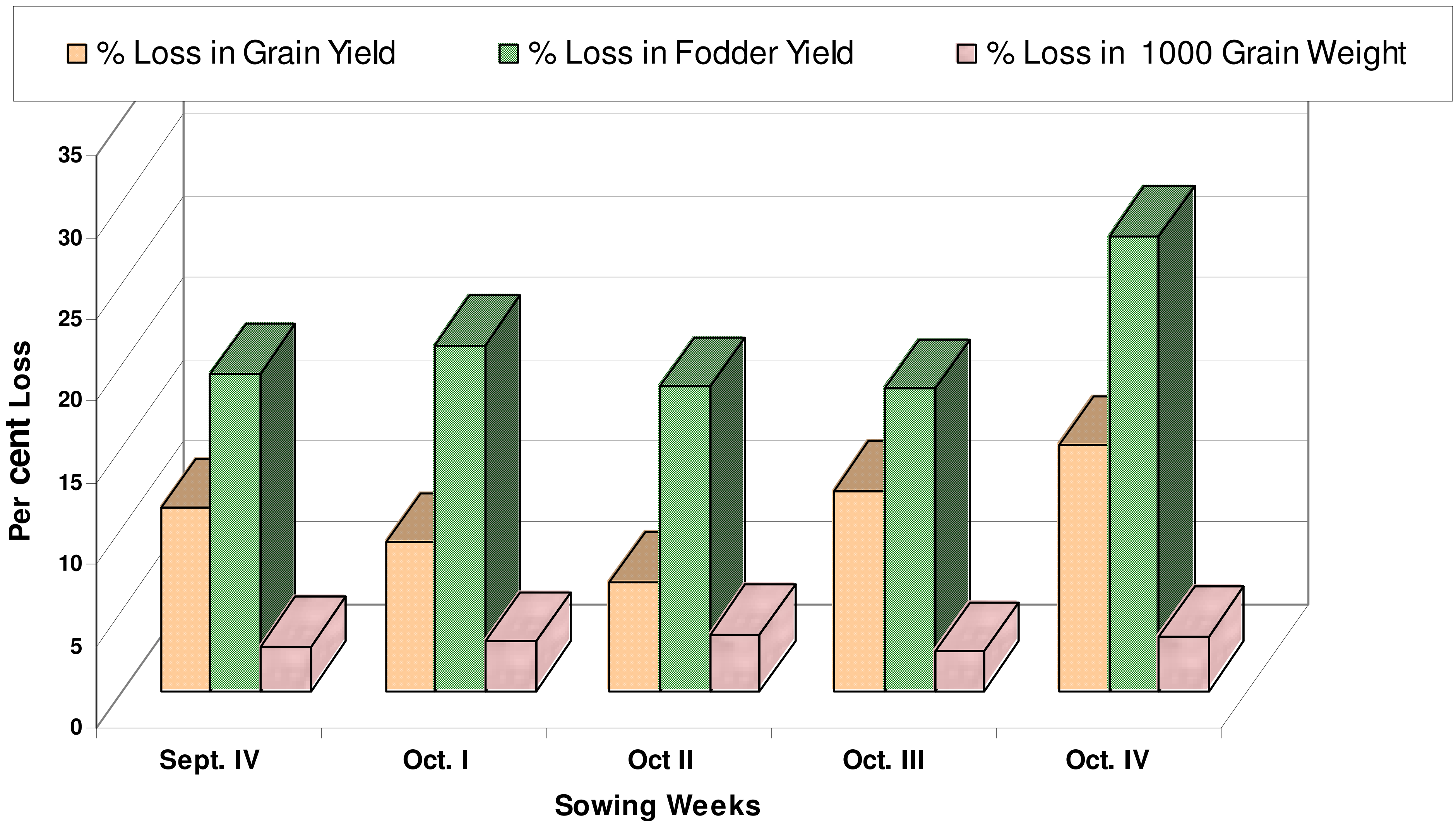


Fig. 1: Loss in grain yield, fodder yield and 1000 grain weight due to shoot bug

Table 4: Influence of different dates of sowing and levels of protection on 1000-grain weight and panicle emergence

Sowing week	1000 Grain weight (g)				% Panicle emergence			
	Protected	**Unprotec-ted**	**Mean**	**% Loss**	**Protected**	**Unprotec-ted**	**Mean**	**% Decrease**
September IV	31.17	30.33	30.75	2.69	96.40 (79.50)*	90.20 (71.99)	93.30 (75.74)	6.43
October I	30.13	29.23	29.68	2.99	92.33 (74.06)	84.40 (66.76)	88.37 (70.41)	8.58
October II	29.83	28.80	29.32	3.45	90.43 (72.04)	80.20 (63.63)	85.32 (67.84)	11.31
October III	29.03	28.33	28.68	2.41	87.53 (69.45)	76.80 (61.33)	82.17 (65.39)	12.26
October IV	28.13	27.20	27.67	3.30	84.30 (66.68)	72.30 (58.27)	78.30 (62.48)	14.23
Mean	29.66	28.78	29.22	2.97	90.20 (72.35)	80.78 (64.40)	85.49 (68.37)	10.56

For comparing	**S. Em. ±**	**C. D. (0.05)**	**S. Em. ±**	**C. D. (0.05)**
Protection	0.32	N.S.	0.75	2.22
Sowing Dates	0.51	1.52	1.18	3.51
Interaction	0.72	N.S.	1.67	N.S.

* Figures in the parentheses are arc sin transformations N.S.= Non-significant

The mean 1000-grain weight under protected and unprotected conditions was 29.66 and 28.78 g, respectively with non-significant differences between each other. The highest 1000-grain weight of 30.75 g was obtained when the crop was sown during IV week of September and it was on par with October I and II week sown crop (29.68 and 29.32 g respectively) and differed significantly from last two sowings viz., October III and IV week with 28.68 and 27.67 g respectively.

The loss in 1000-grain weight in the unprotected condition over protected conditions was 2.69, 2.99, 3.45, 2.41 and 3.30 per cent when the crop was sown during September IV week, October I, II, III, and IV week, respectively with an average of 2.97 per cent across sowing dates (Fig 1).With delay in sowings there was an increased loss in 1000-grain weight.

4.1.1.2.2 Panicle emergence

The results obtained in respect of panicle emergence as influenced by different dates of sowing in protected and unprotected conditions are presented in Table 4.The protection levels and sowing dates exhibited significant differences while their interaction effects showed non significant differences.

The highest panicle emergence of 90.20 per cent was noted in case of protected plot which was significantly superior to unprotected plot with 80.78 per cent.

Similarly highest panicle emergence of 93.30 per cent was recorded in the crop sown during IV week of Sept. and was statistically superior over later four sowings.With delay in sowing, percentage of ear head emergence gradually decreased from88.37 per cent in October I week sown crop to 78.30 per cent in October IV week sown crop.The reduction in panicle emergence in the unprotected condition over protectedin different dates of sowing varied from 6.43 per cent in September IV week to14.23 per cent in October IV week with an average of 10.56 per cent across five sowing dates.Reduction in panicle emergence was more pronounced with delay in sowings.

4.1.1.3 Shoot bug population and sorghum stripe disease incidence

4.1.1.3.1 Shoot bug population

The shoot bug populations per five plants as influenced by different dates of sowing in the protected and unprotected conditions are presented in Table 5. Significant differences were observed between protection levels, sowing dates and their interaction.

The shoot bug population per five plants differed with different levels of protection irrespective of sowing weeks.The unprotected plot recorded significantly higher shoot bug population over protected ones with 39.87 and 3.27 shoot bugs per five plants, respectively with 92.02 per cent over all increase in population in the unprotected plot over protected ones.

The shoot bug population per five plants differed statistically in different sowing weeks irrespective of protection levels.Among the different sowings taken up, Sept. IV week recorded significantly higher population of 29.46 shoot bugs per five plants as compared to remaining sowing weeks, but was on par with population of 25.76 shoot bugs per five plants. October I and II week sown crops with population level of 22.92 shoot bugs per five plants did not differ statistically from each other but recorded significantly higher population than October III week sown crop. With delay in sowing, reduction in shoot bug population was evident.

The shoot bug population per five plants as result of interaction between protection level and sowing weeks differed significantly.Among the different treatment combinations, the crop sown on September IV week under unprotected conditions recorded significantly higher population of 54.43 bugs per five plants as compared to the remaining treatment combinations.Among the remaining treatment combinations under unprotected conditions October I and II week sown crops were at par with each other by recording 47.23 and 42.30 bug population per five plants respectively and they were significantly superior over October III and IV week sown crop under unprotected conditions which in turn were at par with each other.All the five-treatment combinations under protected conditions were significantly inferior to all the treatment combinations under unprotected ones.

4.1.1.3.2 Per cent sorghum stripe disease incidence

The sorghum stripe disease incidence observed on plant as influenced by different dates of sowing in the protected and unprotected plots are presented in the Table 5. Significant differences

Table 5: Influence of different dates of sowing and levels of protection on shoot bug population and disease incidence

Sowing week	Shoot bug population/5 plants*				% Disease Incidence **			
	Protected	Unprotec-ted	*Mean*	% Increase	Protected	Unprotected	Mean	% Increase
September IV	4.50 (2.50)	54.43 (7.37)	29.46 (4.76)	91.73	3.53 (10.80)	8.73 (17.16)	6.13 (13.98)	59.56
October I	4.30 (2.40)	47.23 (6.85)	25.76 (4.61)	90.90	6.20 (14.11)	15.33 (23.01)	10.77 (18.56)	59.55
October II	3.53 (1.87)	42.30 (6.50)	22.92 (4.20)	91.65	10.60 (18.72)	19.53 (26.16)	15.07 (22.44)	45.72
October III	2.57 (1.60)	30.10 (5.53)	16.33 (3.54)	91.46	12.03 (20.27)	22.97 (28.61)	17.50 (24.44)	47.62
October IV	1.43 (1.20)	25.27 (5.50)	13.35 (3.10)	94.34	15.17 (22.86)	27.03 (31.27)	21.10 (27.07)	43.87
Mean	3.27 (1.84)	39.87 (6.24)	21.57 (4.10)	92.02	9.51 (17.35)	18.72 (25.24)	14.11 (21.30)	51.26

For comparing	S. Em. ±	C. D. (0.05)	S. Em. ±	C. D. (0.05)
Protection	0.09	0.26	0.69	2.06
Sowing Dates	0.14	0.41	1.10	3.25
Interaction	0.12	0.36	1.55	N.S.

* Figures in the parentheses are square root transformations
** Figures in the parentheses are arc sin transformations N.S.= Non-significant

were observed between protection level and sowing dates while, their interactions were non-significant.

The disease incidence percentage differed in different levels of protection irrespective of sowing weeks.The unprotected plot recorded significantly higher disease incidence as compared to protected ones with 18.72 and 9.51 per cent respectively, thus accounting for 51.26 per cent over all increased incidences in unprotected plot over protected ones across five dates of sowing.

The disease incidence differed statistically in different sowing weeks irrespective of protection levels.Among the different sowing weeks, sowing taken up during October IV week was significantly superior over remaining treatments by recording higher incidence 21.10 per cent which was at par with October III week sown crop.The October III and II week sown crop were at par with each other by recording 17.50 and 15.07 per cent disease incidence but they recorded significantly higher disease incidence as compared to October I and September IV week sown crop.The crop sown during October I week was significantly inferior over September IV week sown crop by recording 10.77 per cent disease incidence.The crop sown on September IV week was significantly superior over all the treatments by recording less disease incidence of 6.13 per cent.

The disease incidence per cent was not significant in the treatment combinations of protection levels and different sowing weeks.

4.1.1.4 Leaf sugary exudates and per cent plants affected by leaf sugary malady

4.1.1.4.1 Leaf sugary exudates

The leaf sugary exudates deposited on leaf as influenced by different dates of sowing in the protected and unprotected conditions are presented in Table 6.Significant differences were observed between protection level, sowing dates and their interactions.

The leaf sugary exudates differed much in different levels of protection irrespective of sowing weeks.The unprotected plot was significantly inferior over protected ones with leaf sugary exudation grade of 3.70 and 1.31, respectively with 63.86 per cent overall increase in unprotected plot over protected ones.

The leaf sugary exudates grade differed statistically in different sowing weeks irrespective of protection level.Among the different treatments, sowing taken up during September IV week was significantly superior over all other treatments by recording the mean leaf sugary exudates of 3.17 followed by October I week sown crop which was at par with October II and III week sown crop.The crop sown during October IV week was significantly inferior over October I and September IV week sown crops and also at par with October II and III week sown crops.

The leaf sugary exudates grade as a result of interaction between protection levels and sowing weeks differed significantly.Among different treatment combinations the crop sown on September IV week under unprotected conditions recorded highest leaf sugary exudates grade as compared to the remaining treatments and it was followed by October I, II, III and IV week sown crop.All the treatment combinations under protected conditions in all the four sowings were significantly inferior to all the treatment combinations under unprotected plot.

4.1.1.4.2 Per cent plants affected by leaf sugary malady

The plants affected by leaf sugary malady expressed in terms of percentage as influenced by different date of sowing in the protected and unprotected conditions are given in Table 6.All the sowing dates, protection level and their interactions differed significantly.

The plants affected by leaf sugary malady differed significantly in different levels of protection irrespective of sowing weeks.The unprotected plot recorded significantly higher plants affected by sugary malady (78.68%) as against 1.18 per cent plants affected by sugary malady in protected conditions, with over all increase of 98.53 per cent plants affected by leaf sugary malady in unprotected plots over protected ones.

Among all the five treatments, the crop sown on September IV week was significantly superior over all remaining treatments by recording highest per cent malady plants of 45.50 except the treatment where in the crop was sown during October I week which recorded 43.57 per cent leaf sugary malady plants.The crop sown during October II week recorded significantly higher plants

Table 6: Influence of different dates of sowing and levels of protection on leaf sugary exudate

Sowing week	Leaf sugary exudate (1-5 Grade)				% Plants affected by leaf sugary malady			
	Protected	Unprotec-ted	Mean	% Increase	Protected	Unprotected	Mean	% Increase
September IV	1.50	4.83	3.17	68.94	1.80 (7.68)*	89.20 (70.97)	45.50 (39.33)	97.98
October I	1.23	3.93	2.58	68.70	1.40 (6.94)	85.73 (67.86)	43.57 (37.40)	98.36
October II	1.30	3.50	2.40	62.85	1.00 (5.58)	80.40 (63.81)	40.70 (34.69)	98.76
October III	1.33	3.23	2.28	58.82	1.00 (5.72)	72.33 (58.28)	36.67 (32.00)	98.62
October IV	1.20	3.00	2.10	60.00	0.70 (4.76)	65.73 (54.18)	33.22 (29.47)	98.94
Mean	1.31	3.70	2.51	63.86	1.18 (6.14)	78.68 (63.02)	39.93 (34.58)	98.53

For comparing	S. Em. ±	C. D. (0.05)	S. Em. ±	C. D. (0.05)
Protection	0.07	0.21	0.46	1.37
Sowing Dates	0.11	0.33	0.73	2.17
Interaction	0.16	0.47	1.03	3.07

* Figures in the parentheses are arc sin transformations

affected by leaf sugary malady (40.70%) over October III and IV week sown crops by recording per cent leaf sugary malady plants of 36.67 and 33.22 per cent, respectively and was at par with the crop sown during October I week.The crop sown on October III week was significantly superior to crop sown on October IV week by recording 36.67 per cent leaf sugary malady plants.The crop sown during October IV was week significantly superior over all other treatments by recording fewer plants affected by leaf sugary malady (33.22%).

Under treatment combinations of different sowing weeks and protection levels per cent plant affected by leaf sugary malady differed significantly.The crops sown during September IV and October I week under unprotected were significantly inferior by recording 89.20 and 85.73 per cent leaf sugary malady plants respectively over October II, III, IV sown crops under unprotected and were at par with each other.

As the sowing was delayed, there was decrease in the plants affected by leaf sugary malady in unprotected conditions.

4.1.2 Crop loss estimation due to shoot bug with graded level of infestation

4.1.2.1 Plant height, grain yield, fodder yield and 1000-grain weight as influenced by graded level of infestation

The results on reduction in height of the plant and loss in grain yield, fodder yield and 1000-grain weight as influenced by graded level of shoot bug infestation are presented below (Table 7).

