STUDIES ON THE HOST PLANT RESISTANCE TO GREEN LEAFHOPPER, *Amrasca biguttula biguttula* (Ishida.) (HEMIPTERA : CICADELLIDAE) AND DETERMINATION OF MORPHOLOGICAL AND BIOCHEMICAL BASIS OF RESISTANCE TO IT IN SUNFLOWER (*Helianthus annuus* L.)

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2017

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Thesis submitted to the

UNIVERSITY OF AGRICULTURAL SCIENCES, BANGALORE

in partial fulfillment of the requirements for the award of the Degree of

DOCTOR OF PHILOSOPHY

in

AGRICULTURAL ENTOMOLOGY

BENGALURU **SEPTEMBER, 2017**

Affectionately Dedicated to My Beloved Parents, Brother & Husband

DEPARTMENT OF AGRICULTURAL ENTOMOLOGY
UNIVERSITY OF AGRICULTURAL SCIENCES
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CERTIFICATE

This is certify that the thesis entitled **"STUDIES ON THE HOST PLANT RESISTANCE TO GREEN LEAFHOPPER,** ***Amrasca biguttula biguttula*** **(Ishida) (HEMIPTERA: CICADELLIDAE) AND DETERMINATION OF MORPHOLOGICAL AND BIOCHEMICAL BASIS OF RESISTANCE TO IT IN SUNFLOWER (*Helianthus annuus* L)."** submitted by **Ms. Soumya M. Shettar, PALB 4015** for award of the degree of **DOCTOR OF PHILOSOPHY IN AGRICULTURAL ENTOMOLOGY** to the **University of Agricultural Sciences, GKVK, Bengaluru,** is a record of *bona-fide* research work carried out by her during the period of her study under my guidance and supervision and that no part of thesis has been submitted for the award of any degree, diploma, associateship, fellowship or other similar titles.

Bengaluru
September, 2017

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ACKNOWLEDGEMENT

With regardful memories……………………

First and foremost, I praise and thank God for giving me the strength and courage for successfully completing the task.

***"All are equal but some are more than others"** said George Orwell and so is my teacher to me **Dr. K. S. Jagadish** Professor of Agricultural Entomology, UAS, GKVK, Bengaluru and the esteemed Chairman of my Advisory Committee. I would be more thankful to him for his excellent guidance, constant encouragement, keen interest, constructive criticisms and everlasting patience throughout the period of my study and care which go a long way in shaping my life and educational career.*

*I feel immense pleasure in expressing my deep sense of gratitude, esteem and sincere feelings of indebtedness to **Dr. V. V. Belavadi** Professor and Head, Department of Agricultural Entomology, UAS, GKVK, Bengaluru and member of my Advisory committee for his valuable suggestions and sustained cooperation during the course of investigation and providing me an opportunity to undertake research work at ZARS. his unreserved helpful nature and critical evaluation of the thesis.*

I am also grateful to Dr. K. M. Srinivas Reddy, Entomologist, ZARS, UAS, GKVK, Bengaluru Dr. Y. G. Shadakshari Director of Research, UAS, GKVK, Bengaluru and Dr. C. T. Subbarayappa Professor of Soil Science and Agricultural Chemistry, UAS, GKVK, Bengaluru for their helpful suggestions and also serving as the members of my advisory committee.

I acknowledge gratefully the assistance rendered by the Research staff and Supporting staff of ZARS and Department of Agricultural Entomology, UAS, GKVK, Bengaluru who provided me with all the required facilities and information for my work.

*I avail this opportunity to thank my parents who are the Almighty's most treasured gift to me. I feel words are scant for the magnitude of love and affection showered on me by my mother **Smt. Sumangala Shettar** and father **Sri Mallikarjun Shettar** and my mother in law **Smt. Sharada Nidagundi** and Father in law **Sri Basavaraj Nidagundi** whom I wish to idolize* *throughout my life for making me what I am today. At this moment, no words available in this world are sufficient to express my profound love and feelings towards my brother* ***Karthik Shettar*** *and my husband* ***Sangamesh Nidagundi*** *without their affection, prayers and constant encouragement, I would not have come up to this level.*

Above all, I express my warm feelings towards my dearest junior ***Gurudevi Navali*** *for her encouragement and constant support during the period of my research, at every junction and also I thank to* ***my lovely buddies Manisha, Shakuntala, Pavithra*** *and* ***Nagaraj*** *for cheerfully sharing the thrills of my tempestuous life.*

I owe my thanks to my classmates Sunitha madam, Pradeep, Pattan, Kumar, Manjunath, Madhu and Thoa for their constant encouragement, helpful criticism, and enjoyable movements during the study and suggestions for the improvement of thesis.

At this juncture I wish to recall with love, my thanks Seniors ***Tharini, Sanjay Topagi, Veeresh*** *and Juniors* ***Soumya Patil, Sahana*** *and* ***Deeepa****.*

My sincere thanks to the teaching staffs, non-teaching staffs and students of the Depatment of Agricultural Entomology for all the helps rendered.

I am greatly indebted to ***Department of Science and Technology (DST) , New Delhi*** *for providing me financial support as fellowship under* ***DST- INSPIRE*** *Programme.*

Finally I thank ***Lord Ganesha*** *for bestowing me with divine spirit, essential strength and necessary succour to find my way towards a glorious career amidst several hurdles and struggles.*

Omission of any names does not mean the lack of gratitude. Ending is inevitable for all good and it is time to end the acknowledgement.

Above all, I am very much grateful to the College of Agriculture, University of Agricultural Sciences, GKVK, Bengaluru for providing me an opportunity to complete my Doctoral programme.

Bengaluru

September, 2017 ***(Soumya M. Shettar)***

Studies on the host plant resistance to green leafhopper, *Amrasca biguttula biguttula* (Ishida) (Hemiptera : Cicadellidae) and determination of morphological and biochemical basis of resistance to it in sunflower (*Helianthus annuus* L.)

SOUMYA M. SHETTAR

ABSTRACT

Investigations on the infestation of leafhopper (*Amrasca biguttula biguttula* Ishida.) on sunflower (*Helianthus annuus* L.) and host plant resistance studies were carried out during 2015-2017. Field screening of totally 411 genotypes during four seasons revealed that the overall incidence of mean population of leafhoppers ranged from 0.50 to 5.66 per plant and the hopper burn injury grade ranged between 0 to 5. Based on injury grade 10 entries (RH-95-C-1, AHT 12, OPV 2,CMS 103 B, KBSH 53, KBSH 72, OPV3, NCP 198,KBSH 1 and AHT 13) were shortlisted as resistant ,while nine genotypes *viz*., DRSF 108,RHA 284, EC 734840, EC 734844, NCP 22, NCP28, KBSH 41, Morden and UASB 560 were shortlisted as highly susceptible to leafhopper. Their resistance was confirmed and glass house conditions. The spatial distribution of leafhopper studied on sunflower entries during different developmental stages of the plant (at 45 and 75 DAS) revealed that the maximum leafhopper population confined the middle portion of the plant canopy, followed by top portion. The significantly lowest population of leafhoppers was recorded on bottom portion of canopy. Though leaf thickness did not confer any resistance against green leafhoppers, trichome length and trichome density in resistant entries did not support the build up of green leafhopper population. Biochemically, the resistance in sunflower could be attributed to low levels of total soluble sugars and total soluble proteins and increased levels of phenols.

September, 2017

Department of Agril. Entomology
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Dr. K. S. Jagadish
(Major advisor)

ಸೂರ್ಯಕಾಂತಿ (*ಹೆಲಿಯಾನ್‌ಥಸ್ ಆನಸ್*) ಬೆಳೆಯಲ್ಲಿ ಹಸಿರು ಜಿಗಿಹುಳು, *ಅಮರಾಸ್ಕ ಬೈಗುಟುಲ್ಲಾ ಬೈಗುಟುಲ್ಲಾಗೆ* (ಹೆಮಿಪ್ಟೆರಾ:ಸಿಕಾಡೆಲ್ಲಿಡೆ) ಸಸ್ಯ ನಿರೋಧಕತೆ ಬಗೆಗಿನ ಅಧ್ಯಯನ ಹಾಗೂ ಅದರ ಅಂಗರಚನೆ ಹಾಗೂ ಜೀವರಾಸಾಯನಿಕಗಳ ಆಧಾರ ನಿರ್ಧರಿಸುವುದು

ಸೌಮ್ಯ ಎಂ. ಶೆಟ್ಟರ್

ಪ್ರಬಂಧದ ಸಾರಾಂಶ

ಸೂರ್ಯಕಾಂತಿ ಬೆಳೆಯನ್ನು ಭಾದಿಸುವ ಹಸಿರುಜಿಗಿಹುಳು *ಅಮರಾಸ್ಕ ಬೈಗುಟುಲ್ಲಾ ಬೈಗುಟುಲ್ಲಾ* ಯಿಂದ ಉಂಟಾಗುವ ಹಾನಿ ಮತ್ತು ಸಸ್ಯ ನಿರೋಧಕತೆಗೆ ಸಂಬಂಧಿಸಿದ ಅಧ್ಯಯನವನ್ನು ೨೦೧೫ ರಿಂದ ೨೦೧೭ ರವರೆಗೆ ಕೈಗೊಳ್ಳಲಾಯಿತು. ನಾಲ್ಕು ಹಂಗಾಮಿನಲ್ಲಿ, ಒಟ್ಟಾರೆ ೪೧೧ ಸೂರ್ಯಕಾಂತಿ (*ಹೆಲಿಯಾನ್‌ಥಸ್ ಆನಸ್*) ತಳಿಗಳನ್ನು ಹಸಿರುಜಿಗಿಹುಳು ಭಾಧೆಗಾಗಿ ಹೊಲದಲ್ಲಿ ಮೌಲ್ಯಮಾಪನ ಮಾಡಲಾಯಿತು. ಅದರಲ್ಲಿ ಒಂದು ಗಿಡಕ್ಕೆ ಸರಾಸರಿ ಹಸಿರುಜಿಗಿಹುಳುಗಳ್ ಒಟ್ಟು ಸಂಖ್ಯೆ ೦.೫೦ ರಿಂದ ೫.೬೬ ಹಾಗೂ ಅದರಿಂದಾದ "ಜಿಗಿಸುಡು"ವಿನ ಕ್ರಮಾಂಕ ೦.೦೦ ರಿಂದ ೫.೦೦ ರವರೆಗೆ ಕಂಡುಬಂದಿತು. ಇದರ ಆಧಾರದ ಮೇಲೆ ೧೯ ತಳಿಗಳನ್ನು ಹಸಿರು ಗಾಜಿನಮನೆಯಲ್ಲಿ ಹೆಚ್ಚಿನ ಮೌಲ್ಯಮಾಪನಕ್ಕೆ ಒಳಪಡಿಸಿ, ಅಂತಿಮವಾಗಿ ಆ ೧೯ ತಳಿಗಳ ನಿರೋಧಕಶಕ್ತಿಯನ್ನು ಖಚಿತಪಡಿಸಿಕೊಂಡು ಹಸಿರುಜಿಗಿಹುಳುವಿನ ಭಾಧೆಗೆ ಪ್ರತಿಕ್ರಿಯಿಸಿ ಪ್ರತಿನಿಧಿಸುವ ಗುಂಪುಗಳಾಗಿ ಅವುಗಳನ್ನು ನಿರೋಧಕಶಕ್ತಿಗೆ ಅನುಗುಣವಾಗಿ ಎರಡು ಬಗೆಗಳಾಗಿ ವಿಂಗಡಿಸಲಾಯಿತು, ಅವುಗಳೆಂದರೆ ನಿರೋಧಕತೆ (೧೦ ತಳಿಗಳು) ಮತ್ತು ಮೃದುತನ (೯ ತಳಿಗಳು). ವಿವಿಧ ತಳಿಗಳ ಬೆಳವಣಿಗೆ ಹಂತಗಳಾದ, ಬಿತ್ತನೆಯಾದ ೪೫ ಹಾಗೂ ೭೫ ಗಳಲ್ಲಿ ಹಸಿರುಜಿಗಿಹುಳುಗಳ ಪ್ರಮಾಣ ಗಣನೀಯಾವಾದ ಹೆಚ್ಚಿನ ಸಂಖ್ಯೆಗಳಲ್ಲಿ ಗಿಡಗಳ ಮಧ್ಯಭಾಗದಲ್ಲಿ ಕಂಡುಬಂದಿದ್ದು, ನಂತರ ಮೇಲ್ಭಾಗದಲ್ಲಿ ಕಂಡುಬಂದಿದೆ. ಅಂಗರಚನೆಯು ಸೂರ್ಯಕಾಂತಿ ಎಲೆಯ ಸಸ್ಯ ನಿರೋಧಕಶಕ್ತಿಗೆ ಕಾರಣವಾಗದಿದ್ದರೂ, ಎಲೆಯ ಮೇಲಿನ ರೋಮದ ಸಾಂಧ್ರತೆಯು ಹಾಗೂ ರೋಮದ ಉದ್ದ ಹಸಿರು ಜಿಗಿಹುಳುಗಳ ಬೆಳವಣಿಗೆಗೆ ಬೆಂಬಲವಾಗಿರುವುದಿಲ್ಲವೆಂದು ಕಂಡುಕೊಳ್ಳಲಾಯಿತು. ಹಸಿರು ಜಿಗಿಹುಳುವಿಗೆ ಸೂರ್ಯಕಾಂತಿಯಲ್ಲಿ ನಿರೋಧಕ ಶಕ್ತಿಗೆ ಕಾರಣವಾದ ಜೀವರಾಸಾಯನಿಕ ಅಂಶಗಳನ್ನು ಪರಿಶೀಲಿಸಿದಾಗ ಎಲೆಗಳಲ್ಲಿನ ಕಡಿಮೆ ಪ್ರಮಾಣದಲ್ಲಿರುವ ಸಕ್ಕರೆ ಮತ್ತು ಪ್ರೋಟೀನ್ ಹಾಗೂ ಹೆಚ್ಚಿನ ಅಂಶದ ಫಿನಾಲ್ ಅತಿ ಪ್ರಮುಖ ಕಾರಣಗಳೆಂದು ಕಂಡುಬಂದಿದೆ.