4.1.2.1.1 Plant height

The maximum plant height (210.5 cm) was recorded in control treatment(no infestation with cage) followed by release of 5 first instar nymphs per plant (205.2 cm) which were significantly superior to remaining treatments and were on par with each other.Among the remaining treatments release of 10, 15, 20 and 25 first instar nymphs per plant recorded the plant height of 196.4, 189.3, 182.4, 175.3 cm, respectively and differed statistically from each other.The highest in reduction in plant height (170.7 cm) was noticed in the treatment with release of 30 first instar nymphs per plant which was on par with release of 25 first instar nymphs per plant.The correlation coefficient between shoot bug incidence and plant height was negative and highly significant (r = - 0.98).

4.1.2.1.2 Grain yield

The highest grain yield of 42.7 g per plant was recorded in control treatment(no infestation with cage) followed by release of 5 first instar nymphs per plant (39.7 g/plant) and both were on par with each other. While, the latter treatment was on par with release of 10 first instar nymphs per plant (35.6 g/plant). The next best treatments in this regard were release of 15 first instar nymphs per plant and release of 20 first instar nymphs per plant with 31.0 and 27.7 g per plant, respectively. The lowest grain yield(20.7 g/plant) was obtained in the treatment with release of 30 first instar nymphs per plant and it was on par with release of 25 first instar nymphs per plant (24.2 g/plant) which in turn was on par with release of 20 first instar nymphs per plant (Fig 2).The correlation coefficient between shoot bug population and grain yield was negative and highly significant (r = - 0.97).

With respect to avoidable loss, highest loss was recorded in the treatments with release of 30 and 25 first instar nymphs per plant (51.5 and 43.3 % respectively). Remaining treatments with release of 20, 15, 10 and 5 first instar nymphs per plant recorded gradually decreasing avoidable loss of 35.1, 27.4, 16.6 and 7.0 per cent, respectively.

4.1.2.1.3 Fodder yield

The control treatment with no infestation recorded significantly higher fodder yield of 60.3 g per plant as compared to any other treatments. The treatments with release of 5 and 10 first instar nymphs per plant recorded fodder yield of 54.7 and 50.5 g per plant, respectively and were on par with each other.The treatments with release of 15 and20 first instar nymphs per plant were on par with each other by recording fodder yield of 44.8 and 39.7 g per plant, respectively. The treatment with release of 30 first instar nymphs per plant recorded lowest fodder yield (30.5 g/plant) and was on par

Table 7: Plant height, grain yield, fodder yield and 1000 grain weight as influenced by graded level of infestation

Sl. No.	Treatment (Number of first instar nymphs/ plant)	Plant height (cm)	Grain yield (g/plant)	% Avoidable loss	Fodder yield (g/plant)	% Avoidable loss	1000 Grain weight (g)	% Avoidable loss
1	5	205.2 [a]	39.7 [ab]	7.0	54.7 [b]	9.3	29.4 [ab]	2.3
2	10	196.4 [b]	35.6 [b]	16.6	50.5 [b]	16.3	27.8 [bc]	7.6
3	15	189.3 [c]	31.0 [c]	27.4	44.8 [c]	25.7	27.3 [c]	9.3
4	20	182.4 [d]	27.7 [cd]	35.1	39.7 [cd]	34.2	26.2 [cd]	13.0
5	25	175.3 [e]	24.2 [de]	43.3	34.8 [de]	42.3	25.9 [cd]	14.0
6	30	170.7 [e]	20.7 [e]	51.5	30.5 [e]	49.4	25.2 [d]	16.3
7	Control	210.5 [a]	42.7 [a]	-	60.3 [a]	-	30.1 [a]	-
	S. Em. ±	2.2	1.4	-	1.8	-	0.6	-
	C. D. (0.05)	6.7	4.4	-	5.4	-	1.7	-
Correlation coefficient (r) with shoot bugs		- 0.98 **	- 0.97 **	-	- 0.98 **	-	- 0.98 **	-

Values in the column followed by common alphabets are non significant at p=0.05 as per DMRT. ** Significant at 1 and 5% level with release of 25 first instar nymphs per plant (34.8 g/plant) and both were on par with each other (Fig 2).The latter treatment in turn was on par with release of 20 first instar nymphs per plant.The correlation coefficient worked out between shoot bug population and fodder yield was negative and highly significant (r = - 0.98).

With respect to per cent avoidable loss, highest loss was recorded in the treatments with 30 and 25 first instar nymphs per plant with 49.4 and 42.3 per cent, respectively.The per cent loss gradually increased with increase in number of nymphs released *i.e.,* 5, 10, 15 and 20 nymphs per plant exhibited avoidable loss of 9.3, 16.3, 25.7 and 34.2 per cent, respectively.

4.1.2.1.4 1000-grain weight

The treatment with no infestation of shoot bug was significantly superior over all other treatments by recording highest 1000-grain weight of 30.1 g except the treatment with release of 5 first instar nymphs per plant which recorded 1000-grain weight of 29.4 g.The latter treatment was on par with release of 10 first instar nymphs per plant by recording 27.8 g of 1000-grain weight. The 1000-grain weight was unaffected by the release of 10, 15, 20 and 25 first instar nymphs per plant with 27.8, 27.3, 26.2 and 25.9 g, respectively.Release of 30 first instar nymphs per plant recorded least 1000-grain weight of 25.2 g and was on par with release of 20 and 25 first instar nymphs per plant (Fig 2). The correlation coefficient worked out between shoot bug population and 1000-grain weight was negative and highly significant (r = - 0.98).

The highest per cent of avoidable loss was recorded in treatment with release of 30 first instar nymphs per plant (16.3 %) and it gradually decreased with release of 25, 20, 15, 10 and 5 first instar nymphs per plant accounting for 14.0, 13.0, 9.30, 7.6 and 2.3 per cent respectively.

4.1.2.2 Pest incidence and reduction in grain and fodder yield as influenced by graded level of infestation

The results with respect to shoot bug population, reduction grain and fodder yield are presented in Table 8.

4.1.2.2.1 Shoot bug population

The treatments with release of 30 first instar nymphs per plant recorded significantly higher mean shoot bug population per plant (62.5) followed by treatments with release of 25, 20, 15, 10 and 5 first instar nymphs per plant with 49.3, 41.3, 35.6, 28.5 and 22.6, respectively.The control treatment (no infestation with cage) was kept free from shoot bugs.

4.1.2.2.2 Reduction in grain yield

The highest reduction in grain yield to the extent of 22.00 g per plant was recorded in treatment with release of 30 first instar nymphs per plant which was significantly superior over all other treatments except treatment with release of 25 first instar nymphs per plant (18.5 g/plant) which in turn was on par with release of 20 first instar nymphs per plants by recording reduced grain yield of 15.0 g per plant. The treatments with release of 10, 5 nymphs per plant were on par with each other by recording least reduction in grain yield to tune of 7.1 and 3.0 g per plant, respectively which were significantly superior over all other treatments.

The lowest reduction in grain yield was observed in treatments with release of 5 and 10 first instar nymphs per plants with 7.1 and 16.4 per cent, respectively and were significantly superior over rest of the treatments. Release of 15, 20, 25 and 30 first instar nymphs reflected in reduction of 27.5, 34.9, 43.3 and 51.3 per cent respectively.

4.1.2.2.3 Reduction in fodder yield

The treatment with release of 5 and 10 first instar nymphs per plant recorded significantly least reduction in fodder yield(5.6 and 9.9 g per plants respectively) and were on par with each other. The treatment with release of 15 first instar nymphs per plant recorded 15.5 g reduction in fodder yield and was on par with release of 10 and 20 first instar nymphs per plant.

The treatments with release of 30 first instar nymphs per plant was significantly inferior by recording the highest reduction in fodder yield of 29.8 g per plant followed by treatment with release of

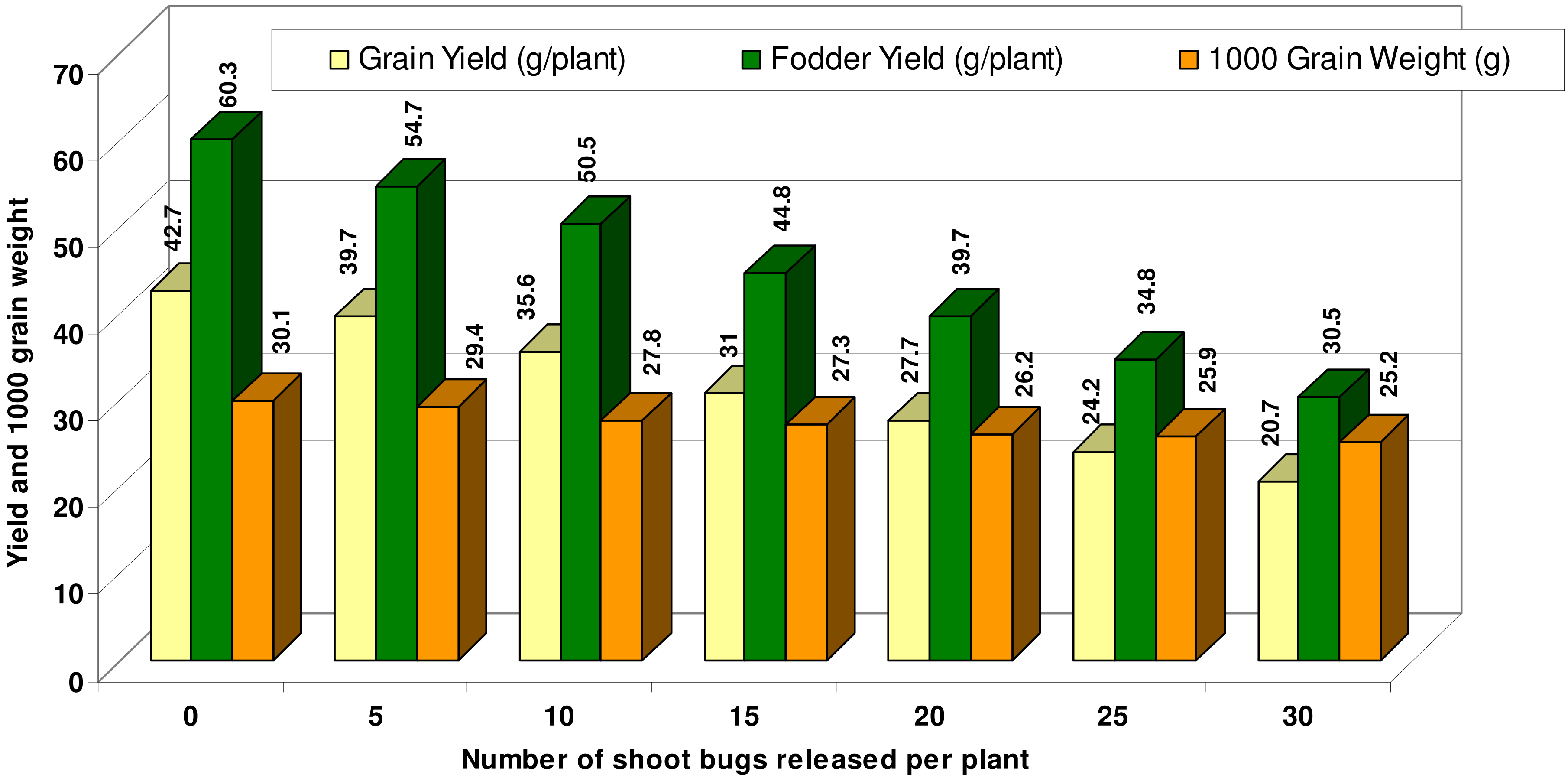


Fig. 2: Grain yield, fodder yield and 1000 grain weight as influenced by artificial release of shoot bugs

Table 8: Pest incidence and reductions in grain and fodder yield as influenced by graded level of infestation

Sl. No.	Treatment (number of first instar nymphs/ plant)	Shoot bug population count/plant *	Reduction in grain yield (g/plant)	% Reduction in grain yield	Reduction in fodder yield (g/plant)	% Reduction in fodder yield
1	5	22.6 [b]	3.0 [d]	7.1 [d]	5.6 [e]	9.1 [e]
2	10	28.5 [c]	7.1 [d]	16.4 [d]	9.9 [de]	16.3 [de]
3	15	35.6 [d]	11.7 [c]	27.5 [c]	15.5 [cd]	25.5 [cd]
4	20	41.3 [e]	15.0 [bc]	34.9 [bc]	20.6 [bc]	33.9 [bc]
5	25	49.3 [f]	18.5 [ab]	43.3 [ab]	25.5 [ab]	42.3 [ab]
6	30	62.5 [g]	22.0 [a]	51.3 [a]	29.8 [a]	49.7 [a]
7	Control	00.0 [a]	-	-	-	-
S. Em. ±		1.8	1.4	3.3	1.8	3.1
C. D. (0.05)		5.8	4.5	10.4	5.8	9.7

* Average of three observations

Values in the column followed by common alphabets are non significant at p=0.05 as per DMRT

25 first instar nymphs per plant which were on par with each other. The latter was on par with release of 20 first instar nymphs per plant by recording reduction in fodder yield of 20.6 g per plant.

4.1.2.3 Economic injury level

The data from the experiment on crop loss estimation due to graded level of infestation was used to compute economic injury level.The regression equation obtained was Y = - 0.20 + 0.15 x.Two sprays were required to keep the crop completely free from shoot bug and the insecticide and its application cost worked out to Rs. 424 per hectare.The cost of sorghum grain and fodder was taken as Rs. 850 and Rs. 55 per quintal, respectively.The economic injury level computed worked out to be 3.13 bugs per plant (GT= 0.47).

4.2 SCREENING OF SORGHUM LINES AGAINST SHOOT BUG

Totally 80 sorghum lines were screened against shoot bug under field conditions. The results obtained are furnished in Table 9.

4.2.1 Varietal reaction

Among the 80 genotypes screened against shoot bug, the lines *viz*., 61508, 61526, 61543, 61544, 61576, 61582, 61587, 61588, 61590, 61592, 61595, 61596, 61607, 61608, 61611, 61612, CK 60B,Swati, and RS 29were promising against shoot bug by recording lower population(less than 2 shoot bugs/plant).The entries, 61504, 61506, 61516, IS 37190, DSV 4, DSV 5, Hathi kunta and M 35-1 were highly susceptible by recording higher population (10.3 to 12.5 shoot bugs/plant).The rest of the entries recorded shoot bug populations between 2 to 10/plant.

4.2.2 Causes of resistance

Based on preliminary screening results, twenty genotypes with varied level of shoot bug infestation were selected for ascertaining the probable cause of resistance.

4.2.2.1 Biophysical basis of resistance

Twenty genotypes comprising of resistant, susceptible and very susceptible to shoot bug were selected from 80 entries screened and their morphological characters are presented in Table 10. It is very clear from the data that, there was no significant correlation between any of the morphological characters and shoot bug incidence. However, plant height, distance between two leaves and leaf angle correlated positively with shoot bug incidence. The genotypes 61507, 61512 having less plant height (cm), distance between two leaves and leaf angle (39.2cm, 4.9cm, 66.1º, and 41.9cm 6.3cm, and 58.6º respectively) recorded low shoot bug population of 2.6 and 2.8 respectively over other plants having more plant height, distance between leaves and leaf angle (DSV 5 and DSV 4). Whereas, number of leaves negatively correlated with shoot bug population per plant. The genotypes having less number of leaves *viz*., Hathi Kunta (6.0), 61506 (6.2) and 61532 (6.6) recorded more shoot bug population of 10.2, 12.1 and 8.2 per plant, respectively.

Table 9: Screening of sorghum lines against Shoot bug

Sl. No.	Entry	No. of shoot bugs/plant	Sl. No.	Entry	No. of shoot bugs/plant
1.	61504	10.9	42.	61578	2.7
2.	61505	4.9	43.	61579	4.3
3.	61506	12.1	44.	61580	2.0
4.	61507	2.6	45.	61581	2.2
5.	61508	1.6	46.	61582	1.1
6.	61510	5.4	47.	61587	1.4
7.	61511	6.4	48.	61588	1.5

8.	61512	4.9	49.	61589	1.4
9.	61515	5.9	50.	61590	1.9
10.	61516	11.3	51.	61592	1.3
11.	61519	3.9	52.	61595	1.4
12.	61520	2.8	53.	61596	1.0
13.	61521	3.9	54.	61602	4.7
14.	61522	7.0	55.	61605	5.0
15.	61523	5.5	56.	61606	4.1
16.	61524	2.0	57.	61607	0.9
17.	61525	4.5	58.	61608	1.8
18.	61526	1.1	59.	61610	2.1
19.	61527	3.8	60.	61611	0.9
20.	61528	6.4	61.	61612	0.9
21.	61530	8.4	62.	61613	0.9
22.	61532	8.5	63.	CK 60B	0.9
23.	61533	4.1	64.	296B	3.1
24.	61540	2.3	65.	104B	8.5
25.	61543	1.3	66.	M 31-2B	2.5
26.	61544	1.9	67.	SPV 1626	5.4
27.	61547	5.2	68.	M 148-138	6.3
28.	61548	2.3	69.	RS 615	7.2
29.	61551	5.3	70.	IS 37190	12.1
30.	61556	4.5	71.	JP 1-1-5	9.3
31.	61557	9.4	72.	Swati (SPV-504)	0.5
32.	61558	7.9	73.	DSV 4	12.5
33.	61559	7.7	74.	DSV 5	10.3
34.	61562	5.2	75.	SFR 7	7.3
35.	61566	4.7	76.	M 35-1	11.5
36.	61567	5.0	77.	Hathi Kunta (S)	10.2
37.	61568	5.6	78.	RS-29 (R)	1.9
38.	61569	6.1	79.	IS-2312	4.1
39.	61570	7.4	80.	DJ-6514	4.2
40.	61573	4.9		S. Em. ±	0.9
41.	61576	1.3		C. D. (5%)	2.6

Table 10: Shoot bug incidence and morphological characters in selected genotypes and correlations

Sl. No.	Genotype	Shoot bug population (no./plant)	Plant height (cm)	Distance between leaves (cm)	No. of leaves/ plant	Leaf angle (degrees)
1	104B	8.5	93.4	18.2	7.6	72.3
2	M 31-2B	2.5	133.0	14.6	11.0	74.5
3	RS 29	1.9	99.4	14.4	8.2	63.3
4	SPV 1626	5.4	179.2	18.2	10.0	68.5

5	M 148-138	6.3	126.6	17.8	7.6	66.8
6	RS 615	7.2	119.4	14.2	9.4	65.4
7	IS 2312	4.1	131.2	14.0	10.6	66.3
8	IS 37190	12.1	153.8	14.2	9.8	64.0
9	JP 1-1-5	9.3	142.2	12.4	13.2	62.8
10	M 35-1	11.5	134.2	16.8	9.0	70.8
11	DSV 4	12.5	140.6	16.2	9.6	69.7
12	DSV 5	10.3	162.0	14.6	11.0	62.7
13	SFR 7	7.3	167.2	19.8	9.0	61.6
14	61505	4.9	78.0	9.0	8.4	72.8
15	61506	12.1	71.0	11.4	6.2	72.6
16	61507	2.6	39.2	4.9	11.2	66.1
17	61512	2.8	41.9	6.3	9.8	58.6
18	61532	8.2	99.0	13.5	6.6	74.5
19	61551	5.3	81.8	10.9	7.6	69.9
20	Hathi Kunta	10.2	85.2	21.8	6.0	79.0
Correlation coefficient (r) with shoot bugs		-	+ 0.34	+ 0.41	- 0.21	+ 0.22

4.2.2.2 Biochemical basis of resistance

Twenty genotypes with varied degree of resistance were selected from 80 genotypes screened and their biochemical constituents are presented in Table 11.From the Table it is clearly evident that there was no significant correlation between any of the biochemical constituents and shoot bug population per plant.However, reducing sugar (%) was positively but non-significantly correlated with shoot bug population.The genotypes having less reducing sugar per cent *viz*., SPV 1626, (0.95%), JP 1-1-5 (1.0%) DSV 4 (1.27%) and 104B (1.46) recorded 5.4, 9.3, 12.5 and 8.5 shoot bug population per plant over the genotypes having more reducing sugar per cent *i.e.* Hathi Kunta (2.41%) and DSV 5 (2.71%) which recorded 10.2 and 10.3 shoot bugs per plant.Whereas, total sugars and total phenols negatively correlated with the shoot bug incidence.All these constituents *viz*., total sugar per cent was less in genotypes M 35-1 (4.69%),61532 (4.92%) and IS 37190(4.94%) which recorded 11.5, 8.2 and 12.1 shoot bug population per plant.With respect to total phenols, the genotypes with less total phenols *viz*., IS 37190 (2.26 mg/g), DSV-4 (2.96 mg/g) and M 35-1 (2.76 mg/g) recorded more shoot bug population of 12.1, 12.5 and 11.5 per plant, respectively over the genotypes having more total phenols (mg/g) *viz*., 61507 (3.43 mg/g) and 61505 (3.0 mg/g) which recorded less shoot bug population of 2.6 and 4.9 per plant, respectively.

4.3 MANAGEMENT OF SHOOT BUG *P. maidis* WITH INSECTICIDES

A field experiment was carried out for the management of shoot bug with 11 insecticidal treatments (consisting of seven seed dressers, one each soil application, whorl application, spray and untreated check) (Plate 3).

Table 11: Chemical constituents in leaves of selected genotypes and correlations with shoot bugs

Sl. No.	Genotype	Shoot bug population (no./plant)	Reducing sugars (%)	Total sugars (%)	Total phenols (mg/g)
1	104B	8.5	1.46	5.43	3.06
2	M 31-2B	2.5	1.17	5.49	2.80
3	RS 29	1.9	2.03	5.14	2.96
4	SPV 1626	5.4	0.95	5.73	2.77
5	M 148-138	6.3	1.17	4.76	2.72
6	RS 615	7.2	1.27	5.17	2.73
7	IS 2312	4.1	1.17	5.16	2.16
8	IS 37190	12.1	1.77	4.94	2.26
9	JP 1-1-5	9.3	1.01	4.72	3.06
10	M 35-1	11.5	1.54	4.69	2.76
11	DSV 4	12.5	1.27	5.65	2.96
12	DSV 5	10.3	2.71	5.73	2.66
13	SFR 7	7.3	2.51	5.64	2.98
14	61505	4.9	1.63	5.61	3.01
15	61506	12.1	1.54	5.64	3.40
16	61507	2.6	1.24	4.96	3.43
17	61512	2.8	2.01	5.66	2.92
18	61532	8.2	1.96	4.92	2.92
19	61551	5.3	2.12	5.32	3.16
20	Hathi Kunta	10.2	2.41	5.78	3.15
Correlation coefficient (r) with shoot bugs		-	+ 0.14	- 0.02	- 0.05

Plate 3: General view of the shoot bug management trial

Table 12: Efficacy of various insecticides against shoot bug, *P. maidis* on *rabi* sorghum

Tr. No.	Treatments	Method of application	Dosage	Shoot bug population per 5 plants at			
				30 DAG	40 DAG	50 DAG	60 DAG
T_1	Imidacloprid 70 WS	Seed dressing	2 g/kg seeds	15.17 cd	17.93 bc	20.73 bc	25.83 b
T_2	Imidacloprid 70 WS	Seed dressing	5 g/kg seeds	9.23 ab	14.10 ab	17.23 ab	21.33 ab
T_3	Thiamethoxam 70 WS	Seed dressing	2 g/kg seeds	12.50 bc	16.30 b	19.30 ab	24.80 b
T_4	Thiamethoxam 70 WS	Seed dressing	3 g/kg seeds	7.80 a	12.33 a	15.60 a	18.53 a
T_5	Carbosulfan 25 DS	Seed dressing	20 g/kg seeds	10.33 ab	14.33 ab	19.57 abc	23.40 ab
T_6	Chlorpyriphos 20 EC	Seed dressing	5 ml + 20 ml water/ kg seeds	18.53 de	22.23 de	28.50 ef	33.40 cd
T_7	Imidacloprid 17.8 SL	Seed dressing	2 ml + 20 ml water/ kg seeds	18.37 de	21.33 cd	25.73 de	32.33 c
T_8	Phorate 10 G	Soil application	20 kg/ha	20.53 e	25.53 e	30.43 f	35.73 cd
T_9	Carbofuran 3 G at 25 DAG	Whorl application	8 kg/ha	18.23 de	20.53 cd	23.47 cd	25.50 b
T_{10}	Endosulfan 35 EC at 25 DAG	Spray	2 ml/l	20.13 e	23.47 de	30.73 f	37.73 d
T_{11}	Untreated Check	-	-	56.40 f	58.13 f	55.67 g	56.10 e
S. Em. ±				1.55	1.32	1.36	1.80
C. D. (0.05)				4.60	3.90	4.00	5.30

Values in the column followed by common alphabets are non significant at p=0.05 as per DMRT. DAG- Days after germination

4.3.1 Efficacy of insecticides against shoot bug

Efficacy of insecticidal treatments against shoot bug population per five plants recorded at 30, 40, 50 and 60 days after germination are presented in Table 12.

4.3.1.1 Efficacy of insecticides against shoot bug at 30 days after germination

All the insecticidal treatments (7.80 to 20.53/ 5 plants) were found to be significantly superior in reducing the shoot bug population as compared to untreated check (56.40/ 5 plants). The lowest shoot bug population of 7.80 per five plants was recorded in seed dressing with thiamethoxam 70 WS @ 3 g per kg seeds and was on par with imidacloprid 70 WS seed dressing @ 5 g per kg seeds (9.23/ 5 plants) and carbosulfan 25 DS seed dressing @ 20 g per kg seeds (10.33/ 5 plants). The next best treatments in this respect were thiamethoxam 70 WS @ 2 g per kg seeds and imidacloprid 70 WS @ 2 g per kg seeds by recording 12.50 and 15.17 shoot bugs per five plants, respectively.Whereas, the bug population in carbofuran 3 G whorl application(@ 8kg/ha) at 25 days after germination, seed dressing with imidacloprid 17.8 SL @ 2 ml in 20 ml of water per kg seeds and chlorpyriphos 20 EC @ 5 ml in 20 ml water per kg seeds recorded 18.23, 18.37 and 18.53 shoot bugs per five plants, respectively and they were at par with each other. This was followed by the soil application of phorate 10 G@ 20 kg per ha and endosulfan 35 EC spray @ 2 ml per litre at 25 days after germination by recording 20.53 and 20.13 shoot bug population per five plants, respectively which were on par with each other.

4.3.1.2 Efficacy of insecticides against shoot bug at 40 days after germination

All the insecticidal treatments were found to be significantly superior in reducing the shoot bug population as compared to untreated check (58.13/5 plants). Among the remaining treatments, thiamethoxam 70 WS seed treatment @ 3 g per kg seeds was significantly superior by recording least number of shoot bug population (12.33/5 plants) and was on par with imidacloprid 70 WS @ 5 g per kg seeds and carbosulfan 25 DS @ 20 g per kg seeds by recording 14.10 and 14.33 shoot bug population per five plants, respectively. This was followed by thiamethoxam and imidacloprid 70 WS @ 2 g per kg seed dressing by recording shoot bug population of 16.30 and 17.93 per five plants, respectively and they were at par with each other. Whereas, shoot bug population in carbofuran 3G whorl application (@ 8kg/ha) at 25 days after germination and imidacloprid 17.8 SL @ 2 ml in 20ml water seed dressing recorded was 20.53 and 21.33 shoot bugs per five plants, respectively and both were on par with imidacloprid 70 WS @ 2 g per kg seed dressing. The soil application of phorate 3 G @ 20 kg per ha was least effective by recording 25.53 shoot bugs per five plants followed by endosulfan 35 EC spray at 25 day after germination (@ 2ml/l) and chlorpyriphos 20 EC seed dressing @ 5 ml in 20ml water by recording 23.47 and 22.23 shoot bugs per five plants and all these three treatments were on par with each other.

4.3.1.3 Efficacy of insecticides against shoot bug at 50 days after germination

All the insecticidal treatments were found to be promising in reducing the shoot bug population as compared to untreated check, which recorded 55.67 shoot bug population per five plants at 50 days after germination. The lowest shoot bug population 15.60 per five plants was recorded in thiamethoxam 70 WS @ 3 g per kg seeds and it at par with imidacloprid 70 WS @ 5 g per kg seeds, thiamethoxam 70 WS @ 2 g per kg seeds and carbosulfan 25 DS @ 20 g per kg seeds by recording 17.23, 19.30 and 19.57 shoot bugs per five plants, respectively. The latter three treatments were on par with imidacloprid 70 WS @ 2 g per kg seeds (20.73/ 5 plants). The mean shoot bug population in whorl application of carbofuran 3G @ 8 kg/ha at 25 days after germination and imidacloprid 17.8 SL @ 2 ml in 20 ml of water seed dressing recorded 23.47 and 25.73 per five plants respectively. The least effective treatments included spray with endosulfan 35 EC @ 2 ml per litre at 25 days after germination, soil application of phorate 10 G @ 20 kg/ha and seed dressing of chlorpyriphos 20 EC @ 5 ml in 20 ml of water by recording 30.73, 30.43 and 28.50 shoot bugs per five plants and were on par with each other.

4.3.1.4 Efficacy of insecticides against shoot bug at 60 days after germination

At 60 days after germination, all the insecticidal treatments were found to be significantly superior in reducing the shoot bug population as compared to untreated check (56.10/ 5 plants). The lowest shoot bug population (18.53/ 5 plants) was recorded in thiamethoxam 70 WS @ 3 g per kg

Table 13: Efficacy of various insecticides used in the management of shoot bug, *P. maidis* on sorghum stripe disease, panicle emergence and yield

Tr. No.	Treatments	Method of application	Dosage	Disease incidence (%)	Panicle emergence (%)	Grain yield (q/ha)	Fodder yield (t/ha)
T_1	Imidacloprid 70 WS	Seed dressing	2 g/kg seeds	12.53 (20.70) [d]	95.20 (77.43) [a]	18.23 [a-d]	5.50 [bc]
T_2	Imidacloprid 70 WS	Seed dressing	5 g/kg seeds	4.33 (12.00) [b]	96.70 (79.87) [a]	19.43 [ab]	6.03 [ab]
T_3	Thiamethoxam 70 WS	Seed dressing	2 g/kg seeds	8.97 (17.40) [c]	95.43 (78.07) [a]	18.53 [a-c]	5.60 [bc]
T_4	Thiamethoxam 70 WS	Seed dressing	3 g/kg seeds	2.57 (9.17) [a]	97.30 (80.63) [a]	20.13 [a]	6.23 [a]
T_5	Carbosulfan 25 DS	Seed dressing	20 g/kg seeds	7.30 (15.63) [c]	96.23 (78.90) [a]	19.27 [ab]	5.70 [a-c]
T_6	Chlorpyriphos 20 EC	Seed dressing	5 ml + 20 ml water/ kg seeds	20.53 (26.90) [ef]	93.73 (75.63) [a]	15.23 [de]	4.50 [d]
T_7	Imidacloprid 17.8 SL	Seed dressing	2 ml + 20 ml water/ kg seeds	17.83 (25.00) [e]	94.43 (76.77) [a]	15.53 [cd]	4.20 [d]
T_8	Phorate 10 G	Soil application	20 kg/ha	22.73 (28.47) [f]	94.23 (76.50) [a]	16.73 [b-d]	4.73 [d]
T_9	Carbofuran 3 G at 25 DAG	Whorl application	8 kg/ha	13.13 (21.23) [d]	95.13 (77.43) [a]	17.30 [a-d]	5.33 [c]
T_{10}	Endosulfan 35 EC at 25 DAG	Spray	2 ml/l	23.53 (29.03) [f]	94.57 (76.63) [a]	16.53 [b-d]	4.63 [d]
T_{11}	Untreated Check	-	-	30.43 (33.47) [g]	85.77 (67.90) [b]	12.13 [e]	3.23 [e]
S. Em. ±				0.85	1.73	1.05	0.19
C. D. (0.05)				2.50	5.10	3.11	0.56

* Figures in the parentheses are arc sin transformations
Values in the column followed by common alphabets are non significant at p=0.05 as per DMRT

seeds and this was at par with imidacloprid 70 WS@ 5 g per kg seeds and carbosulfan 25 DS @ 20 g per kg seeds by recording 21.33 and 23.40 shoot bugs per five plants. The next best effective treatments were thiamethoxam 70 WS @ 2 g per kg seeds, whorl application of carbofuran 3G @ 8 kg/ha at 25 days after germination and imidacloprid 70 WS @ 2 g per kg seeds by recording 24.80, 25.50 and 25.83 shoot bugs per five plants, respectively and these were at par with each other. Whereas, the treatments with spraying of endosulfan 35 EC (@ 2 ml/l) at 25 days after germination, soil application of phorate 10 G @ 20 kg/ha and seed dressing with chlorpyriphos 20 EC @ 5 ml in 20 ml of water were least effective by recording 37.73, 35.73 and 33.40 shoot bug population per five plants, respectively and were on par with each other.