ಸೆಪ್ಟೆಂಬರ್ ೨೦೧೭

ಕೃಷಿ ಕೀಟವಿಜ್ಞಾನ ವಿಭಾಗ
ಕೃ.ವಿ.ವಿ., ಬೆಂಗಳೂರು – ೬೫

ಡಾ. ಕೆ.ಎಸ್. ಜಗದೀಶ
(ಮುಖ್ಯ ಸಲಹೆಗಾರರು)

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I INTRODUCTION

Sunflower is a diploid species (2n = 2x = 34) that belongs to the Helianthinae subtribe, Asteroideae subfamily and Compositae family. Genus *Helianthus* composed of 49 species, including 12 annual and 37 perennial species and 19 subspecies (Seiler, 1992; Skoric, 1993; Seiler and Rieseburg, 1997). Sunflower is the only plant grown world-wide on a large scale that originated and was domesticated in North America (Heiser, 1978). The basic chromosome number for the *Helianthus* genus is 17 and due to the open pollination between the perennial species; several variable polyploidy levels of (2x, 4x and 6x) were found (Heiser, 1978 and Schuster, 1993).

In India, sunflower is an important oilseed crop cultivated in an area of 5.20 lakh ha with a production of 3.35 lakh T and a productivity of 643 kg/ha. Karnataka occupies first position, accounting for an area of 3.84 lakh ha., with a production of 1.93 lakh T and productivity of 503 kg/ ha (Anon., 2016). The cultivated sunflower is largely confined to southern parts of the country *viz.,* Andhra Pradesh, Karnataka, Maharashtra and Tamil Nadu, which together contribute about 90 per cent of total acreage and 78 per cent of total Indian production and therefore, it is recognized as “sunflower state” in the oilseeds scenario of the country (Basavaraj *et al*., 2016). Although sunflower crop has the yield potential of 2.0 to 2.5 T/ ha under favourable conditions, its mean productivity levels are quite low in India.

Sunflower is distinctly superior over other oilseed crops and has been well accepted by the farming community. It was extensively cultivated in past years because of its desirable attributes, such as short duration, adaptability to wide agroclimatic conditions, photo-insensitive nature and tolerance to drought, low seed rate, high multiplication ratio, and comparatively lesser cost of cultivation, besides high quality edible oil, with higher content of poly unsaturated fatty acids (Sindagi and Virupakshappa, 1986).

The crop is cultivated for a variety of uses such as, oil production, ornamental use, as poultry feed and in pharmaceutical industry as a diuretic and for treating certain disorders of the respiratory tract (Putt, 1971; Lofgren, 1978; Dorrel, 1978). Fried sunflower kernel with salt and pepper is a delicacy. Among various vegetable oils, sunflower oil has high level of unsaturated fatty acids *viz.*, linoleic acid, oleic acid and linolenic acid, which constitute about 90 per cent of the total fatty acids. This characteristic feature has categorized sunflower oil as a naturally superior one compared to groundnut or mustard oil (Carter, 1978; Kolte, 1985).

The area under sunflower cultivation in India has increased tremendously from 0.15 lakh ha (1970) to 14.69 lakh ha (1993), but there was drastic decline in the area to less than 8.0 lakh ha during 1994-2002, mainly due to the several biotic and abiotic stress (Shankergouda *et al*., 2006).

In spite of its growing popularity, the crop is often ravaged by a plethora of insect pests and diseases, which are one of the major biotic constraints in the successful production of sunflower. As many as 251 insect and mite species have been recorded on sunflower at the global level (Rajamohan, 1976). Insect pests of sunflower are more diverse in tropical countries than in temperate areas. In India, sunflower crop is damaged by different species of insect pests, of which the polyphagous pests like capitulum borer (*Helicoverpa armigera* Hubner), tobacco caterpillar (*Spodoptera litura* Fab.), Bihar hairy caterpillar (*Spilartia obliqua* Walker), green semilooper (*Thysanoplusia orichalcea* Fab.), cabbage semilooper (*Trichoplusia ni* Hubner), cutworm (*Agrotis* spp.) and leafhopper (*Amrasca biguttula biguttula* Ishida) are considered to be of major economic importance (Basappa, 1995).

Crop loss due to insect pests in sunflower varies from region to region. As a result of severe outbreak of seedling pests, the plant stand of sunflower was reduced by more than 30 per cent (Basappa and Bhat, 1998) in DOR Hyderabad. There are reports of leafhopper alone causing crop loss ranging from 18.5 to 46.3 per cent in Maharashtra (Anon., 1979). The capitulum borer alone causes up to 50 per cent yield loss by directly inflicting damage to flower buds, ovaries and developing seeds in Maharashtra (Lewin *et al*., 1973).

Amrasca biguttula biguttula is one of the important sucking pests of sunflower in India (Rana and Sheoran, 2004). Both nymphs and adults are injurious and suck plant sap, specially the older nymphs. At the early stages of crop, the attacked leaves turn yellowish near the margins. In case of mild infestation, there is curling of borders which later on turns brownish. When the leafhopper attack is severe, yellowish patches develop on the leaves, which gradually turn brown and dry up. The pest sucks the plant sap mainly from the lower surface of leaves and injects toxic saliva into the plant tissue at the time of feeding, resulting into phytotoxic symptoms, known as "Hopper burn". As a result yellowing, browning, bronzing, cupping and withering, necrosis of leaves occur and ultimately, the leaves shed prematurely (Hussain and Lal 1940, Mahal 1973, Bindra and Mahal 1979, Bindra and Mahal 1981).

Many insecticides are being used to control the pest complex of sunflower, which pose health hazards and environmental problems. Host plant resistance is a potential alternate management strategy to reduce pest damage, since it is eco-friendly, cost effective and can be integrated with cultural and biological control measures (Chirumamilla *et al*., 2010).

On the other hand, crop plant uses different ways to protect them from herbivore infestation. Painter (1951) described three mechanisms of plant response, Antixenosis, Antibiosis and Tolerance. Antixenosis refers to the plant properties that reduce colonization by pests seeking food or oviposition sites, due to morphological characteristics or lack of plant attractants. Antibiosis is a resistance influencing biological processes of insects, like survival, growth, generation time, fecundity and longevity (Van Emden, 1997). The quantity and quality of primary as well as secondary plant metabolites frequently associated with antibiosis are also influenced by plant responses. If a crop cultivar is tolerant to herbivore infestation, it shows a reduced response to herbivore damage compared with other non-tolerant plant types. When such different resistance as well as tolerance mechanisms are combined, high levels of overall resistance could be achieved (Pedigo, 1999). Therefore, knowledge of cultivar susceptibility/resistance and the mechanism(s) might be a fundamental component of an integrated pest management program (IPM) against any pest, besides facilitating the prorision of resistant genotypes which can be utilized in leafhopper resistance breeding programme in sunflower.

In view of significant status of leafhopper as a pest on sunflower, and to avoid over reliance on synthetic chemicals, the investigations on exploring resistance to the leafhopper were carried out with the following objectives:

1. Screening of parental lines and germplasm entries of sunflower for their resistance to green leafhopper both under field and artificial conditions.
2. Determination of morphological basis of resistance to green leafhopper.
3. Determination of bio-chemical basis of resistance to green leafhopper.

II REVIEW OF LITERATURE

Sunflower *(Helianthus annuus* L.) is one of the most important oilseed crops of India. The potential of the crop is far from being exploited and the yield levels of sunflower in the country are the lowest in the world due to several biotic and abiotic stresses. Among the biotic factors, insect pests contribute a lot for lowering the production and productivity. Sunflower leafhopper, *Amrasca biguttula biguttula* (Ishida) (Hemiptera: Cicadellidae) is one of the most economically important sucking pests attacking sunflower in India. It has been known to cause severe yield losses by paralyzing the cultivation of the crop. Research work on its incidence, crop loss, biology and host plant resistance in sunflower has been carried out by several researchers. Accordingly, the available literatures on host plant resistance to *A. biguttula biguttula* in sunflower and also that pertinent to the present investigation in other crops are reviewed in the following paragraphs.

2.1 Insect pest fauna of sunflower

In India, more than fifty insect species have been found feeding on sunflower, of which seedling pests *viz.*, cutworm, *Agrotis* spp. and grasshopper, *Atractomorpha crenulata* Fab., soil insects (termites and white grubs), sucking pests such as, leaf hopper (*A. biguttula biguttula*), whitefly (*Bemesia tabaci* Genn.), thrips (*Scirtothrips dorsalis* Hood), defoliators like bihar hairy caterpillar (*Spilarctia obliqua* Walker.), tobacco caterpillar (*Spodoptera litura* Fab.), green semilooper (*Plusia orichalcea* Fab.), cabbage semilooper (*Trichoplusia ni* Hubner) and capitulum borer (*Helicoverpa armigera* Hubner) are of economic importance. Non-insect pests such as rabbits, parakeets, doves, house sparrows, crows, rats etc. have also been reported to cause severe damage to sunflower (Basappa, 1995).

The sucking pests of sunflower which were reported to feed on stem and leaves include, leafhoppers and plant hoppers (*A. biguttula biguttula*, *Empoasca* sp;), thrips (*S. dorsalis, Thrips tabaci* Lind., *Arrhenothrips ramakrishnae* Hood., *Haplothrips ganglbaueri* Schmutz, *Megalurothrips usitatus* Bagnal.,); aphids (*Aphis craccivora* Koch, *Aphis nerii* Forn., *Aphis gossypii* Glov., *Uroleucon compositae* F., *Lipaphis erysimi*

Kalt.), plant bugs (*Eurybrachys tomentosa* F., *Otinotus liginicola* Walk., *Oxycarenus laetus* Kirby., *Clavigrella gibbosa*, *Oxyrachis tarandus* Fab.) and whitefly (*Bemesia tabaci* Genn.) (Basappa, 1995).