4.3.2 Effect of insecticides on sorghum stripe disease, panicle emergence and yield

The results on effect of various insecticides on disease incidence, panicle emergence and yield (both grain and fodder) are presented in Table 13.

4.3.2.1 Sorghum stripe disease

All the insecticidal treatments were effective in suppressing the sorghum stripe disease expression as compared to untreated check, which recorded relatively higher disease incidence (30.43%).Significantly lower disease incidence (2.5%) was observed in seed dressing with thiamethoxam 70 WS seed dressing @ 3 g per kg seeds in comparison with other insecticidal treatments.Among the remaining treatments, the next best chemical treatment in suppressing the disease was seed dressing with imidacloprid 70 WS @ 5 g per kg seeds (4.33%).This was followed by seed dressing with carbosulfan 25 DS @ 20 g per kg seeds and thiamethoxam 70 WS @ 2 g per kg seeds which were equally effective by recording 7.30 and 8.97 per cent disease incidence, respectively.The seed dressing with imidacloprid 70 WS @ 2 g per kg seeds and whorl application of carbofuran 3 G @ 8 kg per ha at 25 days after germination recorded 12.53 and13.13 per cent disease incidence, respectively and they were at par with each other.The insecticidal treatments which were comparatively less effective by showing relatively higher disease incidence included spraying of endosulfan 35 EC (2ml/l) at 25 days after germination, soil application of phorate 10 G @ 8 kg per ha and seed dressing with chlorpyriphos 20 EC @ 5 ml in 20 ml of water with 23.53, 22.73 and 20.53 per cent disease incidence, respectively and were on par with each other (Table 13 and Fig 3).

4.3.2.2 Panicle emergence

All the plots with different chemical treatments showed satisfactorily higher panicle emergence from 93.73 to 97.30 per cent and were statistically superior over untreated check (85.77%).Among all the insecticidal treatments, maximum panicle emergence was noticed in seed dressing with thiamethoxam 70WS @ 3 g per kg seeds (97.30%) followed by imidacloprid 70 WS seed treatment @ 5 g per kg seeds (96.70%) and carbosulfan 25DS @ 20 g per kg seeds (96.23%), respectively.

4.3.2.3 Grain yield

The grain yield recorded in all the insecticidal treatments was comparatively more ranging from 16.53 to 20.13 q ha^{-1} over the untreated check which recorded significantly lower grain yield of 12.13 q ha^{-1}.Among all the treatments, the maximum grain yield of 20.13 q $ha^{-1}$was harvested in seed treatment with thiamethoxam 70 WS @ 3 g per kg seed and it was at par with seed dressing with imidacloprid 70 WS @ 5 g per kg, carbosulfan 25 DS @ 20 g per kg seeds, thiamethoxam @ 2 g per kg seed and imidacloprid 70 WS @ 2 g per kg seeds and whorl application of carbofuran 3 G @ 8 kg/ha at 25 days after germination by harvesting grain yield of 19.43, 19.27, 18.53, 18.23 and 17.30 q ha^{-1}, respectively.The latter three treatments were on par with soil application of phorate 10 G @ 20 kg /ha and spraying of endosulfan 35 EC @ 2 ml/l at25 days after germination with 16.73 and 16.53 q ha^{-1}, respectively.The least effective treatments included seed dressing with imidacloprid 17.8 SL @ 2 ml in 20 ml of water and chlorpyriphos 20 EC @ 5 ml in 20 ml of water by harvesting lowest grain yield of 15.53 and 15.23 q ha^{-1}, respectively (Fig 3).

4.3.2.4 Fodder yield

All the insecticidal treatments were significantly superior in reaping the higher fodder yield ranging from 4.20 to 6.23 t ha^{-1} as compared to untreated check which reaped lowest fodder yield of 3.23 t ha^{-1}.The treatment with thiamethoxam 70 WS @ 3 g per kg seeds produced higher fodder yield of 6.23 t ha^{-1} which was at par with seed dressing by imidacloprid 70 WS @ 5 g per kg seeds and carbosulfan 25 DS @ 20 g per kg seeds by harvesting 6.03 and 5.70 t ha^{-1}, respectively.The latter two treatments were at par with seed dressing by thiamethoxam 70 WS @ 2 g kg seeds and imidacloprid 70 WS @ 2 g per kg seeds by harvesting fodder yield of 5.60 and 5.50 t ha^{-1}, respectively. The next best treatment in this respect included whorl application of carbofuran 3 G @ 8 kg par ha at 25 days after germination by recording fodder yield of 5.33 t ha^{-1} and was significantly superior over soil application of phorate 10 G @ 20 kg per ha, spraying of endosulfan35 EC @ 2 ml/l at 25 days after germination, chlorpyriphos 20 EC @ 5 ml in 20 ml water per kg seed dressing and imidacloprid 17.8 SL @ 2 ml in 20 ml water per kg seed dressing with fodder yield of 4.73, 4.63, 4.50 and 4.80 t ha^{-1}, respectively (Fig 3).The latter four treatments were at par with each other.

4.3.3 Economics of shoot bug, *P. maidis* management

4.3.3.1 Gross returns

On the basis of harvested yield (both fodder and grain yield) of all the imposed treatments, the best treatment was seed dressing with thiamethoxam 70 WS @ 3 g per kg seeds by recording highest gross returns of Rs. 20,542 ha^{-1} which was significantly superior over other treatments except the seed treatment by imidacloprid 70 WS @ 5 g per kg seeds, carbosulfan 25 DS @ 20 g per kg seeds, seed dressing by thiamethoxam 70 WS @ 2 g kg seeds and imidacloprid 70 WS @ 2 g per kg seeds with Rs. 19837, 19512, 18833, 18523 ha^{-1}, respectively (Table 14).The remaining treatments *viz.,* whorl application of carbofuran 3 G @ 8 kg par ha at 25 days after germination, soil application of phorate 10 G @ 20 kg per ha, spraying of endosulfan 35 EC @ 2 ml /l at 25 days after germination, imidacloprid 17.8 SL @ 2 ml in 20 ml water per kg seed dressing and chlorpyriphos 20 EC @ 5 ml in 20 ml water per kg seed dressing recorded gross returns of Rs. 17638, 16827, 16602, 15513 and 15423 ha^{-1} respectively and were at par with each other.

4.3.3.2 Net profit

The seed treatment by thiamethoxam 70 WS @ 3 g per kg seeds resulted in higher net profits of Rs. 15902 ha^{-1} which was on par with the seed treatment by carbosulfan 25 DS @ 20 g per kg seeds, imidacloprid 70 WS @ 5 g per kg seeds, imidacloprid 70 WS @ 2 g per kg seeds, thiamethoxam 70 WS @ 2 g kg seeds and whorl application of carbofuran 3 G @ 8 kg par ha at 25 days after germination with Rs. 15772, 15437, 14663, 14573 and 13458 ha^{-1}, respectively (Table 14).The remaining treatments *viz.,* spraying of endosulfan 35 EC @ 2 ml /l at 25 days after germination, soil application of phorate 10 G @ 20 kg per ha, imidacloprid 17.8 SL @ 2 ml in 20 ml water per kg seed dressing and chlorpyriphos 20 EC @ 5 ml in 20 ml water per kg seed dressing recorded lesser net profit of Rs. 12890, 12327, 11893 and 11868 ha^{-1}, respectively and were on par with each other.

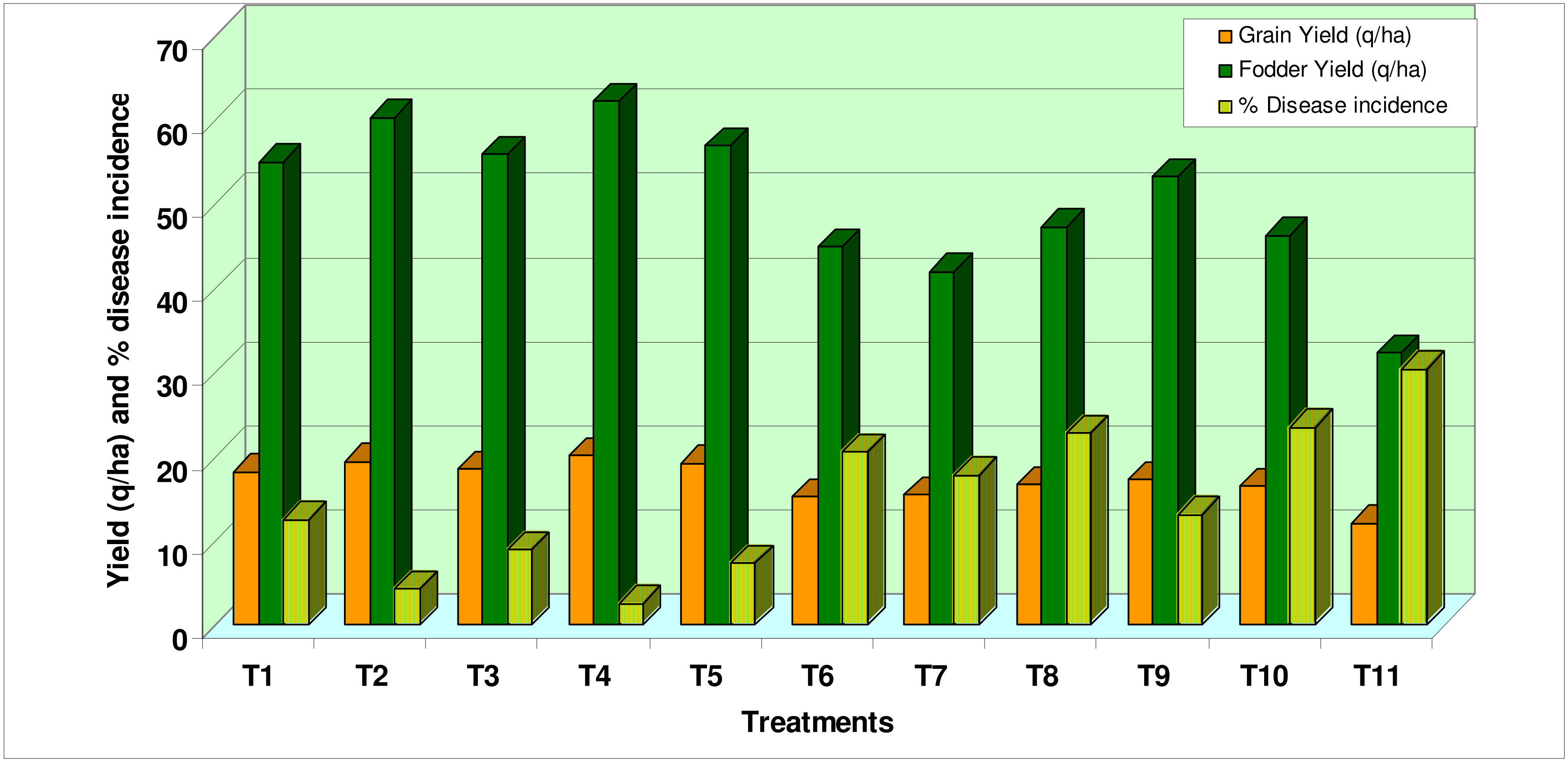


Fig. 3: Grain yield, fodder yield and stripe disease incidence as influenced by insecticidal treatments

Table 14: Economics of shoot bug, *P. maidis* management on sorghum in *rabi* season

Tr. No.	Treatments	Method of application	Dosage	Gross returns (Rs.)	Cost involved (Rs.)		Total cost (Rs.)	Net profit (Rs.)
					Shoot bug management	Other expenditures		
T_1	Imidacloprid 70 WS	Seed dressing	2 g/kg seeds	18523 [a-c]	360	3500	3860	14663 [a-c]
T_2	Imidacloprid 70 WS	Seed dressing	5 g/kg seeds	19837 [ab]	900	3500	4400	15437 [ab]
T_3	Thiamethoxam 70 WS	Seed dressing	2 g/kg seeds	18833 [a-c]	760	3500	4260	14573 [a-c]
T_4	Thiamethoxam 70 WS	Seed dressing	3 g/kg seeds	20542 [a]	1140	3500	4640	15902 [a]
T_5	Carbosulfan 25DS	Seed dressing	20 g/kg seeds	19512 [ab]	240	3500	3740	15772 [a]
T_6	Chlorpyriphos 20 EC	Seed dressing	5 ml + 20 ml water/ kg seeds	15423 [d]	55	3500	3555	11868 [d]
T_7	Imidacloprid 17.8 SL	Seed dressing	2 ml + 20 ml water/ kg seeds	15513 [d]	120	3500	3620	11893 [d]
T_8	Phorate 10 G	Soil application	20 kg/ha	16827 [cd]	1000	3500	4500	12327 [cd]
T_9	Carbofuran 3 G at 25 DAG	Whorl application	8 kg/ha	17638 [b-d]	680	3500	4180	13458 [a-d]
T_{10}	Endosulfan 35 EC at 25 DAG	Spray	2 ml/l	16602 [cd]	212	3500	3712	12890 [b-d]
T_{11}	Untreated Check	-	-	12092 [e]	-	3500	3500	8592 [e]
	S. Em. ±			901	-	-	-	901
	C. D. (0.05)			2657	-	-	-	2657

DAG- Days after germination   Price of sorghum grains Rs. 850/q   Price of Fodder Rs. 550/t

V. DISCUSSION

Of the more than 150 species of insect pests associated with sorghum, about a dozen are economically important in India. Among several factors responsible for lowering grain and fodder yield of sorghum, shoot bug is more predominant in *rabi* season which is causing both qualitative and quantitative losses. Its incidence is noticed in a month's old crop and persists up to harvesting. As sorghum is considered as poor man's crop, marginal and sub-marginal farmers cannot make any efforts to take up control measures because of increased cost of cultivation and practical difficulties to take up control measures. Over use of pesticide has led to the outbreak of pests because of destruction of natural enemies. Also it has led to the environmental pollution, operational health hazards due to residual problems on human beings, animals and poultry.

As the sorghum shoot bug, *P. maidis* is now being considered as a key pest of sorghum in *rabi* tracts of Karnataka and information required to design management practice is scarce. Hence, it is necessary to take up detailed studies on loss estimation, screening of genotypes through analyzing biochemical and biophysical components and management of the pest through seed dressers. The results obtained are discussed here under.

5.1 LOSS ESTIMATION DUE TO SHOOT BUG

For loss estimation, the yield loss assessment data are the primary tool to design a module for insect pest management. These data are very important and considered for determining the status of the pest. Even then very few attempts have been made in the major sorghum growing areas.

The sorghum shoot bug is a major predominant production constraint in *rabi* tracts of Karnataka by causing both direct and indirect economic damage to the crop. Hence, in addition to estimating the direct loss in the form of grain yield and fodder yield, studies were also carried out on the sorghum stripe disease incidence, deposition of leaf sugary exudation and per cent plants affected by leaf sugary malady. To study these and to determine the threshold limits for decision making; experiments were carried out under protected and unprotected conditions with different sowing dates. The yield losses were also studied under caged conditions with graded level of shoot bug infestation.

5.1.1 Estimation of loss under protected and unprotected conditions with different dates of sowing

5.1.1.1 Loss in grain and fodder yield

Date of sowing and protection levels play a vital role in determining final yield of both grain and fodder. With delay in sowings, there was increased loss in grain yield, fodder yield and 1000-grain weight and decrease in panicle emergence per cent due to increased shoot bug infestation under natural conditions. It is well established fact that cloudy weather and moderate temperature prevailing in October month are most favourable for its attack on sorghum crop. Sustenance of plant to biotic stress is dependent on the growth, vigour and age of the plant. The crop that was sown late produced lower biomass (foliage area) at the time when the shoot bug population became virulent. Consequently, the increased stripe disease incidence in later dates of sowing manifested in lowering the grain and fodder yield. On the other hand, the higher and non-virulent population in early sown crop resulted in less loss in grain and fodder yield.

The grain and fodder yield, panicle emergence per centage and 1000-grain weight were very much influenced by sowing dates and protection level. Early sown crop *i.e.,* September IV week sown crop harvested more yield whereas, the crop sown during October IV week harvested less yield. This was mainly due to the prevailing abiotic factors such as cloudy weather and moderate temperature which facilitated for increased disease incidence due to shoot bug. Early sown crop escaped attack by pest with unique plant characteristics. Late sown crop suffered with more incidences which resulted in harvesting lesser yield. Protection level also determined the final yield. Unprotected plots harvested to some extent less yield over protected ones. Reduction in panicle emergence was more pronounced with delay in sowings with an average of 10.56 per cent across five sowing dates. The over all loss of 11.16, 21.11 and 2.97 per cent in the grain yield, fodder yield and 1000 grain weight respectively, was recorded under unprotected conditions as compared to protected ones across five dates of sowings. These results are in agreement with the findings of Chavan *et al.* (1959), Shivamurthappa (1989), and Raja shekar *et al.* (1997) who reported 13.82, 25.46 and 14.1 per cent reduction in grain yield respectively.

5.1.1.2 Disease incidence and leaf sugary exudates

The sorghum stripe disease (SStD) is severe in India particularly in South India, with presence of continuous chlorotic stripes and over lapping circles aligned in rows parallel to the veins progressing from the base towards the tip of leaves in early stage. In advanced stages, the stippling/ circles coalesce to form clear stripes. The affected plant at early stage started with short internodes and produced poor panicles with few grains. (Narayana and Muniyappa, 1995a). A disease characterized by chlorotic stripes and bands, named sorghum stripes disease SStD was observed on sorghum in India with an incidence of less than 0.5 to nearly 10 per cent and this disease is mainly transmitted by delphacid planthopper, *P. maidis* (Peterschmitt *et al*. 1991). The SStV is an isolate of MStV and it is transmitted in a persistent, propogative manner by delphacid plant hopper, *P. maidis* (Tsai and Zitter 1982).

The shoot bug population, per cent disease incidence, leaf sugary exudates and per cent plant affected by leaf sugary malady were altered by weekly sowing dates and protection levels. The shoot bug population was more in early sown crop as compared to late sown crop. Similarly unprotected plots harboured more population of shoot bug over protected ones. These results are in line with Borade *et al*. (1993). The cloudy weather and moderate temperature prevailing in October month favoured the more disease incidence. The crop sown during Oct. IV week under natural infestation recorded more disease incidence as compared to protected ones. Even though the shoot bug population was less in delayed sowings but might be more virulent manifesting in higher disease incidence in delayed sowings. Further, prevailing abiotic factors and physiological conditions of the sorghum plant during cold conditions led to expression of more disease incidence. Depending on the amount of sugary exudates, grading was made. The highest leaf sugary exudate was noticed in early sown crop compared to late sown crop. Unprotected plots recorded more leaf sugary exudates than the protected ones. The per cent plants affected by leaf sugary malady were also more in early sown crop under unprotected conditions as compared to late sown crop and protected ones. Hence, the protections against shoot bug are very much needed in order to prevent this malady. These results are in line with the findings of Mote and Shahane (1993) who reported that, the intensity of LSE was found to be increased with the increase in the population of delphacids.

5.1.2 Estimation of loss under caged conditions with graded level of infestation

Artificial release of insects was directly related to the reduction in grain and fodder yield. With increase in number of insects per plant there was a decrease in yield. The untreated check with no infestation with cloth cage covered recorded highest grain and fodder yield over the other treatments. As the numbers of released insects were more (30 per plant), the lowest plant height, grain and fodder yield and their highest per cent avoidable losses were recorded. The bugs are more congregating in the shoots that might have resulted in suppression of plant height. As a sucking pest it directly sucks sap and also shoot bugs reside at axial of the leaves, suck the sap from the leaves. Autumn weather like cloudy conditions, moderate temperature and physiological condition of the plant enhanced sugary secretion leading to heavy loss of fodder qualitatively and quantitatively which is having equal value as that of grain yield in *rabi* tracts of Karnataka.

The correlation coefficient between shoot bug incidence and plant height (r = - 0.98), grain yield (r = - 0.97), fodder yield (r = - 0.98) and 1000-grain weight (r = - 0.98) was negative and highly significant. The shoot bug population count per plant and per cent reductions in fodder yield were more in highest number of nymphs released plants. The per cent reduction in 5 nymphs per plant and 30 nymphs per plant recorded reduction in the grain yield of 7.1 and 51.3 per cent, respectively. In case of fodder yield also the per cent loss varied from 9.1 to 49.7 per cent with release of 5 and 30 nymphs per plant, respectively. These findings corroborate with the reports of Chavan *et al*. (1959), Shivamurthappa (1989), and Raja sekhar *et al.* (1997) who reported 13.82, 25.46 and 14.1 per cent reductions in grain yield respectively.

5.1.3 Economic injury level

In the present investigation, the economic injury level was worked out to be 3.13 shoot bugs per plant. Though economic injury level may be affected by complex interactions, serves as broad guideline for taking up management practices in semi-arid -tropics. These results are in conformity with the findings of Raja sekhar (1996) who reported 3.7 shoot bugs per plant as economic injury level on *rabi* sorghum

5.2 SCREENING OF *RABI* SORGHUM GENOTYPES AGAINST SHOOT BUG

Delphacid, *P. maidis* is a major problem in *rabi* sorghum in semiarid tracts of India. Among the 80 genotypes screened against shoot bug, the lines *viz*., 61508, 61526, 61543, 61544, 61576, 61582, 61587, 61588, 61590, 61592, 61595, 61596, 61607, 61608, 61611, 61612, CK 60B, Swati, and RS 29 were promising against shoot bug and recorded lower population (less than 2 shoot bugs/plant). The entries, 61504, 61506, 61516, IS 37190, DSV 4, DSV 5, Hathi kunta and M 35-1 were highly susceptible and recorded higher population (10.3 to 12.5 shoot bugs/plant). The results are in agreement with Mote and Shahane (1993 and 1994) and Subbarayudu (2002) with respect to M 35-1 and Swati.

5.2.1 Correlations of biochemical constituents with shoot bug

There was no significant correlation between shoot bug population and the biochemical constituents of all the 20 sorghum genotypes selected for comparison. Although, reducing sugars were positively correlated, the total sugars and total phenols negatively correlated. The genotypes having less reducing sugars *viz*., SPV 1626, JP 1-1-5 and DSV 4 and 104B recorded more infestation of shoot bug population. The total sugars and total phenols showed very weak correlations with shoot bug population. The maximum number of shoot bug population was recorded in genotypes having less total sugars (M 35-1, 61532 and IS 37190). Similarly for total phenols, the genotypes having higher bug population showed less total phenols (IS 37190, DSV 4 and M 35-1). The higher content of total phenols in the genotypes 61506, JP 1-1-5, 104B and Hathi Kunta which recorded more number of shoot bug populations per plant. The plant secretes total phenol as a defensive mechanism against the infestation of shoot bug. These findings are in agreement with Mote and Shahane (1994) who reported increased content of total phenols in infested plant that resulted in suppression of pest by hindering the food digestion particularly protein digestion in insects.

5.2.2 Correlations of biophysical characters with shoot bug

There was no significant correlation between any of the morphological characters and shoot bug infestation. There was a positive correlation between plant height, distance between leaves and leaf angle with shoot bug. Whereas, number of leaves per plant showed negative correlation with shoot bugs. The genotypes *viz.,* 61507 and 61512 were having less plant height, less distance between leaves and less leaf angles were with maximum shoot bug population than others. While the population of shoot bug was more in case of Hathi kunta, 61506 and 61532, which were susceptible to infestation by shoot bug where number of leaves per plant was less. However, these correlations are non-significant and very weak.

5.3 MANAGEMENT OF SHOOT BUG THROUGH SEED DRESSES

The shoot bug is a major hurdle in *rabi* sorghum production by causing dual problem of direct loss by sucking the sap and indirect damage by transmitting sorghum stripe disease. Hence, it comes in the way of harvesting potential yield of grain and fodder. Managing the pest in established sorghum ecosystem through chemical spraying has several limitations. Farmers are unable to go for spraying due to increased cost of production of sorghum and also phytotoxic effect of these insecticides on foliage. Hence, few workers tested new molecules like neonicotinoids for managing the pest in the form of seed dressing.

5.3.1 Efficacy of insecticides against shoot bug

In the present study, the seed dressing with thiamethoxam 70 WS @ 3 g per kg seeds recorded significantly lowest shoot bug population of 7.80, 12.53, 15.60 and 18.53 per five plants at 30, 40, 50 and 60 days after germination, respectively. The next best treatment was Imidacloprid 70 WS @ 5 g per kg seed dressing which closely followed the above treatment by recording 9.23, 14.10, 17.23 and 21.33 shoot bug population per five plants at 30, 40, 50 and 60 days after germination, respectively. Carbosulfan 25 DS seed dressing @ 20 g per kg seeds was next best by recording lower shoot bug population per five plant *i.e.,* 10.33, 14.33, 19.57 and 23.40 at 30, 40, 50 and 60 days after germination, respectively. Both thiamethoxam and imidacloprid 70 WS @ 2g per kg seed recorded shoot bug population of 12.50, 16.30, 19.30, 24.80 and 15.17, 17.93, 20.73 and 25.83 per five plants at 30, 40, 50 and 60 days after germination, respectively. These findings are in agreement with the Bheemanna *et al*. (2003) and Vijaykumar (2004).

Thiamethoxam 70 WS seed dressing @ 3 g per kg seeds and imidacloprid 70 WS @ 5 g per kg seeds were superior over all the treatments by recording least shoot bug population even at 60 days after germination. It is due to high persistence of these new molecules and their unique mode of action by having special chemical properties thus suppressing the pest greatly even up to 60 days after germination. At these dosages only they persisted for longer period whereas, in their lower dosages the persistence and effectiveness was low.

The other chemicals *viz.,* whorl application of carbofuran 3 G, seed dressing with imidacloprid 17.8 SL and chlorpyriphos 20 EC, spraying of endosulfan 35 EC and soil application of phorate 10 G proved relatively less effective in managing the pest up to 60 days after germination. This is mainly due to low efficacy and persistence of the chemicals in managing the pest up to 60 days after germination.

Carbofuran whorl application had given satisfactory results as that of new molecules up to 60 days after germination. This is due to the fact that shoot bug mainly congregate in the shoots, and thus whorl application was very effective in suppressing the pest.

5.3.2 Effect of insecticides on sorghum stripe disease incidence

The thiamethoxam 70 WS @ 3 g per kg seeds was very effective in hindering the disease incidence (2.57%) which was the lowest among the insecticides tested. Next best was imidacloprid 70 WS @ 5 g per kg seed dressing by recording 4.33 per cent disease. Carbofuran 25 DS @ 20 g per kg and thiamethoxam 70 WS @ 2 g per kg seed recorded almost similar disease expression. This was followed by seed treatment with imidacloprid 70 WS @ 2 g per kg seeds. The disease suppression by seed treatment with thiamethoxam 70 WS @ 3 g per kg seeds and imidacloprid @ 5 g per kg seeds are in accordance with the findings of Bheemanna *et al.* (2003) and Vijaykumar (2004).

Whereas, carbofuran 3 G whorl application @ 8 kg per ha, imidacloprid 17.8 SL @ 2ml in 20 ml of water seed dressing, chlorpyriphos 20 EC @ 5 ml in 20 ml of water, phorate 10 G soil application and endosulfan 35 EC spray @ 2 ml/l recorded 13.13, 17.83, 20.53, 22.73 and 23.53 per cent disease incidence. This mainly due to the high shoot bug population in these plots as a result of low efficacy and persistence of chemicals.

5.3.3 Effect of insecticides on panicle emergence

The insecticidal treatments have given satisfactory results by emerging almost equal per cent of panicle ranging from 93.73 to 97.30 per cent. Among the treatments thiamethoxam 70 WS @ 3 g per kg resulted in higher per cent panicle emergence (97.30). This was followed by imidacloprid 70 WS @ 5 g per kg seed dressing by recording 96.70 per cent panicle emergence. This was followed by, carbosulfan 25 DS @ 2 g per kg seeds. Panicle emergence per cent of 95.43 was seen in seed dressing with thiamethoxam 70 WS @ 2 g per kg seeds. The remaining treatments like, chlorpyriphos 20 EC @ 5 ml in 20 ml of water, phorate 10 G soil application, imidacloprid 17.8 SL, endosulfan 35 EC spray and carbofuran 3 G @ 8 kg per ha recorded 93.13 to 95.73 per cent panicle emergence. Whereas, the untreated check recorded least panicle emergence of 85.77 per cent. These results are in close agreement with the findings of Vijaykumar (2004).

5.3.4 Effect of insecticides on grain yield

The maximum grain yield of 20.13 q ha^{-1} was recorded in seed dressing with thiamethoxam 70 WS at 3 g per kg seeds. The next highest grain yield was in imidacloprid 70 WS @ 5 g per kg seeds by recording 19.43 q ha^{-1}. Carbosulfan 25 DS @ 20 g per kg and thiamethoxam 70 WS @ 2 g per kg seed dressing were recorded 19.27 and 18.53 q ha^{-1} grain yield. Imidacloprid 70 WS @ 2 g per kg seed dressing recorded 18.23 q ha^{-1} grain yield. Chlorpyriphos 20 EC @ 20 g per kg seeds, imidacloprid 17.8 SL @ 2 ml in 20 ml of water, endosulfan 35 EC spray @ 2 ml/l, phorate 10 G @ 20 kg per/ha soil application and carbofuran 3G @ 8 kg/ha whorl application were recorded 15.23 to 17.30 q ha^{-1}. The maximum grain yield was recorded in plots treated with new molecules. These are in close agreement with the findings of Vijaykumar (2004).

5.3.5 Effect of insecticides on fodder yield

The highest fodder yield was recorded in the treatment with thiamethoxam 70 WS @ 3 g per kg seeds (6.23t/ha). Imidacloprid 70 WS @ 5 g per kg seeds and carbosulfan 25 DS @ 20 g per kg seed dressing recorded 6.03 and 5.70 t ha^{-1} of fodder yield. Whorl application carbofuran 3 G @ 8 kg per ha recorded 5.33 t ha^{-1} fodder yield. Phorate 10 G @ 20 kg/ha soil application, endosulfan 35 EC spray @ 2ml/l, chlorpyriphos 20 EC @ 5ml in 20 ml of water and imidacloprid 17.8 SL @ 2 ml in 20ml of water seed dressing recorded 4.73, 4.63, 4.50 and 4.2 t ha^{-1} fodder yield, respectively. Untreated check harvested less fodder yields *i.e.*, 3.23 t ha^{-1} which was significantly inferior over other treatments. The new molecules recording maximum fodder yield is in line with the findings of Vijaykumar (2004).

5.3.6 Economics of shoot bug management

The results of economics of management of shoot bug indicated that the highest gross returns of Rs. 20,542 ha^{-1} and net profit of Rs. 15,902 ha^{-1} was obtained in a treatment with seed dressing by thiamethoxam 70 WS @ 3 g per kg seeds. The maximum net profits are mainly due to maintaining minimum population of shoot bug during the entire cropping seasons, followed by the net profit of Rs. 15,772 ha^{-1} recorded in seed dressing with carbosulfan 25 DS @ 20 g per kg seeds. This was followed by imidacloprid 70 WS @ 5 g per kg seed dressing which recorded the net profit of Rs. 15,437 ha^{-1}. Imidacloprid and thiamethoxam 70 WS @ 2 g per kg seed dressing recorded almost equal net profits of Rs. 14,663 and 14,573 ha^{-1}, respectively. The next best net profit of Rs. 13,458 ha^{-1} was recorded in carbofuran 3 G @ 8 kg/ha whorl application. Endosulfan 35 EC spray @ 2ml per litre recorded the net profit of Rs. 12,890 ha^{-1}. This was followed by soil application of phorate 10 G @ 20 kg/ha (Rs. 12,327 ha^{-1} net profit). Almost equal net profit of Rs. 11,893 and 11,868 ha^{-1} were obtained in seed dressing with imidacloprid 17.8 SL @ 2 ml in 20 ml of water and chlorpyriphos 20 EC @ 5 ml in 20 ml of water per kg seed dressing respectively. The increased net returns obtained with new molecules are in close conformity with the reports of Vijaykumar (2004).