2.1.1 Leafhopper infesting on sunflower

A. biguttula biguttula is one of the important sucking pests of sunflower in India. The incidence would start from seedling stage and prevail through the entire plant life. Both nymphs and adults suck the plant sap and causes stunted growth of the plant, cupped and crinkled leaves, burning of leaf margin and their severe infestation produces the characteristic "hopper burn" symptoms. Though it may appear on the crop around the year, it is serious during certain months at different places (Rana and Sheoran, 2004).

2.1.2 Crop loss assessment by sunflower leafhopper

Crop loss due to insect pests in sunflower varies from region to region. As a result of severe outbreak of seedling pests, the plant stand of sunflower crop could be reduced by more than 30 per cent (Basappa and Bhat, 1998). The leafhopper alone causes crop loss ranging from 18.5 to 46.3 per cent in Maharashtra (Anon., 1979). At Digraj, leafhopper caused 9.5 to 46.3 per cent yield loss, whereas, at Akola, sucking pests caused 15.2 to 18.5 per cent yield loss (Anon., 1997).

Amrasca devastans (Distant) in cotton has been prevalent from vegetative to reproductive phase of crop growth. The loss in seed cotton yield due to leafhopper is accounted to be 390 kg ha-1 and 330 kg ha-1(Murugesan and Kavitha 2010).

2.1.3 Host range of sunflower leafhopper

Leafhopper *A. biguttula biguttula* is a polyphagus pest with wide host range, which includes cotton, bhendi. beetlevine, potato, brinjal, cocoa, castor, soyabean, sweet potato, marigold, sapota, amaranthus (Afzal and Ghani, 1953; Cherian and Kylasam, 1938; Lewin *et al*, 1973; Rajamohan *et al*., 1974; Raju and Rao, 1984).

2.1.4 Synonyms

A. biguttula biguttula (Ishida) was described under different synonyms which were mentioned below.

Amrasca biguttula biguttula (Ishida, 1913) Kapoor and Sohi, 1972: Dworakowaska and Viraktamath, 1975: 530; Sohi, 1976:236.

Chlorita biguttula (Ishida) 1913: 1 (Issued March12, 1913)

Chlorita biguttula Shiraki, 1913:96 (Issued March31, 1913)

Emposca bipunctata Schumacher 1915: 127; Dworakowaska, 1970; 712 (Synonymized)

Chlorita bimaculata Matsumera 1917: 393.

Chlorita bimaculata Matsumera, 1913: 62

Emposca devastans Distant, 1918: 93; Dworakowaska, 1970; 712 (Synonymized)

Fauna of British India Rhynchota, 7: 93 (n. sp)

Amrasca devastans (Distant, 1918) Ghauri,1967: 163.

Sundapteryx biguttula biguttula (Ishida, 1913); Dworakowaska, 1970; 712 (proposed new genus and new combination),

Amrasca biguttula biguttula (Ishida, 1913) Kapoor and Sohi 1972: 51; Dworakowaska and Viraktamath, 1975: 530

Empoasca nigropunctata Merino, 1936: 389; Sohi, 1976: 52 (Synonymized)

Empoasca quadrinotatissima Dlabola, 1957: 296; Dworakowaska, 1970: 712 (Synonymized).

2.2 Host plant resistance

Host plant resistance is one of the safe and cost effective methods. WTO has set the limitations for maximum residual limits (MRL) for agricultural crops, horticultural crops and its products, so it is necessary to work on the non chemical pest control methods in agricultural crops; host plant resistance is one of these methods. The growth and the selection of resistant cultivars against the pests is vital approach of IPM (Bhatti *et al*., 1976).

A resistant genotype can give a pedestal on which integrated control measures can be most dynamic when used with the combination of other methods for control. The resistant genotypes have the important position in integrated pest management (IPM). The available variability including both indigenous and exotic germplasm has been utilized to a considerable extent in the improvement of sunflower. Different workers have screened various germplasms for resistance to leafhopper which is reviewed as under:

2.2.1 Screening of selected entries for resistance to leafhopper (*A. biguttula biguttula*)

2.2.1.1 Screening of selected entries for sunflower resistance to leafhopper (*A. biguttula biguttula*)

Fick (1978) observed reliable resistance to leafhoppers in sunflower germplasm collection as well as *Helianthus argophillus* x *H. annuus* derivatives at Bengaluru. The germplasm accessions showing resistance were, Acc NO. 771, 775, 892, 1035, 1042, 1055, 1009, 702 R and 1134.

In the studies carried out by Deshmukh and Akhare (1979) for three years 1975-77 at Akola on the response of early and dwarf varieties of sunflower to leafhopper *A. biguttula biguttula*, it was found that Morden and Cernianka-66 exhibited lesser leafhopper population on them indicating that the two varieties were comparatively resistant to the leafhopper.

Bhat and Virupakshappa (1993) screened some germplasm lines against leafhoppers in sunflower and the entry No. 771, 775, 892, 1009, 1035, 1042, 1407, 1055, 1134, 702 R, KBSH-8, BSH-1 S- 55, EC-61039 and 35811 either supported comparatively lower population or not expressing cupping symptoms compared to susceptible genotypes.

Least number of leafhoppers was recorded on TNAU-SWF-7 whereas, morden had 13 leafhoppers per plant and was more susceptible than all others. The injury grade ranged from 0-2 in GAU-SUF-46 to 3.0 in EC-68414. In an Advanced Varietal Trial (AVT), the leafhoppers per plant were the highest on GAU-SUF-15 with 9.7 per plant and the least was on GAU-SUF-81 with 4.5 hoppers per plant. Entries CS0912 and CS 213 had respectively the highest and the lowest leafhopper incidence (Anon., 1999).

Entries GMU-204, 205, 208 and 220 were found tolerant to leafhoppers at Akola. GMU-206, 217, 265, 285 and 286 recorded lowest population of thrips at Raichur (Anon., 2006).

Balasubramanian and Gopalan, 1981 reported that the germplasms, released hybrids and varieties screened for resistance to major sucking pests at different locations in Tamilnadu and the leafhopper population was considerably less on KBSH-1, GUJ-SUN1, and BSH-1. At Raichur, 7113, 1888, 1425 entries recorded lesser population of leafhoppers.

Different sunflower genotypes were screened against *T. tabaci*. The genotypes 9706 and JH2 99S were partially resistant, whereas, XF-263 and Award were found to be highly susceptible to the pest as compared to Hysun-33. The genotypes 9707, JH1 99S and parsun-1 were partially susceptible to the pest. Hysun-777, T-562, PSF-025 and 1435 were moderately susceptible against thrips, whereas PNSF-1 and 9706 were found susceptible. A negative correlation was also found between pest population and the yield of sunflower genotypes. Further, they noticed that against leafhoppers, *Empoasca* spp., 9705, JH2 995 and Hysun-777 were partially susceptible. The entries T-562, XF-263, PNSF1, 1435 and PSF-025 were partially susceptible, while Parsun-1 and 9706 were found susceptible and 9707 and Award were highly susceptible (Ashfaq and Aslam 2001a; 2001b).

Several entries were screened under All India Co-ordinated Research Project at various centers every year for pests and diseases of sunflower. Acc. No. 294 and 313 registered least leafhoppers incidence at Akola. Whereas, Acc No. 295 recorded lowest population of thrips and promising accessions against thrips were 297, 150, 316 and 320 (Anon., 2002).

At Orissa, Mandal and Dash (2003) screened fifteen genotypes of sunflower against leafhopper, *A. biguttulla biguttula*. None of the genotypes were found highly resistant, two genotypes *i.e.*, RPT 25 and RPT 16, were found resistant with 3.1 to 6 leafhopper per three leaves.

GMU-412, 478, 479 and 488 were found to have multiple resistances to insect pests of sunflower entries RSFV-901-1, DRSF-119, SS-2038, KSFH-437 were also found resistant to thrips and leafhoppers (Anon., 2006).

One hundred and twelve accessions of sunflower (*Helianthus annuus* L.) were screened under field conditions in two seasons at Sambavar Vadakarai and Udappankulam villages of Tirunelveli district of Tamilnadu, India during January to April and June to September, 2009 respectively for their resistance against leaf hopper (*A. biguttula biguttula* Ishida) by Hyacinth and Selvanarayanan (2011). Observations on the number of nymphs/adults per plant were recorded at weekly interval. In the first season, four accessions *viz*., KBSH 1, AHT 14, GK 2002 and GMU 698 harboured the least population whereas in the second season, the accession KBSH 1 proved to be promising.

Suganthy and Uma (2011) screened the promising germplasm entries of sunflower for confirmation of reaction to key pests *viz*. leafhoppers, thrips, whiteflies, defoliators and head borer in the TNAU, Coimbatore during *Kharif*, 2007. Results revealed that all the five germplasm entries *viz*., GMU 407, GMU 415, GMU 424, GMU 473 and GMU 493 were promising to the key pests of sunflower. GMU 473 recorded the maximum of 5.0 thrips and 3.0 *S. litura* larvae per plant with the defoliation of 25 per cent as against 7 and 0 per cent defoliation in the checks, Morden and TCSH 1, respectively. GMU 424 recorded the maximum of 0.4 leafhoppers per plant as against 28 and 19 hoppers per plant in Morden and TCSH 1, respectively and also screening under glasshouse condition revealed that GMU 473 recorded the maximum grade of 0.5 for hopper burn injury grade as against 3.5 and 2.2 in the checks Morden and TCSH 1 respectively. GMU 415 and GMU 493 recorded the lowest grade of 0.1.

Sarwan Kumar and Dhillon (2014) conducted two years field study under natural conditions to evaluate the reaction of 8 sunflower hybrids *viz.*, PSH 930, PSH 569, PSH 652, NSFH 36, PSFH 118, SH 3322, GKSFH 2002 and Jwalamukhi to insect -pests infestation during spring 2006 and 2007 at PAU, Ludhiana. During the early stage of crop growth sucking pests *viz.*, leafhopper and whitefly were abundant. Among the eight hybrids evaluated, PSH 569 and GKSFH 2002 harboured lower population of leafhopper nymphs than the rest of the hybrids while Jawalamukhi , PSH 652, GKSFH 2002 and PSH 652 were found promising against whitefly. Similarly, GKSFH 2002, PSH 652, SH 3322 and Jawalamukhi were promising against head borer. Among the different hybrids, the population of leafhopper, whitefly and head borer was lower on GKSFH 2002 than the other hybrids.

2.2.1.2 Screening of selected entries of cotton resistance to leafhopper (*A. biguttula biguttula*)

Verma and Afzal (1940) screened different varieties of cotton against *Empoasca devastans* (Dist) and reported the Desi cottons were practically immune to the leafhoppers. Varietal differences in resistances were observed in case of American cottons of the commercial importance. Among them LSS was found to be most resistant and 289 F/K 25 the most susceptible one. Other varieties namely 4F and 289 F/43 came in between these two extremes. It was seen that the chief difference between the comparatively resistant or susceptible varieties lay in the number of eggs laid in the leaf veins of these strains. The eggs when once laid had no difficulty in hatching and nymphs of all stages also could feed and reach normal maturity on all cottons.

Mathur and Bhandari (1978) screened sixteen varieties of cotton against *A. devastans* (Dist). The studies revealed that only B1007 and Badnawar of Madhya Pradesh showed resistance to the pest and remained in grade I; while RS 76 appeared to be moderately resistant and was placed in grade II; Carolina queen, Stonevillae and Deltapine with smooth leaves proved to be the most susceptible variety.

Krishnananda and Agarwal (1979) selected some varieties of cotton based on well defined visual characters of leaves like hairiness, leaf surface and toughness of veins *etc*, out of them 7 were resistant, 6 medium resistant and 7 were susceptible to the leafhopper.

The counting of nymphs from underside of few leaves selected from different portions of the plant was considered as a better index of leafhopper population in cotton (Afzal and Ghani 1946) and okra (Annappan 1960, Uthamasamy *et al.*, 1973, Bindra and Mahal, 1979, Mahal and Singh, 1979). The leaves in the middle canopy of okra and cotton plants harbored the highest population (Mahal and Singh, 1979). The resistant varieties harbored lower population of leafhopper nymphs than the susceptible varieties in okra (Bindra and Mahal 1979, Sandhu *et al.*, 1974), brinjal (Bindra and Mahal, 1981) and cotton (Singh and Atwal 1976, Sikka *et al.*, 1966).

The criteria of susceptibility index for testing level of resistance under field conditions should be given priority over either leafhopper nymphal population or leafhopper injury index alone (Mahal 1978, Mahal and Singh 1982, Lal 1989). Mahal *et al.* (1991) suggested that one-week old was considered as the optimum age of okra plant for rapid artificial screening of germplasm based on development and survival of leafhopper nymphs and also reported that *A. biguttula biguttula* exhibited a prolonged development and a reduced survival of nymphs on resistant varieties IC 7194 and New Selection than on Pusa Sawani at various ages of plant. The ovipositional preference of adults of, *A. biguttula biguttula* on different plant ages of two varieties of okra was studied by Mahal *et al.* (1993a) and it was found that fewer nymphs emerged from the leaves of the resistant variety IC 7194 (9.83) as compared to 13.23 nymphs on the susceptible variety Pusa Sawani. The studies also revealed that all the four plant ages (one, two, three and four week old crop) were suitable for artificial screening of okra germplasm and one week old plants were preferred for achieving rapid results.

Kanwat and Kumawat (2001) screened 42 entries of elite cotton germplasm for resistance to leafhopper *A. biguttula biguttula*. Infestation was graded based on scale of 0 to 4, where 0=highly resistant (no infestation) and 4=highly susceptible (exhibiting excessive curling, copper red spots and leaf drying). Results revealed that, out of 42 entries, none was highly resistant to the leafhopper. However, three entries of the compact plant and some early maturing types *viz.*, NZC-453, NZC-454, NZC-460, RS-970 and RS-990 recorded a leafhopper injury grade of 2 (moderately resistant). No morphological character in the lines to which resistance may be attributed was observed. Ten lines were highly susceptible to leafhoppers, (*viz.*, NZC-450, NZC-463, NZC-467, NZC-468, RS-974, RS-977, RS-978, RS-981, RS-984 and RS-985) and the remaining were susceptible.

Imtiaz *et al.* (2002) studied the resistance level of ten cotton cultivars, AEH-1, AEH-2, AEH-4, AEH-6, CRIS-9, CRIS-121, CRIS-124, CRIS-128, CRIS-129 and Red okra to sucking pest complex, leafhoppers, thrips and white flies. Results revealed that, cultivars AEH-1, AEH-4 and AEH-6 were highly susceptible to leafhopper, where as cultivars CRIS-129, CRIS-121, CRIS-124, Red okra, CRIS-128, AEH-2 and CRIS-9, showed medium response to leafhopper attack.

Syed *et al.* (2003) investigated the relative resistance of 20 cotton varieties against sucking pests' *viz.*, leafhoppers, thrips, white flies and mites. Results revealed that, the highest leafhopper population of 2.72 per leaf was observed on Greg -25V variety, while lowest population was found on variety Rajhans (2.06/ leaf).

Abida *et al.* (2004) investigated forty cotton varieties registered for cultivation in Punjab province for their relative resistance against leafhoppers at the stage of square formation and based on their reaction to leafhoppers, the cotton genotypes were categorized into different classes.

Radhika *et al*. (2004) evaluated seventy four entries of *Gossypium hirsutum*, leafhopper injury grades were recorded for each entry using 1 to 4 scale. The entries were categorised based on injury index. The results revealed that one entry was resistant while 50 were moderately resistant, 14 were susceptible and nine were entries highly susceptible.

Chandramani *et al*. (2004) screened 466 cotton breeding entries. Results revealed that, Anjali, TKKH 1, TKH 1179, PKV Rajat, TSH 9417, ARB 8824, CNO 6, CNH

1025, CPD 612, MCU 11, SVPR 2, and SVPR- 3 in summer 2001, entries SVPR 3, MCU 11, Anjali, TKKH 1, TKH 1179, TSH 9417, 9804, 8219, 8235, 8352 in summer 2002 and entries RAH 111, CNH 2124, RHC 940, RAC 9553, PKV and Rajat in summer 2003 and entries SVPR 2,TSH 9704, GJHV 392, GJHV 360, GSHV 97/13, RAC 1094, GSHH 19/59, CNH 301 were found resistant to leafhopper damage.

Pushpa and Raveendran (2005) artificially screened 13 *G. hirsutum* lines and 30 hybrids to identify the resistant genotypes for use in breeding programmes. From the study, it was found that KC 2 was highly resistant, Stoneville, DHY 286, Khandwa 2 were resistant and MCU 7 highly susceptible. Among the 30 hybrids, most of the hybrids came under resistant category. The genotypes KC 2, DHY 286 and Khandwa 2 were resistant to leafhoppers.

Ali and Aheer (2007) tested eight genotypes of cotton for their resistance against whitefly, thrips, and leafhoppers. Genotypes did not show significant differences for leafhopper and thrips population. Maximum populations of whitefly (7.55/leaf) and leafhopper (2.26/leaf) were recorded.

Balakrishnan *et al*. (2007) evaluated a total of 140 cotton genotypes from AICCIP (All India Coordinated Cotton Improvement Project) in the field under unsprayed conditions for their reaction to leafhopper, *A. biguttula biguttula*. Okra (*Abelmoschus esculentus* L.) was grown as infestor row at the rate of one row for every four rows of cotton. On the basis of injury rating scale of 0-3, 36 entries were rated as moderately resistant, 58 as susceptible and 46 as highly susceptible, while none of the entries was rated as resistant.

Jindal *et al.* (2007) investigated the relative resistance of 346 cotton genotypes against sucking pests leafhopper and whitefly. The leafhopper injury grade, leafhopper and whitefly population/leaf were recorded on each genotype. They grouped the genotypes in to resistant and susceptible based on injury grade and pest population.

Muhammad *et al.* (2009) conducted studies on five cultivars of cotton for resistance against whitefly, thrips, leafhopper, and aphid. The cultivar FH-634 was found to be the most resistant to the sucking pest complex, whereas, FH-682 was found to be the most resistant line to the leafhopper. Leafhopper and whitefly populations almost remained above economic threshold level throughout the season.

Muhammad and Anjum (2010) studied the seasonal dynamics of cotton leafhopper, whitefly and thrips on transgenic Bt cotton line IR-FH-901, expressing Cry1Ac insecticidal protein with its parent, non transgenic cotton cultivar FH-901 and concluded that, there is no difference in transgenic Bt and non- Bt cotton for leafhopper, whitefly and thrips attack and application of suitable insecticide is required to control these pests on transgenic cotton.

Screening of twenty six cotton accessions by Murugesan and Kavitha (2010) against the leafhopper, *A. devastans* was carried out by following ICCC grades. The susceptiblity of cotton entries varied significantly. Based on the resistance index the entries were grouped under five categories as, Highly resistant- KC 2, SVPR 2; Resistant- TKH 1128: Intermediate- MCU 5, MCU 10, NISD 2, TKH 1143,TKH 1175: Susceptible- TKH 1789, TKH 1173, TKH 1174, TKH 1178, TKH 1179, TKH 1185, TKH 1186, TKH 1209, TKH 1225, TKH 1233 and Highly susceptible- ICMF 20, LRA 5166, TKH 1133, TKH 1172, TKH 1176, TKH 1182, TKH 1197, TKH 1198. Meanwhile they studied the mechanism of resistance, the leafhoppers discriminated cotton entries for orientation and settling and feeding. Highly susceptible entries were preferred for settling and feeding. Varieties less preferred for settling were less preferred for oviposition too. Since antixenosis and antibiosis were considered for mechanism of resistance various plant parameters *viz.,* plant height, internodal length, petiole length, leaf area, thickness of leaf, trichome density on the ventral surface of the leaves, hair length, hair density on mid-vein, distance between bases of hairs in mid vein, chlorophyll content, moisture content and protein content were estimated and correlated with leafhopper ovipostion and damage caused. Plant height, internodal length, trichome density on the ventral surface of the leaves, hair length, hair density on mid-vein had negative association with leafhopper damage and oviposition by leafhopper; leaf area, leaf thickness and protein content had no significant association. Susceptible entries had less chlorophyll and more moisture.

Khan *et al*. (2011) emphasized the importance of host plant resistance in integrated pest management (IPM) against insect pests. Relative infestation on five Bt transgenic cotton genotypes (IR-443, IR-FH-901, IR-448, IR-1524 and IR-1513) was investigated against sucking complex (leafhoppers, thrips and whiteflies) and bollworm complex, pink (*Pectinophora gossypiella*) and spotted (*Earias* spp.) during two consecutive years. Results reflected that IR-443 proved to be the most successful genotype showing lowest infestation of leafhoppers, thrips and whiteflies in both years as compared to other Bt cotton genotypes followed by IR-FH-901. Highest yield was recorded from IR- 443 which was significantly higher than in IR-1513 and was statistically on par with the other 3 genotypes. Overall performance of IR-443 was found excellent followed by IR-FH-901.

Results of Rohini *et al*. (2011) showed that, genoytpes LK-861 and JK-276-4 were resistant to aphids; LK-861 and Mallika non Bt were resistant to thrips; and RAH-100, 4085, DHY-286 sel and G.cot 16 were resistant to leafhopper and recorded lowest injury index due to presence of higher quantity of biochemical components like tannins, phenols and gossypol. The genotypes LK-861, Mallika non Bt, Acala-2, CNHPY-6 and CPD-431 were found to be resistant to whiteflies and leafhoppers.

Salman *et al.* (2011) studied the resistance levels of six cotton varieties MNH-635, NIAB-86, SLH-257, CIM-446, CIM-482 and NIAB Karishma to leafhoppers. The cultivars NIAB-86, MNH-63 and SLH-257 were highly susceptible to leafhopper. Whereas, the cultivar NIAB Karishma and CIM-482 showed medium response to leafhopper attack.

Said (2011) conducted cotton varietal screening and chemical control trials to decipher the comparative resistance of nine varieties of cotton and comparative efficacy of various pesticides against sucking insect pests (whitefly, leafhopper and thrips) of cotton. Among all the tested varieties, two were found relatively resistant to sucking insect pests as they showed least infestation and higher seed cotton yield.

The six genotypes of cotton *viz.*, BT-703, CIM-557, CIM-608, CIM-573, BT-3701 and FH-113 showed significant differences against sucking insect pest population. Whitefly adult population exhibited negative response with gossypol glands on leaf lamina, midrib and vein and also with plant height. Whitefly adult and nymphal population correlated positively with hair density on leaf lamina and vein and length of hair on leaf midrib. The nymphal and adult population of leafhopper showed positive correlation with gossypol glands on leaf lamina, vein and length of hair on leaf lamina, midrib and vein. Adult and nymph population of leafhopper revealed negative response with hair density on leaf lamina and midrib and also with plant height and leaf lamina thickness. (Khalil *et al*., 2015).