FUTURE LINE OF WORK

1) Detailed studies on sorghum stripe disease and vector relationships
2) Exploration of bio-agents for the management of shoot bug
3) Extensive studies on the host plant resistance to evolve resistant varieties
4) Detailed life table studies of shoot bug in relation to biotic and abiotic factors
5) Detailed studies to understand mechanism of resistance

VI. SUMMARY

The present investigations were undertaken at the All India Co-ordinated Sorghum Improvement Project, Regional Agricultural Research Station and College of Agriculture and, Bijapur, Karnataka during *rabi* 2004-05 on various aspects of shoot bug, *P. maidis* relating to its loss estimation, varietal reaction and management through seed dressers. The results are summarized here under.

The loss estimation studies conducted under field conditions with natural infestation revealed that, the over all loss of 11.16, 21.11 and 2.97 per cent in grain yield, fodder yield and 1000 grain weight, respectively was recorded under unprotected conditions as compared to protected ones across five dates of sowings. The unprotected plot recorded significantly higher sorghum stripe disease incidence as compared to protected ones with 18.72 and 9.51 per cent respectively, thus accounting for 51.26 per cent over all increased incidences in unprotected plot over protected ones.

The unprotected plot was significantly inferior over protected ones with leaf sugary exudation grade of 3.70 and 1.31, respectively with 63.86 per cent overall increase in unprotected plot over protected ones across five dates of sowings. The crops sown during September IV and October I week under unprotected conditions were significantly, inferior by recording 89.20 and 85.73 per cent leaf sugary malady affected plants respectively over October II, III, IV sown crop under unprotected and were at par with each other. As the sowing was delayed, there was decrease in the plants affected by leaf sugary malady in unprotected conditions.

The loss estimation studies conducted under field conditions with graded level of infestation revealed that, the maximum plant height (210.5 cm) was recorded in control treatment (no infestation with cage) followed by release of 5 first instar nymphs per plant (205.2 cm) which were significantly superior to remaining treatments and were on par with each other. Among other treatments release of 10, 15, 20 and 25 first instar nymphs per plant recorded the plant height of 196.4, 189.3, 182.4, 175.3 cm, respectively and differed from each other. The highest reduction in plant height (170.7 cm) was noticed in the treatment with release of 30 first instar nymphs per plant which was on par with release of 25 first instar nymphs per plant.

With respect to avoidable loss in grain yield, highest loss was recorded in the treatments with release of 30 and 25 first instar nymphs per plant (51.5 and 43.3% respectively). Remaining treatments with release of 20, 15, 10 and 5 first instar nymphs per plant recorded gradually decreasing avoidable loss of 35.1, 27.4, 16.6 and 7.0 per cent, respectively. With regard to per cent avoidable loss in fodder yield, highest loss was recorded in the treatments with 30 and 25 first instar nymphs per plant with 49.4 and 42.3 per cent, respectively. The per cent loss in fodder yield gradually increased with increase in number of nymphs released. Release of 5, 10, 15 and 20 nymphs per plant exhibited avoidable loss of 9.3, 16.3, 25.7 and 34.2 per cent, respectively. The highest per cent of avoidable loss of 1000-grain weight was recorded in treatment with release of 30 first instar nymphs per plant (16.3 %) and it gradually decreased with release of 25, 20, 15, 10 and 5 first instar nymphs per plant accounting for 14.0, 13.0, 9.30, 7.6 and 2.3 per cent respectively. The correlation coefficients between shoot bug incidence and plant height (r = - 0.98), grain yield (r = - 0.97), fodder yield (r = - 0.98) and 1000-grain weight (r = - 0.98) were negative and highly significant. In the present investigation, the economic injury level was worked out to be 3.13 shoot bugs per plant.

Among the eighty genotypes screened against shoot bug, the lines *viz.*, 61508, 61526, 61543, 61544, 61576, 61582, 61587, 61588, 61590, 61592, 61595, 61596, 61607, 61608, 61611, 61612, CK 60B, Swati, and RS 29 were promising against shoot bug by recording lower population of less than 2 shoot bugs per plant. The entries, 61504, 61506, 61516, IS 37190, DSV 4, DSV 5, Hathi kunta and M 35-1 were highly susceptible which recorded higher population (10.3 to 12.5 shoot bugs/plant). The rest of the entries recorded shoot bug populations between 2 to 10/plant.

Twenty genotypes comprising of resistant, susceptible and very susceptible to shoot bug were selected from 80 entries screened and their morphological and biochemical characters were correlated with shoot bug population. There was no significant correlation between any of the morphological characters and shoot bug incidence. However, plant height, distance between two leaves and leaf angle correlated positively with shoot bug incidence. Similarly there was no significant correlation between any of the biochemical constituents and shoot bug population. However, reducing sugar (%) was correlated positively and non-significantly with shoot bug population. Whereas, total sugars and total phenols were negatively and non-significantly correlated with the shoot bug incidence.

At 60 days after germination, all the insecticidal treatments were found to be significantly superior in reducing the shoot bug population as compared to untreated check (56.10/ 5 plants). The lowest shoot bug population (18.53/ 5 plants) was recorded in thiamethoxam 70 WS @ 3 g per kg seeds and this was at par with imidacloprid 70 WS @ 5 g per kg seeds and carbosulfan 25 DS @ 20 g per kg seeds and recorded 21.33 and 23.40 shoot bugs per five plants. The next best treatments were thiamethoxam 70 WS @ 2 g per kg seeds, whorl application of carbofuran 3G @ 8 kg/ha at 25 days after germination and imidacloprid 70 WS @ 2 g per kg seeds which recorded 24.80, 25.50 and 25.83 shoot bugs per five plants, respectively and these were at par with each other. Whereas, the treatments with spraying of endosulfan 35 EC (@ 2 ml/l) at 25 days after germination, soil application of phorate 10 G @ 20 kg/ha and seed dressing with chlorpyriphos 20 EC @ 5 ml in 20ml of water were least effective and these recorded 37.73, 35.73 and 33.40 shoot bug population per five plants, respectively and were on par with each other.

Significantly lower disease incidence (2.57%) was observed in seed dressing with thiamethoxam 70 WS seed dressing @ 3 g per kg seeds in comparison with other insecticidal treatments. Among the remaining treatments, the next best chemical treatment in suppressing the disease was seed dressing with imidacloprid 70 WS @ 5 g per kg seeds (4.33%). This was followed by seed dressing with carbosulfan 25 DS @ 20 g per kg seeds and thiamethoxam 70 WS @ 2 g per kg seeds which were equally effective and recorded 7.30 and 8.97 per cent disease incidence, respectively.

All the insecticidal treatments showed satisfactorily higher panicle emergence from 93.73 to 97.30 per cent and were statistically superior over untreated check (85.77%). Among all the insecticidal treatments, maximum panicle emergence was noticed in seed dressing with thiamethoxam 70 WS @ 3 g per kg seeds (97.30%) followed by imidacloprid 70 WS seed treatment @ 5 g per kg seeds (96.70%) and carbosulfan 25 DS @ 20 g per kg seeds (96.23%), respectively.

The maximum grain yield of 20.13 q ha^{-1} was obtained in seed treatment by thiamethoxam 70 WS @ 3 g per kg seed and it was at par with seed dressing with imidacloprid 70 WS @ 5 g per kg, carbosulfan 25 DS @ 20 g per kg seeds, thiamethoxam @ 2 g per kg seed and imidacloprid 70 WS @ 2 g per kg seeds and whorl application of carbofuran 3 G @ 8 kg/ha at 25 days after germination by harvesting grain yield of 19.43, 19.27, 18.53, 18.23 and 17.30 q ha^{-1}, respectively. The latter three treatments were on par with soil application of phorate 10 G @ 20 kg /ha and spraying of endosulfan 35 EC @ 2 ml/l at 25 days after germination with 16.73 and 16.53 q ha^{-1}, respectively. The least effective treatments included seed dressing with imidacloprid 17.8 SL @ 2 ml in 20 ml of water and chlorpyriphos 20 EC @ 5 ml in 20 ml of water by harvesting lowest grain yield of 15.53 and 15.23 q ha^{-1}, respectively.

The treatment with thiamethoxam 70 WS @ 3 g per kg seeds produced higher fodder yield of 6.23 t ha^{-1} which was at par with seed dressing by imidacloprid 70 WS @ 5 g per kg seeds and carbosulfan 25 DS @ 20 g per kg seeds by harvesting 6.03 and 5.70 t ha^{-1}, respectively. The latter two treatments were at par with seed dressing by thiamethoxam 70 WS @ 2 g kg seeds and imidacloprid 70 WS @ 2 g per kg seeds by harvesting fodder yield of 5.60 and 5.50 t ha^{-1}, respectively. The next best treatment in this respect included whorl application of carbofuran 3 G @ 8 kg per ha at 25 days after germination by recording fodder yield of 5.33 t ha^{-1} and was significantly superior over soil application of phorate 10 G @ 20 kg per ha, spraying of endosulfan 35 EC @ 2 ml/l at 25 days after germination, chlorpyriphos 20 EC @ 5 ml in 20 ml water per kg seed dressing and imidacloprid 17.8 SL @ 2 ml in 20 ml water per kg seed dressing with fodder yield of 4.73, 4.63, 4.50 and 4.80 t ha^{-1}, respectively. The latter four treatments were at par with each other.

On the basis of fodder and grain yields of all the imposed treatments, the best treatment was seed dressing with thiamethoxam 70 WS @ 3 g per kg seeds by recording highest gross returns of Rs. 20,542 ha^{-1} with net profit of Rs. 15,902 ha^{-1}. The next best treatment in this regard was carbosulfan 25 DS @ 20 g per kg seed dressing by recording gross return of Rs. 19,512 ha^{-1} which resulted in net profit of Rs. 15,772 ha^{-1}. The treatments in the descending order of fetching net profit included: seed dressing by imidacloprid 70 WS @ 5 g per kg seeds, seed dressing by imidacloprid 70 WS @ 2 g per kg seeds, seed dressing by thiamethoxam 70 WS @ 2 g kg seeds, whorl application of carbofuran 3 G @ 8 kg par ha at 25 days after germination, spraying of endosulfan 35 EC @ 2 ml /l at 25 days after germination, soil application of phorate 10 G @ 20 kg per ha, imidacloprid 17.8 SL @ 2 ml in 20 ml water per kg seed dressing, chlorpyriphos 20 EC @ 5 ml in 20 ml water per kg seed dressing and recorded net profit of Rs.15,437; 14,663; 14,573; 13,458; 12,890; 12,327; 11,893 and 11,868 ha^{-1}, respectively.

VII. REFERENCES

AGARWAL, R. K., VERMA, R. S. AND BHARAJ, G. S., 1978, Screening of sorghum lines for resistance against shoot bug. *JNKVV Research Journal*, **12**: 116.

AMMAR, E. D., GINGERY, R. E. AND MADDEN, L. V., 1995, Transmission efficiency of three isolates of maize tenui virus in relation to virus titre in the planthopper vector. *Plant Pathology*, **44**: 239-243.

ANONYMOUS, 1996, *ICRISAT Asia Regional Annual Report*. International Crop Research Institute for the Semi-Arid Tropics, Patancheru, Andhra Pradesh, India, p. 288.

ANONYMOUS, 1999, *NRC on sorghum, Annual Report*, National Research Center on Sorghum Rajendranagar, Hyderbadh, Andra Pradesh,India, p 100.

ANONYMOUS, 2001, *Package of Practices for Higher Yields, (Region-II, Zone-3)*, University of Agricultural Sciences, Dharwad and Karnataka State Department of Agriculture, Bangalore, Karnataka, p. 315.

ANONYMOUS, 2004, *FAO Bulletin of Statistics*, pp. 38-44.

ASHMEAD, W. H., 1890, The corn Delphacid, Delphax maidis. *Psyche*, 5: 321-324.

*AYYAR, T. V. R., 1919, *Proceedings of 3rd Entomology Meeting*, Pusa, pp. 270-271.

AYYAR, T. V. R., 1940, *Handbook of Economic Entomology for South India*, Government Press, Madras, p. 98.

BAGAL, S. R. AND TREHAN, K. N., 1945, Life history and bionomics of two predacious and one mycophagous species of coccinellidae. *Journal of Bombay Natural History Society*, **45**: 566-575.

BHEEMANNA, M., PATIL, B. V., HANCHINAL, S. G., ANANDKUMAR, V. AND SURESH, 2003, Management of sorghum shoot bug by seed treatment. *Proceedings of the National Symposium on Frontier Areas of Entomological Research*, Indian Agricultural Research Institute, New Delhi, 5-7 November, 2003, p. 25.

BORADE, B.V., POKHARKAR, R.N., SALUNKHE, G.N. AND GNDHALE, D.N., 1993, Effects of dates of sowing on leaf sugary malady on *rabi* sorghum. *Journal of Maharashtra Agricultural Universities*, **18**: 124-125.

CAPOOR, S. P., RAO, D. G. AND VARMA, P. M., 1968, Chlorosis of sorghum. Indian *Journal of Agricultural Sciences*, **38**: 198-207.

CARNEGIE, A. J. M. AND HARRIS, R. H. G., 1969, The introduction of mirid egg predators (Tytthus sp.). *Proceedings of South African Sugar Technology Association*, **43**: 113-116.

CATINDIG, J. L. A. AND BARRION, A. T., 1995, Evaluation of rice, maize and 56 rice field weeds as hosts of planthopper, *Peregrinus maidis* (Ashmead). *International Rice Research Notes*, **20**: 25-26.

CATINDIG, J. L. A., BARRION, A. T., HEONG, K. L. AND LITSINGER, J. A., 1994, Development and biology, host plant range and egg parasitoids of six phytophagous homopterans. *25th Anniversary and Annual Scientific Meeting of Pest Management Council of the Philippines*, 3-6, May 1994, pp. 29-30.

CHANDRA SHEKAR, B. M., DHARMA REDDY, K., SINGH, B. U. AND REDDY, D. D. R., 1993, Antixenosis components of resistance to corn planthopper, *Peregrinus maidis* (Ashmead), in sorghum. *Insects Science and its Application*, **14**(1): 77-84.

CHAO, C. H., CHEN, C. C., CHIANG, H. W. AND WANG, E. S., 1988, The assurance of maize stripe virus in Taiwan. *Bulletin of Taichung District Agricultural Improvement Station*, **216**: 23-31.

CHAVAN, U. M., ARGIKAR, C. P. AND THOBBI, V. V., 1959, Some preliminary observations on the sugary disease of jowar. *Agricultural College Magazine*, Dharwad, **12**: 36-43.

CHAUDHARI, S. D., KARANJKAR, R. R. AND CHUNDARWAR, R. D., 1994, Efficacy of some insecticides to control shoot fly, delphacids, aphids and leaf sugary disease in sorghum. *Entomon*, **19**: 63-66.

CHELLIAH, S. AND BASHEER, M., 1965, Biological studies of *Peregrinus maidis* (Ashmead) (Araeopidae:Homoptera) on sorghum. *Indian Journal of Entomology*, **27**: 466-471.

CHERIAN, M. C. AND KYLASAM, M. S., 1937, Preliminary studies on the freckled yellow and stripe disease of cholam. *Proceedings of the Association of Economic Biologists*, Coimbatore, **5**: 57-63.

*COTTON, R. T., 1919, Insects attacking vegetables in Puerto Rica. *Journal of Department of Agriculture,* Puerto Rica, **2**: 265-314.

*DISTANT, W. L., 1914, Notes on some injurious African Rhynchota. *Bulletin of Entomological Research*, **5**: 241-242.

*FLETCHER, T. B., 1914, *Proceedings of 2nd Entomology Meeting*, Pusa, pp. 184-185.