2.2.1.3 Screening of selected entries of okra for resistance to leafhopper (*A. biguttula biguttula*)

Mahal (1973) screened 10 varieties of okra and found the varieties New Selection, Sel-2-2, Sel-1 and Sel-6-2 as resistant to leafhopper with low nymphal population as well as extent of damage and Pusa Sawani as susceptible to leafhopper. Uthamasamy *et al* (1973) observed Pusa Sawani, A.E. 15 and A.E. 30 to be resistant to leafhopper at Coimbatore, Tamil Nadu.

Sandhu *et al.* (1974) screened 94 lines of okra against leafhopper at Ludhiana and reported Crimson Smooth Long as highly resistant to the leafhopper. While, *Abelmoschus manihot*, *A. manihot* var. *Teba* (I.W. 552), *A. moschatus* (E.C. 1502), *A.* pungens (I.W. 129), *A. tuberculatus* (I.W.495), Bhindi Sawani, I.C 7194, I.C. 8899 were observed to be moderately resistant with slight cupping and yellowing of leaves.

Uthamasamy (1980) reported that non-preference and antibiosis conferred the resistance in variety A.E. 22. Teli and Dalaya (1981) screened 29 varieties of okra and 7 F1 hybrids against *A. biguttula biguttula* during late summer and rainy seasons of 1977 in Rahuri, Maharashtra. Low leafhopper population was recorded in White Velvet, Clemson Spineless, Early Long Green, AE 27 and IC 75. The lines: HB-45, HB-39 and HB-43 were reported to be the most resistant to *A. biguttula biguttula* at Hisar, Haryana by Kishore *et al* . (1983).

Mahal and Singh (1982) made a diallel set of one susceptible variety Pusa sawani and three resistant varieties *viz.*, Sel-2.2, New selection and IC-7194 of okra and the segregating generations (BC1, BC2, F2) along with the hybrids and parents of six direct crosses were tested at the cotyledonary stage for screen house resistance to *A.biguttula biguttula*. The result revealed that resistance in respect of reduced nymphal survival was controlled by dominant genes in all the crosses except cross Pusa sawani X New selection in which case it was controlled by dominant genes.

Uthamasamy (1986) investigated the preference of *A. biguttula biguttula* for oviposition and feeding. Okra variety A.E. 22 was found to be less preferred for oviposition and feeding by leafhopper than the other susceptible variety Pusa Sawani. Rate of multiplication of leaf hoppers on resistant variety was low as compared to the susceptible variety. Singh (1988) reported a higher survival (95.35-97.42%), shorter developmental duration (6.15-6.94 days), longer size (2.24-2.37 mm) and weight (0.46-0.48 mg) of *A. biguttula biguttula* on the susceptible genotypes: Pusa Sawani, KS 305 and AC 302 of okra, while poor survival (29.69-55.90%), longer developmental period (9.99-11.84 days), smaller size (1.97-2.20 mm), and weight (0.30-0.38 mg) on resistant genotypes Line 14-78 and wild type, *Abelmoschus moschatus* (Linn). More than 8 leafhopper nymphs in the highly susceptible genotypes: Pusa sawani, KS 305 and AC 302 were observed as compared to less than 1 nymph per leaf in the highly-resistant genotype: *A. moschatus* were found.

Barrgoa and Bernardo (1993) reported that significantly more adults of *A. biguttula biguttula* preferred to feed and oviposit on the susceptible variety Smooth Green than on the resistant varieties of okra (Accession 9 and Accession 12). The resistant varieties exhibited antixenosis, antibiosis and tolerance as mechanisms of resistance in them and were less preferred for feeding as well as for oviposition and significantly more deaths of leafhoppers occurred on these resistant hosts. Taylo and Bernardo (1995) observed that more newly hatched nymphs were emerged on susceptible variety Smooth Green than on moderately resistant variety, Accession 12. Sharma and Sharma (1997a) also reported poor survival, longer developmental period and smaller size of the *A. biguttula biguttula* nymphs on resistant variety IC 7194 throughout the season as compared to susceptible varieties MR 12, MR 10-1 and Pusa Sawani. Sharma and Sharma (1997c) observed that the nymphal population of *A. biguttula biguttula* remained significantly lower on IC 7194 throughout the season which indicated its higher degree of resistance. The order of preference for okra cultivars was Pusa Sawani >MR 10-1>MR 12>IC 7194.

Hooda *et al.* (1997) evaluated 105 okra cultivars for resistance to leaf hopper. On the basis of nymphal abundance and leafhopper injury index, two resistant genotypes (Siswal Local and IC 7194), nine moderately resistant genotypes (IC 6653, IC 8899, IC13617, Sel. 1, HB 94, IC 6316, 6 Dhari, Sel. 2-2, Line 6 (1) and two highly susceptible genotypes (Pusa Sawani and Pusa Reshmi) were identified. Gul (1998) evaluated six varieties *viz.* T-13, Rich Green, Perking Dwarf, Pusa Green, Climson Spineless and Swat Local against leafhopper in okra and reported all varieties as susceptible to leafhopper.

Six okra varieties/hybrids *viz.*, Parbhani Kranti, Arka Anamika, LBH-55, H-7, Amtala hybrid and Kamdhenu were evaluated at Pundibari, West Bengal for resistance against leafhopper. Arka Anamika and Parbhani Kranti were found to be moderately resistant against leafhoppers (Ghosh *et al.*,1999). Bhat (1999) also observed Varsha Uphar and Arka Anamika to be less preferred by leafhoppers as compared to Shagun and Parbhani Kranti. Sharma and Sharma (2001b) evaluated the different okra varieties for resistance to *A. biguttula biguttula* and Pusa Sawani was observed to be the most susceptible.

Srinivasa and Sugeetha (2001) screened 9 okra cultivars for resistance against *A. biguttula biguttula*. KS 410 registered the lowest number of hoppers, while GOH- 1 was the most preferred by hoppers. Jalgaonkar *et al.* (2002) also reported KS-410 and Pusa Sawani to be susceptible to leafhopper. Kumar and Singh (2002) reported that the leafhopper nymphal population per leaf was lowest in Punjab Padmini (1.87), followed by DOV-91-4 (1.96) and Arka Anamika (1.98). Highest leaf injury was observed in Pusa Sawani (3.77). The lowest leaf injury was recorded in Arka Anamika (12.61%) followed by Punjab Padmini (13.27%) and highest in Pusa Sawani (61.06%).

Singh (2007) reported that the varieties *viz.*, Pusa Makhmali, P-8, Harbhajan and Parbhani Kranti harbored more leafhopper population. Singh *et al*. (2007) based on 14 year studies conducted at Varanasi, reported that out of eight *Abelmoschus* spp. *viz. A. esculentus*, *A. moschatus*, *A. ficulneus*, *A. tuberculatus*, *A. crinitus*, *A. manihot*, *A. tetraphyllus* and *A. pungens*, the *Abelmoschus* spp. *viz. Abelmoschus angulosus*, *A. moschatus* and *A. crinitus* were found with high level of tolerance to leafhopper and *A. caillei* showed symptomless carrier to leafhopper.

Iqbal *et al.* (2008) screened 30 genotypes of okra during 2006 at Faisalabad. Out of these, 3 genotypes Pusa Sawani, Dera Local and Okra-3 showed susceptibility, 3 genotypes Karam-5, Sabz Pari and Clean Spineless showed intermediate responses and 3 genotypes: Makhmali, Punjab Selection and Green Wonder showed resistance against leafhopper.

Dabhi *et al.* (2012) categorized okra genotypes: VRO-5, VRO-6 and Red Long as resistant and genotypes: AOL-03-02, AOL-04-03, AOL-04-05, Pusa Sawani and Gujarat Okra-2 as moderately resistant against leafhopper at Anand, Gujarat. Gonde *et al.* (2013) screened 17 varieties of okra against *A. biguttula biguttula* at Allahabad, UP and reported the varieties VRO-3 (1.66 leafhopper/leaf) and Kashi Pragati (1.78 leafhopper/leaf) as resistant against leafhoppers. The varieties Pusa Sawani (4.18 leafhopper/leaf) and KS 410 (3.82 leafhopper/leaf) were found to be susceptible to leafhopper. Punjab-8 was reported to be tolerant to leafhopper (Anon, 2015). Ullah *et al*., 2012 they revealed that, tested okra genotypes differed significantly in relation to leaf hopper population density. Same pattern was observed for morphological attributes except hair density on leaf veins. Genotype Arka Anamika had minimum population (1.61±0.31 hoppers/leaf) and found comparatively more resistant to leafhopper's attack. In contrast, genotype Anokhi proved as highly susceptible with maximum leafhopper population (3.07±0.56 hoppers/leaf). Correlation co-efficients between population of *A. biguttula biguttula* and different physico-morphic characters of okra revealed highly significant, strong and negative correlation for hair density on lamina and fruit yield per plant while non-significant, weak and negative correlation for hair density on midrib, leaf area and dry shoot weight.

Effect of leafhopper population on different okra varieties was observed by Javed *et al*. (1992) on the time frame at different life stages of the plant and effect of physio-morphic characters. Results revealed that, Arka Anamika (6.96 insects/plant) to be the most resistant cultivar among all the five tested cultivars followed by Super Green (8.11inects/plant). Ambika (13.3 insect/plant) was least resistant cultivar among all the five tested cultivars. Plant leaves of okra cultivars having high density of trichomes showed high resistance towards the leafhopper infestation.

Halder *et al.* (2016) reported okra genotypes SB-6 and SB-10 as susceptible and VROB-181 as tolerant under Varanasi conditions.

2.2.2 Role of plant morphological characteristics in host plant resistance

In case of insect pests, mechanical stimulation is perceived chiefly through the effect on articulated spines and hairs situated on many parts of the insect or pest body. The antennae, mouth parts and ovipositor or structures connected with the ovipositor, usually bear considerable number and variety of these hairs and setae. The continual palpitation of the antennae or mouth parts of many species of insects or pests appears to be a part of the means by which they learn about their surroundings (Painter, 1951). Many structural differences in plant varieties have been reported to be concerned with resistance. The morphological factors are known to interfere physically with insect locomotion and especially with the mechanism of host selection, feeding, ingestion, mating and oviposition (Norris and Kogan, 1980). The reviews pertaining to resistance factors or mechanism in sunflower against leafhoppers are scanty. However, pertinent literatures on mechanisms of host plant resistance of other sucking pests are presented here under.

2.2.2.1 Morphological factors

Plant morphology is known to play an important role in imparting resistance or susceptibility to a cultivar. Physical appearance of the plant like colour, hairiness, hardness, trichomes, surface waxes, incrustation of minerals in cuticle and anatomical adaptation of organs may affect the preference or non-preference for egg laying, feeding and development of an insect (Dhankhar, 1997). Afzal and Abbas (1943) observed that the moisture percentage of the leaves, pH value of their cell sap or the toughness of cuticle of leaf vein could not be used by the plant breeders as criteria in their selection work, because the character associated resistance should be an easily recognizable morphological character. It was suggested that hairiness would be an excellent tool for resistance studies against leafhopper. Other workers also reported that hairiness interfered with the feeding and oviposition by leafhopper (Husain and Lal, 1940).

According to some authors, dense pubescence interfered with the biological activity of leafhoppers favourably, while a group of workers found it far as resistance to leafhoppers is concerned. The presence or absence of shelter for insects has sometimes been of importance in resistance (Jones *et al.*, 1934). It has been shown that a small angle of contact of leaves between which the insects prefer to live contributed towards an increase in the population on the varieties with such leaves. Some of the examples covering these aspects are as listed below.

Further, Afzal and Abbas (1944) and Parnell *et al.* (1949) indicated that host plant resistance to leafhoppers is due to the leaf hairiness in cotton. Along with trichome density, trichome length and their angles of insertion also contribute towards leafhopper resistance (Parnell *et al*., 1945).

However, all hairy cotton genotypes are not resistant to leafhoppers (Parnell, 1925; Husain, 1938; Husain and Lal, 1940; Afzal and Ghani, 1946; Tidke and Sane, 1962). The hairy leaf cultivar, Stoneville 474 had significantly higher numbers of silver leaf whitefly eggs, nymphs and adults compared to eight other smooth leaf cotton cultivars (Chu *et al*., 2000).

In cotton, the insect resistance is associated with various morphological traits (Jayaraj and Sellamma, 1988; Jenkins, 1989 and Watson, 1989). There are certain morphological characteristics in cotton such as hairiness (glabrous v/s hairy), leaf shape (okra v/s normal) and the presence or absence of nectar-producing glands on leaves or flowers which make the plant less attractive, this can reduce their survival or growth.

Hairiness is one of the important easily recognizable insect resistant traits in cotton. In numerous species there is a negative correlation between the trichome density and insect feeding, oviposition responses and the nutrition of larvae. Specialized hooked trichomes may impale adults or larvae as well. Hairiness has been reported to have resistance against the sucking insect pests of cotton.

Tidke and Sane (1962) established a correlation between hairiness of leaf and leafhopper population in cotton genotypes which was further confirmed by Ali *et al.* (1995b). The degree of leafhopper resistance has definite correlation with the pilosity of the plant. The more tufted types were less prone to leafhopper attack. On the relative importance of the characteristics of hairiness studied, length of hair seemed to be of prime importance, closely followed by density of hair on lamina. Whereas, hair on the midrib did not seem to play any role in resistance to pest. Length of hair with higher hair density on the lamina was considered to be the best selection index in breeding resistance to leafhopper attack (Sikka *et al.*, 1966).

Bhat *et al.* (1981a) studied 11 cotton genotypes for the relative loss of seed cotton yield due to leafhopper and bollworms and reported that the hairiness in the genotypes was a cause of resistance to leafhopper in entries which showed minimum loss but they were susceptible to bollworm infestation.

Sharma and Agarwal (1983) studied the role of the biophysical components like leaf hairiness in varietal resistance in cotton to leafhoppers. Raza *et al.* (2000) conducted a study to determine the role of physico-morphological plant characters like number of gossypol glands, hair density and length of hair towards resistance/susceptibility against leafhoppers in 10 cotton genotypes. Results revealed that leafhopper adult population had negative correlation with hair density on leaf lamina and midrib.

Khan and Agarwal (1984) carried out laboratory and field studies in India on the oviposition preference of *A. biguttula biguttula* on 11 varieties of cotton. Varieties of *G. hirsutum* with the effective hair length on the ventral surface of the leaf mid veins longer than the ovipositor of females, were not preferred. Varieties of *G. herbaceum* or *G.*

arboreum with shorter effective hair lengths were also not preferred. The least preferred varieties were Sanguineum, Sujay, Badnawar-1 and M-495. The results revealed that, the effective hair length on the ventral surface of mid veins was significantly negatively correlated with the number of eggs laid.

Dhillon *et al*. (1998) studied the antixenosis response, *i.e.* ovipositional preference by leafhopper (*A. biguttula biguttula*) females and settling of leafhopper nymphs in 13 cultivars of cotton under free choice conditions. Results revealed that under free choice test, settling by third instar nymphs was relatively low on Jhurar and SRT 1 at both 2 leaf and 5 leaf stages of plant growth, while it was quite variable among other cultivars. Ovipositional preference in terms of fecundity cum fertility was low in case of F 1378, SRT 1 and Jhurar than that in F 846 at 5 leaf stage of plant growth. No nymphs emerged at 2 leaf plant stage. The antixenosis response of cotton cultivars tested was variable with respect to the magnitude of density, length and angle of hair on leaf veins. However, these hairiness factors seemed to be responsible for low egg laying by leafhopper females in SRT 1 and Jhurar.

Singh and Agarwal (1988) discussed physical and biochemical factors including leaf thickness and hairiness to resistance against insect pests. According to them, hairiness is the characteristic of resistance against leafhoppers. Similarly, Ambekar and Kalbhor (1981) also found that length of hair and hair density on midrib and leaf lamina of cotton were found to contribute towards resistance against leafhoppers.

Sivasubramanian *et al.* (1991) screened a total of 24 entries against leaf hoppers and concluded that hairiness as indicated by the length and density of trichomes on leaf lamina as well as on veins was considered responsible for conferring resistance. The trichome density on the ventral surface of the leaves, hair length and hair density of mid vein on ventral surface of the leaves exhibited significant negative association with leafhopper damage and oviposition (Murugesan and Kavitha, 2010). Hairiness on ventral surface was reported to be the most important morphological character and was positively related to leafhopper resistance (Uthamasamy, 1985a; Mohankumar, 1996).

Javed *et al.* (1992) tested four cotton varieties for physio-chemical plant factors contributing towards resistance for insect pests. A negative correlation was established between the leafhopper attack and the number of hairs per unit leaf area and gossypol content.

Syed *et al.* (1996) tested physical characteristics *viz.*, hair density and gossypol glands on six cotton varieties implicated in resistance against sucking pests and reported that genotypes with high density of hairs on midrib and leaf lamina exhibited resistance to leafhoppers, but were susceptible towards whitefly infestation. Similarly, Khan *et al.* (2001) also reported that the varieties having greater number of hairs and total minerals in leaf tissue were found to be resistant to cotton leafhoppers and thrips.

The primary source of resistance in *G. hirsutum* is the presence of trichomes (Lee, 1985). The degree of hair or trichome density on the leaves of *Gossypium* species and cultivars is related to varying degrees of resistance/susceptibility to sucking pests, like whiteflies (Meagher *et al.*, 1997), aphids and leafhoppers (Jenkins, 1989 and Watson, 1989).

Ahmad *et al.* (1999) found that hairiness on the leaf veins was a reliable character for resistance against cotton leafhopper. They opinioned that incorporating hairiness in the commercial varieties will help in decreasing at least one spray from the spraying schedule.

Praparat *et al.* (2001) studied the damage caused by the cotton leafhopper *A. bigutulla bigutulla* using hopper burn index. The numbers of cotton leafhopper from 2 leaves, one from the top and the other from the middle portions of the canopy from 10 plants in 3 middle rows of each tested variety were recorded on days 45, 60 and 75 after germination. Visual rating on leafhopper damage was employed and hopper burn index was calculated. It was found that on day 45, M2 populations of every tested line expressed moderate resistance to the leafhopper except R1 susceptible as indicated by hopper burn indices. As the plants grew older to days 60 and 75, the resistance reduced.

The hopper burn indices were of negative correlation to the leafhopper whose amounts were high on day 45 and decreased and rose again on days 60 and 75 respectively.

Muhammad *et al*. (2004) studied the resistance based on antibiosis in cotton genotypes BH-118, CIM-443, CIM-448, FH-634 and FH-87 under laboratory conditions. Results revealed that, all the genotypes differed significantly for all the antibiosis parameters of leafhopper *(A. biguttula biguttula)* and morpho-physical plant characters. BH-118 was comparatively resistant, minimum emergence of leafhopper nymph, minimum nymphal period, minimum number of leafhoppers reaching adult stage, minimum survival percentage of leafhopper nymph, maximum mating period and minimum oviposition period. CIM- 443 appeared as susceptible, maximum emergence of leafhopper nymphs, maximum nymphal period, maximum number of leafhopper nymphs reaching adult stage, maximum survival percentage of leafhopper nymphs, minimum mating period and minimum pre-oviposition period. Hair density and gossypol glands on midrib, vein and lamina exerted significant and positive correlation with mating period, nymphal emergence and oviposition period, respectively. Hair density and gossypol glands on midrib, vein and lamina also showed negative and significant correlation with oviposition period, nymphal emergence and oviposition period, respectively.

Sajjad *et al.* (2004) evaluated eighteen cotton cultivars against *A. devastans*. The cultivars, CRIS-82 and MNH-536 were highly infested by *A. devastans*. The lowest seasonal infestation was recorded for CRIS-467 and CRIS-134. The cultivars with the greatest hair density were resistant to leafhopper, whereas the cultivars with the lowest hair density were susceptible to leafhopper. Hair length had no significant effect on the population of leafhopper.

Gulzar *et al.* (2005) selected ten genotypes of cotton, catalogued in relation to resistance against leafhopper, *A. devastans*. All the tested genotypes of cotton significantly differed in relation to all morphological plant traits. Hair density on vein and lamina of upper leaves, the length of hair on midrib and vein of upper leaves, midrib of middle leaves and midrib and vein of bottom leaves, gossypol glands on midrib, vein and lamina of upper, middle and bottom leaves and thickness of leaf lamina on midrib and bottom leaves played a significant and negative role towards resistance for leafhopper adult population. The length of hair on midrib, vein of middle leaves, gossypol glands on lamina of middle leaf resulted in significant and negative correlation with leafhopper nymph population while all the other morphological traits showed non-significant correlation to leafhopper population.

Indrayani *et al.* (2007) evaluated thirteen cotton accessions for leafhopper resistance and reported that every accession of cotton can be attacked by *A. biguttula i.e.* the insect population was not significantly different among accessions. whereas, the accessions exhibited significant difference for the damage symptom. Accessions that categorized as lightly hairy were moderately resistant to *A. biguttula.* These were AC 134, Stoneville 7, Fai Nai, SHR, CRDI-1, Kanesia 5, Kanesia 8 and Kanesia 9. Remaining accessions were categorized as glabrous and were susceptible to the sucking pest. Similarly Muhammad *et al.* (2012) evaluated three cotton strains *viz.,* Cyto-46(474/cm^2), Cyto12/91 (1011/cm^2) and Cyto-55(633/cm^2) showing varying degrees of trichome density for tolerance to sucking pests and found that sucking pests, specially leafhoppers, could be managed by choosing the variety having moderate hair density. Similar results were also reported by Arif *et al.* (2006), Bashir *et al.* (2001), Gulati and Turner (1928) and Sana (1989). In contrast to this Raza *et al.* (2000) and Kaplan *et al.*, (2009) reported that although leafhopper abundance did not decrease as trichome density increased but leafhopper injury was found to be negatively correlated with the trichome density.

Zumba and Myers (2008) evaluated 154 cotton germplasm accessions which was a subset from the National Collection of *Gossypium* germplasm including commercial checks. The genotypes Delta Pearl and FM 958 were graded as having few hairs on leaves and the commercial check PSC 355 was scored as intermediate. 26 germplasm accessions recorded smooth leaves. Most of the germplasm accessions evaluated exhibited low to intermediate leaf hairs. All the commercial checks and one hundred and eighteen of the germplasm accessions evaluated exhibited few hairs on their calyx, whereas twenty seven germplasm accessions did not exhibit hairs on the calyx.

Ashfaq *et al.* (2010) investigated nine Bt genotypes and non-transgenic genotype CIM-496 (control), to determine the correlation of abiotic factors and physio-morphic characters of Bt cotton with leafhopper (*A. devastans)* populations. The results suggest that maximum population of the leafhopper was observed on transgenic genotypes. The effect of physio-morphic characteristics of transgenic and non-transgenic varieties had similar kind of varied relationship with the leafhoppers.

Irfan *et al.* (2010) studied four genotypes of Bt cotton *viz,* BT-121, BT-456, FH-160, FH-216 to assess the effect of leaf pubescence on the incidence of sucking insect pests. Leafhopper adult had negative correlation, with number of hair on midrib (0.277), vein (0.051) and lamina (0.207) and length of hair (0.023). Leafhopper nymph was negatively correlated with number of hairs on midrib (-0.114) and vein (-0.160) and length of hair (-0.202) while it had positive correlation with number of hairs on lamina (0.082). This indicates that incorporation of hairiness in Bt cotton genotypes will greatly reduce the sucking pest damage due to leafhoppers and thereby helps to reduce the number of sprays in Bt cotton.