*FULLAWAY, D. T., 1919, The corn leafhopper, *Peregrinus maidis* (Ash.). *Hawaii Bd. Agri. Forestry Honolaly*, **4**: 16.

GANDHALE, D. N., PATIL, A. S., AWATE, B. G., JADHAV, D. B. AND NAIK, L. M., 1986, Evaluation of insecticides for the control of aphids and delphacids on jowar. *Pesticides*, **20**: 17-18.

GARUD, T. B., SYED ISMAIL AND SHINDE, B. M., 2000, Sorghum stripe disease in Maharashtra: Incidence and source of resistance. *International Sorghum and Millet Newsletter*, **41**: 50-51.

GINGERY, R. E., 1988, The rice stripe virus group. In *The Filamentous Plant Viruses* (Ed. Milne, R.G.), New York, Plenus Press, pp. 297-329.

*GUPPY, P. L., 1914, Birds and their value to the agriculturist. *Bulletin Department of Agriculture*, Trinidad and Tobago, **13**: 148-156.

HOSAMANI, M. M. AND CHITTAPUR, B. M., 1997, *Sorghum Production Technology*. (Eds. Sarasajakshi M. Hosamani), University of Agricultural Sciences, Dharwad, p. 86.

HOUSE, L. R., 1980, *A Guide to Sorghum Breeding*. International Crop Research Institute for the Semi-Arid Tropics, Patancheru, Andhra Pradesh, India, p. 238.

JONES, T. H., 1915, *Insects Affecting Vegetable Crops in Puerto Rica*. United States Department of Agriculture, Washington, D. C., **19**: 11.

JYOTHI, R., MUNIYAPPA, V. AND NARAYANA, Y. D., 1995, Virus vector relationships of maize mosaic virus and planthopper (*Peregrinus maidis*) in sorghum. *Indian Journal of Virology*, **11**: 61-66.

KULKARNI, K. A., HOLEHOSUR, S. N. AND NAGESHACHANDRA, B. K., 1979, A predacious mite on the sorghum shoot bug, *Peregrinus maidis* (Homoptera: Delphacidae) at Dharwad. Paper Presented in *the First All India Symposium in Acarology*, held at the University of Agricultural Sciences, Bangalore, 23-25 April, 1979, p. 110.

KULKARNI, K. A., THIMMAIAH, G. AND RAMAKRISHNA, V. C., 1975, Studies on sorghum, shoot bug [*Peregrinus maidis* (Ashmead)]. *Sorghum Newsletter*, **18**: 33.

*LEFROY, H. M., 1909, *Indian Insect Life.* Indian Agricultural Research Institute, Pusa, p. 728.

*LEFROY, H. M., 1915, The more important insects injurious to Indian agriculture. *Indian Entomological Series*, **1**: 239.

*LOFTIN, V. C. AND CHRISTENSON, L. D., 1934, A report on the corn aphids (*Aphis maidis* Fitch.) in Cuba. *Bulletin of 4th Congress of International Society of Sugarcane Technology*, **115**: 20.

MALI, V. R. AND BHAGAWAT, V. Y., 1975, Virus and virus like diseases of sorghum in Marathwada. *Sorghum Newsletter*, **18**: 45-46.

*MORIN, ACOSTA, J. C., 1964, *Peregrinus maidis* in successive sowings of maize and its relation to climatic factors. *Revista de la Facultad de Agronomia Universidad Central de Venezuela*, **3**: 42-68.

MOTE, U. N. AND SHAHANE, A. K., 1993, Studies on varietal reaction of sorghum to delphacid, aphid and leaf sugary exudation. *Indian Journal of Entomology*, **55** : 360-367.

MOTE, U. N. AND SHAHANE, A. K., 1994, Biophysical and biochemical characters of sorghum varieties contributing resistance to delphacid, aphid and leaf sugary exudations. *Indian Journal of Entomology*, **56**: 113-122.

MOTE, U. N., BAPAT, D. R., KADAM, J. R. AND GHULE, B. D., 1985, Studies on the causes of "leaf sugary malady" on sorghum and its control. A paper presented in *Annual Sorghum Workshop* held at P.K.V., Akola, May, 6-8, 1985.

MUIR, F., 1917, On the synonymy of *Delphax maidis* Ashmead. *The Cannadian Entomologist*, **49**: 147.

NAIDU, R. A., HARIKRISHNAN, R., MANOHAR, S. K., REDDY, D. Y. R., RATNA, A. S., KING, S. B. AND BANDOPADHYAY, R., 1989, The occurrence of maize mosaic virus on sorghum in India. *Annals of Applied Biology*, **114**: 301-310.

NAIK, L.M., 1965, Investigations into the causes of "Sugary Disease" on jowar and their control. *M. Sc. (Agri.) Thesis*, Poona University, Maharashtra, India.

NARAYANA, Y. D. AND MUNIYAPPA, V., 1995a, Survey, symptomatology and detection of an isolate of maize stripe virus on sorghum in Karnataka. *Indian Phytopathology*, **48**: 171-176.

NARAYANA, Y. D. AND MUNIYAPPA, V., 1995b, Effect of sorghum stripe virus on plant growth and grain yield of sorghum. *Indian Journal of Virology*, **11**: 53-58.

NARAYANA, Y. D. AND MUNIYAPPA, V., 1996, Evaluation of technique for the efficient transmission of sorghum stripe virus by vector (*Peregrinus maidis*) and screening for disease resistance. *Tropical Agriculture* (Trinidad), **73**: 119-123.

NAULT, L. R. AND AMMAR, E. D., 1989, Leaf hopper and planthopper transmission of plant viruses. *Annual Review of Entomology*, **34**: 503-529.

NELSON, N., 1944, A photoelectric adoption of Somagyi method for determination of glucose. *Journal of Biological Chemistry*, **153**: 375-380.

OGUNLANA, O.M. AND PEDIGO, I.P., 1974, Economic injury levels of potato leaf hopper on soybean in Iowa. *Journal of Economic Entomology*, **67**: 29-32.

PAWAR, V. M. AND KADAM, J. R., 1995, Entomological aspects of integrated pest management in important crops. *Maharashtra State Level Conference on Integrated Pest Managemen*t, 26th May, 1995.

PEMBERTON, C. E., 1937, *Entomology*. Republic Commission of Sugarcane Experimental Station, Hawaii, pp. 22-27.

PETERSCHMITT, M., RATNA, A. S., SACKS, W. K., REDDY, D. V. R. AND MUGHOGHO, L. K., 1991, Occurrence of an isolate of maize stripe virus on sorghum in India. *Annals of Applied Biology*, **118**: 57-70.

PRABHAKAR, B., RAO, P. K. AND RAO, B. H. K. M., 1981, Note on Hemipterous species complex on sorghum at Hyderabad. *Indian Journal of Agricultural Sciences*, **51**: 818-819.

PREM KISHORE, 1990, Strategies for pest management in sorghum in India. *Journal of Entomological Research*, **14**: 16-20.

PREM KISHORE, 1996, Evolving management strategies for pests of millets in India. *Journal of Entomological Research*, **20**: 287-297.

PREM KISHORE, 2000, Eco-friendly viable options for formulating management strategy for insect pests of sorghum and pearl millet. *Journal of Entomological Research*, **24**(1): 63-72.

RAJA SEKHAR, P. R., 1996, Assessment of crop loss and economic injury level due to shoot bug, *Peregrinus maidis* Ashmead on sorghum. *Annals of Agricultural Research*, **17**(3) : 333-334.

RAJA SEKHAR, P., 1997, Biology and life table studies on Peregrinus maidis (Ashmead) infesting sorghum. *Journal of Insect Science*, **10**: 16-18.

RAJA SEKHAR, P., KULKARNI, N. AND REDDY, D.M., 1995, Field resistance to shoot bug, *Peregrinus maidis* (Ashmead) on sorghum. *Journal of Insect Science*, **8**: 102-103.

RATHORE, V. S., RAGHUWANSHI, R. K., SOOD AND KAUSHIK, U. K., 1970, Control of sorghum pests. *PANS*, **16**: 358-360.

RAWAT, R. R. AND MODI, B. N., 1969, New host records of predaceous bug, *Geocoris tricolor* Fab. (Hemiptera: Lygaeidae) from India. *Indian Journal of Entomology*, **3**: 74.

RAWAT, R. R. AND SEXENA, D. K., 1967, Studies on the bionomics of *Peregrinus maidis*. *JNKVV Research Journal*, **1**: 64-67.

REMES LENICOV, A. M. M., MARIANI, R. AND DE REMES LENICOV, A. M. M., 2001, Discovery of the vector of maize virus, *Peregrinus maidis* (Homoptera:Delphacidae) in the province of Buenos Aires. *Neotropica*, **47**: 48.

REYNAUD, B., GUINET, I. AND MARCHAND, J. L., 1987, IARD/CIRAD Maize breeding programme for virus resistance. *Eastern Central and Southern Africa Regional Maize Workshop*, Harare (Zimbabwe), 15-21 March, 1987.

*RITCHIE, A. M., 1917, Report of the Government Entomologist for the year 1916-1917. *Supplement Jamaica Gazette*, **4**: 92-97.

ROCHA-PENA, M. A., MONREAL, C. T., BECERRA, E. N. AND RUIZ, P., 1984, Occurrence of maize stripe virus in Tabasco state, Mexico. *Turrialba*, **34**: 233-235.

SDOODEE, R., TEAKLE, D. S. AND LOUIE, R., 1997, Preliminary identification of maize stripe tenui virus in Thailand. *Plant Disease*, **81**: 228.

SHARMA, H. C., 1985, Strategies for pest control in sorghum in India. *Tropical Pest Management*, **31**: 167-185.

SHARMA, M., BHARAJ, G.S. AND SHINDE, C.B., 1982, Evaluation of different insecticides for the control of jowar shoot bug, *Peregrinus maidis* (Ashmead) at Indore [Madhya Pradesh]. *Pestology*, **6**: 13-14.

SHIVAMURTHAPPA, KULKARNI, K. A. AND LINGAPPA, S., 1989, Estimation of crop loss in sorghum due to the shoot bug, *Peregrinus maidis* (Ashmead). *Karnataka Journal of Agricultural Sciences*, **2**: 82-88.

SINGH, S. P., RAO, N. S. AND HENNEBERRG, T. J., 1993, Leafhoppers and their natural enemies. *Technical Bulletin,* Project Directorate of Biological Control, ICAR, **6**: 65.

SINGH, B. U. AND RANA, B. S., 1992, Stability of resistance to corn planthopper, *Peregrinus maidis* (Ashmead) in sorghum germplasm. *Insect Science and its Application*, **13**: 251-263.

STONE, J.D. AND PEDIGO, I.P., 1972, Development of economic injury level of green clover worm on soybean in India. *Journal of Economic Entomology*, **65**: 197-201.

SUBBARAO, D. V. AND LAKSHMINARAYANA, K. P., 1975, Screening material in advanced yield trials for relative damage due to major insect pests. *Sorghum Newsletter*, **18**: 20-21.

SUBBARAYUDU, B., 2002, Shoot bug incidence on sorghum in southern India. *International Sorghum and Millet Newsletter*, **43**: 56-57.

SWINDLE, L. D., 1980, Foreword. In *A Guide to Sorghum Breeding*, (Ed. L. R. House) International Crop Research Institute for the Semi-Arid Tropics, Patancheru, Andhra Pradesh, India.

TALLAMY, D. W., STULL, J., EHRESMAN, N. P., GORSKI, P. M. AND MASON, C. E., 1997, Cucurbitacins as feeding and oviposition deterrents to insects. *Environmental Entomology*, **26**: 678-683.

TEETES, G.L., SESHU REDDY, K.V., LEUSCHNER, K. AND HOUSE, L.R., 1983, *Sorghum Insect Identification Handbook*. Information bulletin no. 12, International Crop Research Institute for the Semi-Arid Tropics, Patancheru, Andhra Pradesh, India, p.124.

TEJKUMAR, S., 1979, Studies on crop loss in groundnut (*Arachis hypogaea* Lin.) due to leaf miner, *Stomoptreryx subsecivella* Zeller (Lepidoptera: Gelechiidae) and determination of economic injury levels. *Ph. D. Thesis*, University of Agricultural Sciences, Bangalore, p. 172.

*TSAI, J. H., 1996, Development and oviposition of *Peregrinus maidis* (Homoptera: Delphacidae) on virus host plants. *Florida Entomologist*, **79**: 19-26.

TSAI, J. H., STEINBERG, B. AND FALK, B. W., 1990, Effectiveness and residual effects of seven insecticides on *Dalbulus maidis* (Homoptera: Cicadellidae) and *Peregrinus maidis* (Homoptera: Delphacidae). *Journal of Entomological Sciences*, **25**: 106-111.

TSAI, J. H. AND ZITTER, T. A., 1982, Characteristics of maize stripe virus transmission by the corn delphacid. *Journal of Economic Entomology*, **75**: 397-400.

VERMA, J. S., 1955, Biological studies to explain the failure of Cyrtorhinus mandulus (Breddin) as an egg predator of *Peregrinus maidis* (Ashmead) in Hawaii. *Proceedings of Hawaiian Entomological Society*, **15**: 623-634.

VIJAYKUMAR, L., 2004, Bio-ecology, seasonal incidence and management of sorghum shoot bug, *Peregrinus maidis* (Ashmead) (Homoptera: Delphacidae). *M. Sc. (Agri.) Thesis*, University of Agricultural Sciences, Dharwad, p. 98.

*WATSON, J. R., 1939, Entomology. *Report of Florida Agricultural Experiment Station*, *1937-38*, pp. 82-106.

*WESTGATE, J. M., 1918, *Report of the Hawaii Agricultural Experiment Station, 1917*, States Relation Sciences, United States Department of Agriculture, Washington, DC., p. 56.

*WILLIAMS, C. B., 1921, Sugarcane pests and diseases in Trinidad in 1920. Bulletin, Department of Agriculture, *Trinidad and Tobago*, **19**: 111-121.

*YANG, C. R., 1990, Occurrence of maize stripe in Taiwan. *Plant Protection Bulletin Taipei*, **32**: 162-166.

ZITTER, T. A., 1982, Incidence of maize stripe disease on maize. *Journal of Economic Entomology*, **75**: 407-409.