Cotton strains having different hair length and density were evaluated for tolerance to *Bemisia tabaci, A. devastans* and *Thrips tabaci,* and survival of predators and parasitoids. The seed treatment effect on the population of these insect pests and natural enemies were also studied. Population of *B. tabaci* was higher on the strain Cyto-46, having trichome density of 474±12.9 per cm^2 and hair length of 705±44.8 microns and minimum on strain Cyto-12/91, having trichome density of 1011±21.0 per cm^2 and hair length of 644±27.3 μ. (Naveed *et al*., 2011)

Bhatti *et al*. (1976) were observed the variations among the resistance and susceptible genotypes of Bt cotton due to plant height, hair density, thickness of leaf lamina, leaf area, length of hair, moisture percentage and total minerals. The results revealed that hair density on midrib, vein and lamina had negative and significant correlation; length of hair on midrib and vein had non significant correlation. While, thickness of leaf lamina exerted positive and significant correlation with the leafhopper population per leaf. Gossypol glands on midrib and vein showed positive and significant correlation while on lamina had negative and significant effect. Total minerals exerted positive and significant effect whereas, reducing sugar, calcium and manganese showed negative and significant correlation with the leafhopper density. Multiple linear regression models revealed that hair density on midrib and total minerals in the leaves were the most important characters.

Anand (1946) while working on reaction of glabrous and hairy types of cotton to aphid resistance concluded that differential attraction of the aphids was seen and this could be due to the difference in the light intensities reflected from the two sorts of leaves, leading to fewer aphids in glabrous cotton leaves than on hairy types.

Trichomes play a vital role in the plant defense particularly among phytophagous insects. Annappan (1960) observed that characters of leaf hairiness does not always accounts for leafhopper resistance in cotton. Leaf area and its succulency play a part in leafhopper resistance. The more the leaf area, more is the nymphal population. Similarly, other workers also reported that hairiness on the undersurface of leaves was positively correlated with resistance to cotton leafhopper in cotton (Tidke and Sane 1962, Sikka *et al.*, 1966, Ambekar and Kalbhor, 1981) and okra (Mahal 1973, Bindra and Mahal., 1981) in terms of either leafhopper population or the extent of injury inflicted by it.

Leaf toughness serves as a limiting factor in population build up of certain pests (Kadapa *et al*., 1988). Leaves of resistant cotton genotypes have been found to be thinner compared to susceptible genotypes to insect pests. The thinner leaves in resistant genotypes coupled with the higher density of upper and lower epidermal cells and mesophyll cells make the lamina of these genotypes to be very compact. The susceptible genotypes are characterized by thick leaf lamina with loosely arranged epidermal and mesophyll cells, thus making the leaves succulent and susceptible to insect pests (Thimmaiah, 1992: Chandrashekara, 1994).

Khan and Agarwal (1984) observed that in cotton varieties, short effective hair length on ventral surface of mid-vein and numbers of eggs laid by *A. biguttula biguttula* were negatively and significantly correlated. Resistant varieties had more and longer hairs on the midrib and lamina than the susceptible varieties. The number and length of hairs rather than the density influences plant resistance (Uthamasamy, 1985b).

Thimmaiah (1992) studied the anatomical differences in pest resistant and susceptible genotypes in cotton and results revealed that, resistant genotypes registered a lesser thickness of leaves, diameter of petiole, midrib and stem tip as compared to susceptible genotypes. Cell density of tissue of the resistant genotypes was higher than in the susceptible genotypes, suggesting the insect pest resistance to be positively correlated with compact tissues. Thus, the anatomical parameters of resistance genotype could supplement the host plant resistance mechanisms.

Mehetre and Patil (2004) studied the anatomical basis of resistance in cotton for sucking pest complex. Specific leaf anatomical structures control resistance or susceptibility to various sucking pests. Hence, to breed a genotype resistant to sucking pests, modification in cellular structure of leaf at genic level is required. Asiatic cotton species have relatively longer distance of phloem from lower epidermis, compact cell arrangement of parenchyma tissue and longer palisade tissue while wild species have genetic resistance against the pest with very compact palisade tissues. Attempts have been successful in improving the *G. arboreum* lines with genic resistance of wild species through introgression breeding approach. Hybrid crosses between *G. arboreum* x *G. hirsutum* are difficult to obtain. Successful hybridization between haploid *G. hirsutum* x *G. arboreum* var. G- 27 has been reported.

Ahmad *et al.* (2005) evaluated different varieties of cotton for resistance to leafhopper in Faisalabad, Pakistan and reported that hair density on vein and lamina of upper leaves, the length of hair on midrib and vein of upper leaves, midrib of middle leaves and midrib and vein of bottom leaves, gossypol glands on midrib, vein and lamina of upper, middle and bottom leaves and thickness of leaf lamina on midrib and bottom leaves played a significant and negative role towards resistance for leafhopper adult population. The length of hair on midrib, vein of middle leaves, gossypol glands on lamina of middle leaf was negatively and significantly correlated with leafhopper nymph population, while all the other morphological traits showed non-significant correlation to leafhopper population.

More *et al*. (2007) in their anatomical studies in apomictic lines IS-244/4/1 and IS-181/7/1 revealed that distance to phloem from lower epidermis was 31 and 33.2 mm respectively, which was on par with *Gossypium arboreum* check PA-183 (36.4 mm). *G. hirsutum* check (NH-545) had significantly less (23.6 mm) distance to phloem from lower epidermis compared to other genotypes. Parenchymatous cells were more compact in *G. arboreum* check PA- 183 and apomictic lines (IS-244/4/1 and IS-181/7/1) than *G.hirsutum* check NH-545. Palisade compactness, parenchyma tissue width of apomictic lines IS-244/4/1 and IS-181/7/1 were similar to that of *G. arboreum* check but were less in *G. hirsutum* check. Similarly, in interspecific hybrid derivatives with PA-183, the phloem distance from upper epidermis confirmed the resistance of these lines to sucking pest complex.

Kulkarni and Khadi (2009) opinioned that, leafhoppers cause significant production losses of cotton in Asia. Although higher trichome density confers host-plant resistance, it has negative effect on the agronomic performance. Leaf anatomical studies in wild and cultivated *Gossypium* species and introgression derivatives (42 entries) were done to understand physical basis of resistance. Based on the variability studies of different anatomical features, diversity analysis and correlation and path coefficient studies, following conclusions were made to explain leafhopper resistance in cotton. Non pubescent nature does not indicate susceptibility. Lower palisade cells in leaf lamina act as physical barrier for feeding and oviposition. Thicker lamina coupled with absence of pubescence or lower palisade depicts susceptibility, but with their presence they confer resistance. The sucking distance (distance between lower midrib epidermis to phloem) alone, without knowing nature of cortex cell arrangement does not depict resistance or susceptibility. Higher cortex cell density irrespective of sucking distance is indicative of resistance. The physical resistance is a plant factor as stylet length of leafhopper (0.526 mm) is much longer than the sucking distance (0.465 mm) observed in the *Gossypium* species.

Ali and Ali (1993) in field studies in Bangladesh showed that, the okra leaf isogenic cotton lines had significantly lower numbers of *A. devastans* than the regular leaf isogenic lines. The okra leaf isogenic lines also gave higher yields than the regular leaf isogenic lines under the study conditions.

Uthamasamy (1980) reported that the okra variety AE 22 was less preferred for oviposition by *A. devastans* due to its hairiness on leaf lamina and midrib. Thickness of the midrib of okra and of cotton was reported to have a positive relationship with the oviposition of leafhoppers (Ambekar and Kalbhor 1981, Sharma and Sharma 1997b). Similar studies were conducted on 12 genotypes of cotton in Delhi and it was found that the mean leafhopper population was negatively correlated with leaf hairiness (Sharma and Agarwal, 1983).

Uthamasamy (1986) also reported that the resistance in okra varieties to the leafhopper is governed by non-preference and antibiosis mechanisms. The difference in the behaviour of the leafhopper could be attributed to higher hair density and hair length on the lower leaf surface. The incidence of *A. biguttula biguttula* was significantly negatively correlated with the hair density and hair length on the lower leaf surface of okra leaf (Singh, 1988). Similarly, relationship between nymphal population and both density and length of hair on mid-vein of okra leaves was reported inverse and significant by Lal (1989).

Soft stem hair present in Parbhani Kranti, Pusa Sawani and P-8 and lower hair density on mid veins of Pusa Sawani leaves can partly explain higher leafhopper population harbored by these varieties (Mahal *et al.,* 1993a, Sharma and Arora 1993, Gill *et al.,* 1997, Hooda *et al.,* 1997, Dhankhar and Mishra, 2001, Thakur *et al.,* 2003). The correlation between hair density, hair length and angle of insertion of hair on mid-vein and mean leafhopper-injury indices was negative and significant especially in case of three principal veins in okra (Dhillon, 1997).

Anitha and Nandihalli (2009) found a significant negative correlation of leafhopper population in okra with number of hairs on leaf lamina and leaf midrib but a significant and positive correlation with the thickness of the midrib.

Correlation co-efficients between population of *A. biguttula biguttula* and different physico-morphic characters of okra found to be highly significant. A strong and negative correlation was found for hair density on lamina and fruit yield per plant, while non-significant, weak and negative correlation was observed for hair density on midrib, leaf area and dry shoot weight (Ullah *et al.*, 2012).

Halder *et al.* (2016) also reported that the susceptible genotypes of okra had lower hair density than the tolerant genotypes and had significant and negative correlation with leafhopper population at Varanasi.

In brinjal, thickness of lamina and midrib were found positively correlated with leafhopper infestation, while the thickness of lateral veins, density of midrib hair and length of midrib hair did not have significant correlation with leafhopper infestation (Subbaratnam *et al.*, 1983).

Cassi-Lit and Bernardo (1990) also reported a significant negative correlation between the trichome length and *A. biguttula biguttula*, while Ali *et al* (1995b) and Bashir *et al.* (2001) observed an inverse and significant relationship of hair-density on the midrib, veins and lamina with the leafhopper population. High density of leaf hair seems to be the prevalent type of resistance.

Ali *et al.* (1995b) also reported that the varieties with higher number of hair were found to be resistant to leafhopper, but length of hair on the leaf-lamina was not so important for the leafhopper resistance. However, Taylo and Bernardo (1995) from Philippines concluded that the emergence of *A. biguttula biguttula* was significantly and negatively correlated with the density of trichomes and length of trichome. The density and length of trichomes and leaf hardiness were significantly higher in Accession 12 than the Smooth Green variety of okra. Long dense leaf trichomes probably impeded the feeding and egg deposition and the greater quantity of readily utilizable free sugar may led to the greater attraction and fecundity of the hoppers on Smooth Green.

The resistance to leafhopper was associated with higher trichome density, longer trichome length (Hooda *et al.,* 1997). Lal *et al.* (1997) found denser as well as longer hair on the resistant varieties IC 7194 and New Selection than on the susceptible variety Pusa Sawani.

Iqbal *et al.* (2011b) also reported a negative and significant correlation of mid vein hair density and hair length of upper, middle and lower leaves of okra leaves with the leafhopper population. In another study, the hair density and length of hair on the leaf lamina, midrib and veins in selected varieties of brinjal showed a highly negative and significant correlation with the leafhopper population. Hair density on the lamina and the leaf area showed 78.2 per cent and 5.9 per cent role, respectively in the population fluctuation of leafhopper. The results showed that the physio-morphic characters of the brinjal plant play vital role in the population fluctuation of leafhopper (Muhammad *et al.,* 2012).

2.2.3 Biochemical factors imparting resistance

Plant tissues are largely made up of water, proteins, carbohydrates, minerals and lipids. Thus providing a potential source of water and nutrients by which the insect pests acquire the required quantities of energy, nitrogen, proteins and carbohydrates. The infesting pests must consume proportionately large quantities of plant leaf for each unit of insect pest growth. At the same time plants have developed a number of defence mechanisms that resist the damage caused by the pests or insect feeding. The resistance mechanism evolved by plants includes biochemical factors which act as repellent, toxic or otherwise and make the plant unsuitable for utilization.