* Originals not seen

Appendix 1: Monthly Weather data recorded at RARS, Bijapur during 2004-05

Month 2004		Temp (°C)		RH (%)		Rainfall (mm)	Rainy Days	Sun shine hours	Evapo-ration (mm/day)
		Max	Min	AM	PM				
January	Actual	29.9	13.8	72	41	4.0	1	7.9	4.4
	Average	29.3	15.3	68	39	4.4	0		
February	Actual	32.8	16.1	70	38	0.0	0	8.4	7.0
	Average	33.3	17.4	61	34	2.3	0		
March	Actual	37.9	20.6	64	29	0.0	0	10.0	11.1
	Average	36.7	20.7	58	32	6.0	0		
April	Actual	38.8	23.4	62	25	0.5	0	9.6	12.4
	Average	38.9	22.5	77	34	21.2	2		
May	Actual	35.6	22.9	86	41	108.9	9	6.2	8.6
	Average	38.8	23.2	69	36	38.4	3		
June	Actual	31.9	21.8	90	58	144.7	9	4.1	6.8
	Average	33.8	22.8	80	52	86	6		
July	Actual	30.1	21.2	90	62	153.2	10	4.4	6.6
	Average	30.0	21.7	83	61	72.2	5		
August	Actual	29.9	20.7	91	59	23.0	3	5.8	5.6
	Average	30.5	21.7	85	62	78.1	5		
September	Actual	30.4	20.9	86	62	120.0	12	5.6	5.2
	Average	31.3	21.4	85	58	151.6	8		
October	Actual	30.6	19.1	81	51	100.8	6	8.5	6.4
	Average	31.5	21.1	78	54	96.2	6		
November	Actual	30.4	15.1	81	35	0.0	0	8.1	6.1
	Average	30.1	17.8	73	50	30.6	2		
December	Actual	29.6	10.8	79	32	0.0	0	10.0	6.0
	Average	29.3	15.7	72	44	7.3	1		
Annual	Actual	32.3	18.9	79	44	655.1	50	7.4	3.0
	Average	32.8	20.1	73	46	590.7	38		
Average: Temperature; 1965 to 2000, RH;: 1973 to 2000, Rainfall; 1901 to 2000									
Month 2005									
January	Actual	30.7	14.3	75	33	0.0	0	9.0	6.2
	Normal	29.3	15.3	68	39	4.4	0		
February	Actual	32.5	15.4	69	25	0.0	0	9.2	6.6
	Normal	33.3	17.4	61	34	2.3	0		

Appendix 2: Weekly meteorological data at RARS, Bijapur (2004-05)

Std. Wk.	Dates		No. of rainy days	Rainfall (mm)	Relative humidity		Temperature (^{o}C)	
					Morning	After noon	Maximum	Minimum
2004								
19	May	07-13	4	14.4	82	41	35.4	23.2
20		14-20	3	60.8	78	57	34.3	22.5
21		21-27	0	0.0	76	31	35.9	22.6
22		28-03	4	30.0	77	38	36.4	21.8
23	June	04-10	1	24.2	84	61	33.0	22.4
24		11-17	2	27.8	87	68	30.2	22.3
25		18-24	2	5.9	90	51	30.5	20.9
26		25-01	3	77.8	89	61	31.6	21.4
27	July	02-08	2	12.2	91	55	31.0	21.3
28		09-15	4	101.2	90	64	30.5	21.1
29		16-22	2	11.2	90	55	31.1	21.3
30		23-29	2	22.0	91	73	29.2	21.1
31		30-05	4	21.4	91	77	26.7	21.3
32	Aug	06-12	3	2.6	89	66	28.8	20.9
33		13-19	1	0.2	91	53	30.2	20.9
34		20-26	2	2.8	90	57	30.3	20.7
35		27-02	2	10.2	89	40	32.1	19.6
36	Sept	03-09	3	27.0	88	62	29.8	21.4
37		10-16	3	9.3	94	61	29.3	19.9
38		17-23	4	21.5	91	65	31.2	21.4
39		24-30	5	54.6	91	64	30.9	21.1
40	Oct	01-07	4	76.8	90	62	30.2	20.9
41		08-14	2	24.0	89	58	30.8	20.6
42		15-21	0	0.0	80	38	30.3	15.9
43		22-28	0	0.0	83	48	31.2	19.3
44		29-04	0	0.0	84	45	29.7	18.5
45	Nov	05-11	0	0.0	83	45	29.7	17.5
46		12-18	0	0.0	84	38	32.0	16.5
47		19-12	0	0.0	78	18	30.5	11.7
48		26-02	0	0.0	78	32	29.5	11.0
49	Dec	03-09	0	0.0	77	31	29.1	10.3
50		10-16	0	0.0	81	30	29.6	10.8
51		17-23	0	0.0	77	29	30.5	9.9
52		24-31	0	0.0	82	36	29.6	12.2
2005								
1	Jan	01-07	0	0.0	84	37	30.6	14.8
2		08-14	0	0.0	78	29	30.7	11.2
3		15-21	0	0.0	69	31	30.1	12.8
4		22-28	0	0.0	75	33	31.7	17.3
5		29-04	0	0.0	71	37	29.5	14.8
6	Feb	05-11	0	0.0	68	24	32.4	15.8
7		12-18	0	0.0	57	15	35.4	14.3
8		19-25	0	0.0	72	31	31.7	16.7
9		26-04	0	0.0	69	35	15.3	32.4

Appendix 3: Daily rainfall data recorded at RARS, Bijapur during 2004

Date	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
1	0.0	0.0	0.0	0.0	0.0	4.4	0.0	0.0	7.6	0.0	0.0	0.0
2	0.0	0.0	0.0	0.0	11.2	0.0	0.0	0.0	0.0	22.6	0.0	0.0
3	0.0	0.0	0.0	0.0	1.5	4.6	10.6	8.2	0.0	4.6	0.0	0.0
4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.2	0.0	15.2	0.0	0.0
5	0.0	0.0	0.0	0.5	0.0	0.0	1.6	1.4	5.4	4.4	0.0	0.0
6	0.0	0.0	0.0	0.0	0.0	24.2	0.0	0.4	16.0	0.0	0.0	0.0
7	0.0	0.0	0.0	0.0	4.6	0.0	0.0	0.4	5.6	0.0	0.0	0.0
8	0.0	0.0	0.0	0.0	1.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0
9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
10	0.0	0.0	0.0	0.0	4.4	0.0	32.6	0.0	4.6	0.0	0.0	0.0
11	0.0	0.0	0.0	0.0	0.0	0.0	49.2	0.0	3.1	0.0	0.0	0.0
12	0.0	0.0	0.0	0.0	4.2	0.0	5.8	1.8	0.0	13.8	0.0	0.0
13	0.0	0.0	0.0	0.0	0.0	0.0	13.6	0.2	0.0	10.2	0.0	0.0
14	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.6	0.0	0.0	0.0
15	0.0	0.0	0.0	0.0	0.0	18.6	0.0	0.0	0.0	0.0	0.0	0.0
16	0.0	0.0	0.0	0.0	41.8	0.0	7.0	0.0	0.0	0.0	0.0	0.0
17	0.0	0.0	0.0	0.0	1.2	2.4	0.0	0.0	0.0	0.0	0.0	0.0
18	0.0	0.0	0.0	0.0	13.0	1.5	4.2	0.0	1.6	0.0	0.0	0.0
19	0.0	0.0	0.0	0.0	4.8	4.4	0.0	0.0	0.0	0.0	0.0	0.0
20	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.0	4.2	0.0	0.0	0.0
21	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.5	0.0	0.0	0.0
22	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	11.2	0.0	0.0	0.0
23	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
24	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.4	0.0	0.0	0.0
25	0.0	0.0	0.0	0.0	0.0	0.0	15.2	0.8	37.4	0.0	0.0	0.0
26	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.4	0.0	0.0	0.0
27	0.0	0.0	0.0	0.0	0.0	21.6	0.0	2.6	8.2	0.0	0.0	0.0
28	0.0	0.0	0.0	0.0	6.6	6.4	0.0	0.0	0.0	0.0	0.0	0.0
29	4.0	0.0	0.0	0.0	0.0	49.8	6.8	0.0	0.0	0.0	4.0	4.0
30	0.0	0.0	0.0	0.0	14.4	0.0	6.6	0.0	4.2	0.0	0.0	0.0
31	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Actual RF	4.0	0.0	0.0	0.5	108.9	144.7	153.2	23.0	120.0	100.8	0.0	0.0
Average-RF	4.4	2.3	6	21.2	38.4	86.0	72.2	78.1	151.6	96.2	30.6	7.3
Actual RD	1	0	0	0	9	9	10	3	12	6	0	0
Average-RD	0	0	0	2	3	6	5	5	8	6	2	1
Total Annual rainfall during 2004 - **655.1mm**							Rainy days during 2004					**50**
Mean annual rainfall for 1901-98- **594.3mm**							Average rainy days					**38**

RF= Rainfall RD= Rainy Days

Appendix 4: Pedigree details of sorghum lines received from NRCS, Hyderabad for screening against Shoot bug

Entry No.	Origin	Pedigree
F5s:	Guinea bred lines x Bold grain/high yielding B-lines	
	1 61504	(GM 973188 x ICSB 101) –6-3-2-1-1
F6s:	Guinea x Stem borer B lines	
	2 61505	(GM 974129 x 27B)-1-1-3-1-1-1
	3 61506	(GM 974131 x 27B)-1-1-1-1-1-1
F6s:	Guinea type selections from ICSP-B population	
	4 61507	ICSP-B-98R Sel-10-1-1-2-2-1
	5 61508	ICSP-B-98R Sel-10-1-2-1-1-1
	6 61510	ICSP-B-98R Sel-17-2-5-1-1-1
	7 61511	ICSP-B-98R Sel-17-2-5-2-1-1
F8s:	Caudatum west African Three-way crosses	
	8 61512	[ICSB 308 x CEM 328-3-3-1-1) x SPDL 94023]-2-1-1-1-1-1-1
	High Yielding Bold grain lines	
	9 61515	(SOLAR 1-12xICSR 68)-1-1-2-1-1-1-4-1-3-2-1
	10 61516	[{{SPV462x[296Bx(296BxQL3)]-6-4-1]-27-2-2-6-3-1-2-3}x296B}-2xSPSFBR 94024]-1-1-1-1-1-1-1-1-1
	11 61519	[{{SPV462x[(ICSB 101xPM17467B)-4-2-6x (ICSB6xPM17467B)-6-1-1]}-9-1-3-1-2-7-1x296B}T-16xSP46523]-2-1-1-1-2-1-2-2-1
	12 61520	(GM 970130 x ICSB 73)-9-1-1-1-1
	13 61521	[(ICSB 583 x ICSB 79) x 296B]-1-3-3-2-1-1-2-1-1
	14 61522	(ICSB 508 x ICSB 79)-2-2-1-1-1-2-1-1-1
	15 61523	(ICSB 508 x ICSB 79)-2-2-1-1-1-2-1-1-2
	16 61524	(ICSB 215 x SPDL 94023)-6-2-1-1-1-1-1-1-1
F5s:	**ACID RILs**	
	17 61525	(PMS 7B x 296B)-1-2-1-1
	18 61526	(C 43 x 296 B)-2-5-1-1
	19 61527	(C 43 x 296 B)-2-6-1-1
	20 61528	(AKMS 14B x PKV 801)-2-1-1-1
	21 61530	(PKV 801 x 296B)-1-5-1-1
F8s:	**Grain mold resistant B-lines X Bold grain/High yielding B-lines**	
	22 61532	(PKV 400 x ICSB 101)-2-1-1-1-1-1
	Grain mold white grain based ICSP-B-Population lines	
	Late Flowering Lines	
	23 61533	(ICSB 383 x ICSB 101)-2-1-1-1-2-1
	24 61540	[{R150-1x[296Bx(296BxQL3)-6-8-5]-28-3-10-1-2-3-1-1-4-2}x296B]-8-2-1-1-3-2-1-1[{{SPV462x[(ICSB101xPM17467B)-4-2-6x(ICSB6xPM117467B)-6-1-1]}-9-1-3-1-2-7-
	25 61543	1x296B}T-16xSP46523]-2-1-1-1-2-1-2-1-1
	26 61544	(B 58581 x ICSB 276)-4-1-1-1-1

Entry No.	Origin	Pedigree
	High yielding R-lines	
	27 61547	C-43
	28 61548	[ET 2039 deri x (SC 108-3 x GPR 148)}-29-3-1
	29 61551	Good Grain 1485
	30 61556	B 92143
	31 61557	B 92155
	32 61558	(GM 973237 x ICSB 101)-1-1-1-1
Entry No.	**Origin**	**Pedigree**
	33 61559	(GM 973291 x SP 1632-1)-3-1-1-1
	34 61562	[{[SPV 462x(ICSB 102xPS28060-3)]-4-2-2-2-4-5x296B}-7xICSB 463]
	35 61566	(IS 6965 x ICSV 745)-2-1
	36 61567	(IS 6965 x ICSV 745)-5-1
	37 61568	(IS 6965 x R 150)-3
	38 61569	(IS 6965 x SPV 462)2-2
	39 61570	(IS 6965 x SPV 462)-5
	B1 Lines	
	40 61573	[(ICSA 4xICSA13) x ICSA 7]-4-1-1-1
	41 61576	[(296Bx SPV 105) x (2077B x M 35-1)]-19
	42 61578	(Indian Synthetic 89-1 x Rs/R 20-682) 5-1-3
	43 61579	[((((BT~624xUChV2)x B lines bulk)-5-1-1-1)xTRL 74/C 57) x(((BT~623 x UChV 2)x
	44 61580	[(((BT~624xUChV2)× B lines bulk)-5-1-1-1)x SP 36257]-6-1-2-2
	45 61581	[(((BT~623x((SC 108-3 x GPR 148)-18-4-1)) x B lines bulk)-5-1-2-5)x SP 36257]-5-2-1-1-1-1-3
	46 61582	[(((Indian Synthetic 89-1 x RS/R 20-682)-5-1-3)xIS 18757)x (((BT~623 xUChV2) xB
	47 61587	[IS 29016 x (((296B x BT~624) x B lines bulk) 2-1-1-1-3)]-1-1
	48 61588	[IS 29016 x (((296B x BT~624) x B lines bulk)-2-1-1-1-3)]-2
	49 61589	[IS 29016 x (((296B x BT~624) x B lines bulk)-2-1-1-1-3)]-1-1
	50 61590	[((((BT~623 x((SC 108-3 x GPR 148)-18-4-1)) x B lines bulk)-5-1-2-5x((PS21194 x SPV
	51 61592	[((Indian Synthetic 89-2 x Rs/R 20-682)-5-4-2) x PS 30715-1]-1-4-1
	52 61595	[(Indian Synthetic 422-1)xPS 18822-4]-10-2-3-2-2
	53 61596	[(((Indian Synthetic 89-2 x Rs/R 20-682)-5-4-2) x PS 18822-4]-4-2-3-1-1

	B2 Lines	
	54 61602	[((((BT~623 x ((SC 108-3 x GPR 148).18-4-1)) x B lines bulk)-5-1-2-5) x SP 36257]-5-2-1-1
	55 61605	[((Indian Synthetic 89-1 x Rs/R 20-682)-5-1-3) x SP 36257]-3-3-1-2
	56 61606	[(((Indian Synthetic 89-1 x Rs/R 20-682)-5-1-3) x TRL 74/C 57) x PM 17467B]-1
	57 61607	ICSP IB/R MFR-S 7-303-2-1
	58 61608	ICSP IB/R MFR-S 10-41-2-9-3-2-1-1
	59 61610	ICSV 1125 BF
	60 61611	ICSV 1171 BF
	61 61612	R 150-2
	62 61613	TAM 428
	63 Check	CK 60B
	64 Check	296 B

CROP LOSS ESTIMATION AND MANAGEMENT OF SHOOT BUG *Peregrinus maidis* (Ashmead) IN *RABI* SORGHUM

RAJU ANAJI **2005** **Dr. R. A. BALIKAI**
Major Advisor

ABSTRACT

The investigations were undertaken at the AICRP on sorghum, RARS, Bijapur during *rabi* 2004-05 on loss estimation, varietal reaction and management of shoot bug.

Natural infestation of shoot bug resulted in the yield loss of 11.16, 21.11 and 2.97% in grain yield, fodder yield and 1000-grain weight across the different dates of sowing. The unprotected plot recorded significantly higher sorghum stripe disease incidence as compared to protected ones (18.72% and 9.51%). Under graded level of infestation, the yield reduction ranged from 7.1 to 51.3% and 9.1 to 49.7% in grain and fodder yield with release of 5 to 30 first instar nymps per plant. The economic injury level of shoot bug is 3.13 per plant.

Among the 80 genotypes screened against shoot bug the lines *viz*., 61611, 61612, CK 60B, Swati, and RS 29 were promising by recording lower population (<2 shoot bugs/plant). Other entries recorded shoot bug population between 2 to 10 plant^{-1}.

The lowest shoot bug population (18.53 / 5 plants) was recorded by thiamethoxam 70 WS @ 3 g kg^{-1} seeds and was at par with imidacloprid 70 WS @ 5 g kg^{-1} seeds. Carbosulfan 25 DS @ 20 g kg^{-1} seeds recorded 21.33 and 23.40 shoot bugs per five plants. The maximum grain yield of 20.13 q ha^{-1} was observed in seed treatment with thiamethoxam 70 WS @ 3 g kg^{-1} seed. The seed treatment with imidacloprid 70 WS @ 5 g kg^{-1} and carbosulfan 25 DS @ 20 g kg^{-1} recorded grain yield of 19.43 and 19.27 q ha^{-1}, respectively.

The treatment with thiamethoxam 70 WS @ 3 g kg^{-1} seeds produced higher fodder yield of 6.23 t ha^{-1} which was at par with seed dressing by imidacloprid 70 WS @ 5 g kg^{-1} seeds and carbosulfan 25 DS @ 20 g kg^{-1} seeds by harvesting 6.03 and 5.70 t ha^{-1}, respectively.

The seed treatment by thiamethoxam 70 WS @ 3 g per kg seeds resulted in higher net profits of Rs. 15902 ha^{-1} which was on par with the seed treatment by carbosulfan 25 DS @ 20 g per kg seeds.