2.2.3.1 Total soluble phenols

Newton and Anderson (1929) proposed the phenol hypothesis to explain resistance. They suggested that rust resistance in wheat is due to the liberation of phenolics in the host cells, due to invasion of the fungus and that the phenols liberated kill the host cell and inhibit the growth of the pathogen.

Sachan and Sachan (1991) found a significant negative correlation between the aphid population and phenol content of mustard cultivars indicating that higher amounts of phenol were responsible for low aphid population. Significant higher content of phenol was observed in RW15-6, RW2-2 and B85 (14.67, 13.83 and 12.67mg/g., respectively) of resistant group, followed by the varieties of moderately resistant groups, whereas the low phenol content was observed in Varuna and Porbiraya varieties of susceptible group (5.17 and 5.67mg/g), respectively.

Sharma and Agarwal (1983) found that the mean leafhopper population on cotton was negatively correlated with gossypol, sugar and free amino acids and positively correlated with free phenols and tannins.

Young leaves, stem tip and squares of resistant cotton genotypes contained higher level of total phenols and tannin than the susceptible genotypes (Thimmaiah, 1992; Chandrashekara, 1994).

Hooda *et al.* (1997) reported that higher concentration of sugars, silica, potassium, tannins, and phenols in the leaves of resistant genotypes of okra were associated with resistance to leafhopper.

Halder *et al.* (2016) reported a significant and negative correlation between total phenol content and leafhopper incidence on okra. The present study was conducted at University Research Farm Koont, during the year 2014. Six brinjal cultivars were tested for their host suitability against the leafhopper. The results revealed that maximum number of nymphs and adult were observed on Giant Round cultivar with 0.35 and 1.35 per leaf respectively. The minimum population of nymphs and adult were observed on Pusa Purple Long with 0.01 and 0.01 per leaf respectively. According to physico-morphic characters the maximum numbers of hairs on leaf lamina and leaves midrib were recorded on Pusa Purple Long cultivar with 279.00 and 72.25 cm^2 and minimum on Giant Round with186.75 and 23.00 cm^2 respectively. Highest plant height was noticed on Pusa

Purple Long with 61.92 cm while the minimum brinjal plant height was observed on Giant Round *i.e.* 44.59 cm. Brinjal plant stem girth on Giant Round was higher with 54.70 cm and minimum on Pusa Purple Long with 28.42 cm. Maximum yield was observed on Pusa Purple Long with 0.42 kg while the Giant Round had low yield of 0.04 kg. So Pusa Purple Long has been recommended for the cultivation in the Pothwar region.

Vaishali *et al.* (2012) observed that the amount of total phenolics were relatively low in susceptible varieties than the resistant varieties and hybrids. Cotton plants with high phenolic content showed low incidence of leafhoppers.

Simmonds (2003) studied the flavonoid-insect interactions and observed that the phenols act as antifeedant to insect herbivores. Massey *et al.*, (2006) reported that silica may act as an anti herbivore defence by increasing the abrasiveness and reducing the digestibility of grass leaves.

2.2.3.2 Total soluble protiens

Proteins are the source of amino acids which are essential for the production of tissue and enzyme in insects. Some amino acids such as arginine, lysine, leucine, isoleucine, tryptophane, histidine, phenylalanine, methionine, valine and threonine are essential amino acids for most of the insects. The diet plays an important role in egg production, yolk production and for oogenesis in many insects (Chapman, 1969).

Singh *et al*. (1972) reported higher protein content in all the resistant strains of cotton to leafhoppers as compared to the susceptible strains and concluded that leafhopper may take food from organic constituents, preferably proteins and lipids. These constituents were found in lesser amount in the susceptible strains.

The cotton varieties susceptible to pests or diseases have been found to contain higher amount of protein (Chakravorthy and Sahni, 1972; Balasubramanian and Gopalan, 1981; Bhat *et al.*, 1981a).

Bhat *et al*. (1981b) observed higher content of soluble proteins in susceptible strains (22.53 mg) as compared to resistant strains (18mg/g fresh leaf) of cotton in relation to leafhopper infestation.

Varieties that supported lower BPH population (11.5 hopper) had lesser protein content (6.96%) in comparison to susceptible rice variety MTU-7029 (45.3 hopper/plant) recording the highest protein content (16.4%). The results indicated that the presence of lower quantity of protein was related with resistance of rice varieties to BPH. (Sujatha *et al.*, 1987).

Uthamasamy (1980) observed that the okra variety AE 22 was less preferred for feeding by *A. devastans* due to its poor nutritive value. Similarly, the biochemical parameters associated with resistance to leafhopper such as peroxidase activity, isoenzyme activity of enzyme, soluble protein and tannin were studied in a set of diverse genotypes of American cotton and Asiatic cotton differing in susceptible reaction to this insect pest. Lower the value, more resistant the genotype would be in a natural condition. The susceptible types had peroxidase isoenzymes with high electrophoretic mobility, besides having isoenzyme with low mobility and vice-versa (Bhat *et al.,* 1981b).

A positive correlation between the protein contents and survival as well as oviposition of the leafhopper was reported by Singh and Taneja (1989). Ali *et al.* (1995a) did not observe any role of proteins against the leafhopper attack and reported that reducing sugars had positive and significant correlation with the leafhopper density. Comparatively lower proteins, moisture and sugar content present in leaves of Arka Anamika and Varsha Uphar were accountable for their resistance and more proteins, moisture and sugars in leaves of Parbhani Kranti, P-8, Pusa Sawani and Shagun are responsible for the susceptibility of these varieties (Chavan *et al.,* 1991, Bhat, 1999).

Comparison of relative differences between the susceptible and resistant cotton genotypes with reference to distribution of protein in the leaves, petioles, stem tips and boll rinds recorded higher total protein content in susceptible genotypes as compared to the resistant ones (Thimmaiah *et al.,* 1997).

Sahoo and Patnaik (2003) found lower amount of protein in resistant entries (15.4 to 15.4 to 16.6% in seeds and 7.9 to 8.2% in pod coat) as compared to susceptible (18% in seeds and 11.6% in pod coat) and check (18.2 and 11.6%) in seeds and pod coat, respectively). They inferred that low protein content could afford resistance to most of the pod borer species in pigeonpea and form a basis for selection of varieties.

Kabre and Ghorpade (1999) reported significantly low protein content (13.21%) in least susceptible genotype (X2(Y) 5089) of maize as compared to highly susceptible CM-202 (16.42%). The protein content was positively correlated with stem borer susceptibility. The differential survival of the leafhopper on resistant and susceptible varieties of cotton was observed. The protein content had positive influence on leafhopper growth, development and damage caused by them (Mohan Kumar and Venugopal, 1999).

2.2.3.3 Total soluble sugars

Afzal and Ghani (1953) observed association between resistance and percentage of moisture, hairiness and toughness of vein and further noticed that pH of the cell sap and moisture content of leaf vein was of less importance. Inadequate concentrations of sugars, amino acids, organic acids and minerals and the high concentrations of toxic phenols play an important role in the poor multiplication of *A. devastans*. The varieties poor in nutritive values are less preferred for feeding by leafhoppers.

Raju and Reddy (1982) reported a negative and significant correlation of nymphal population of leafhopper in cotton with total phenols and orthodihydroxy phenols and a positive and significant correlation with reducing sugars and tannins.

Singh (1988) evaluated the leafhopper on susceptible genotypes of okra *i.e.* Pusa Sawani, KS 305 and AC 302 and resistant genotypes: Line 14-78 and wild specie *Abelmoschus moschatus* and found higher amounts of total sugars, non-reducing sugars, tannins and silica in the leaves of resistant genotypes, because these factors had significant negative correlation with pest incidence. Moisture content and pH had positive correlation with leafhopper incidence. The effects of reducing sugars, protein and free amino acids were less significant.

The comparative bio-chemistry with respect to the host plant resistance to cotton plants to leafhoppers, *A. devastans* (Distant) revels that resistant strains irrespective of strain characters contain higher amounts of lipids and other minerals. Susceptible strains are found to be rich in reducing sugars and calcium. Negative association of sugars with seed cotton yield indicates that higher sugar content makes the plant parts more palatable to insect to feed (Mundas, 1992).

Blackgram varieties resistant to whitefly and leafhoppers recorded higher amount of reducing sugars (2.4 to 2.62%) as compared to the susceptible ones (Chhabra *et al*., 1993).

According to Taylo and Bernardo (1995), total free sugars and starch were the variable chemical components when susceptible variety Smooth green and moderately resistant okra Accession 12, were compared. Only the total free sugar percentage was found consistently and significantly higher in susceptible than in the resistant plants. Extra floral nectaries on okra leaves contain sugar and phenol but the amount of these did not differ significantly in the susceptible and resistant varieties, suggesting no apparent influence of these parameters on host preference by *A. biguttula biguttula.*

Correlation coefficient between leaf hopper population and tannin content was positive and significant (Shinde *et al.,* 2014). The total soluble sugar in leaves of okra genotypes ranged from 2.47% (AKOV-107-04) to 3.82% (AKOV106) followed by 3.75% (AKOV-98-04-1), and 3.71% (Parbhani Kranti). The phenol content in leaves of okra genotypes ranged from 1.92 (AKOV-106) to 2.64 mg/g (AKOV-107-04). The total soluble sugars and phenols present in leaves of okra genotypes had non significant correlation with leaf hopper and aphid incidence (Mudgalkar *et al.,* 2015).

Iqbal *et al.* (2011a) reported that crude protein, nitrogen, lignin, reducing sugars, phosphorus and copper showed positive correlation, whereas neutral detergent fiber, acid detergent fiber, cellulose, silica, total ether, non-reducing sugars, total sugars, calcium and magnesium had negative correlation with the population of leafhopper on okra. When computed together, all the chemical components showed 99.7 per cent role on leafhopper population fluctuation.

Hu *et al.* (2010) studied the effects of 16 sugars (arabinose, cellobiose, fructose, galactose, gentiobiose, glucose, inositol, lactose, maltose, mannitol (a sugar alcohol), mannose, melibiose, ribose, sorbitol, trehalose, and xylose) on sweet potato whitefly *Bemisia tabaci* and it was found that insecticidal activity of the sugars was likely due to an antifeedant effect on the whitefly.

Correlations were done between biochemical characters of resistant and susceptible cotton varieties and the leafhopper growth, development and damage caused by them. Total and reducing sugars were low in resistant entries as compared to susceptible ones (Mohan Kumar and Venugopal, 1999).

Other factors

Carbohydrates contribute for the dry matter production in plants which is synthesized through the process of photosynthesis, plants utilize the carbohydrates as a component of special substances like nucleic acids and glucosides and structural material. The role of sugars as feeding stimulant in insects has been reported by several workers (Dethier, 1953; Thorsteinson, 1960). Glucose and fructose induce digestive enzyme activity as the case with disaccharides like sucrose and maltose (Ishaaya and Meisner, 1973). This report indicated an indirect idea of sugar availability in the host-plant and decides the insect pest population in plant parts of individual plants and among the cultivars of a species.

Chakravorty and Sahni (1972) after conducting studies on cotton reported that the resistant and tolerant strains were rich in silica. Silica content of leaves of medium or less hairy resistant and tolerant strains was low but tannin content was high. The susceptible strains were poor in both silica and tannin and contained more protein, lime and sulphate proportionally. The leaves of susceptible strains were either less hairy or smooth. Singh *et al.* (1972) studied the selected eleven strains of cotton for their sources of resistance against cotton leafhopper, *A. devastans* (Distant) and observed that the resistant strains, irrespective of their hair characters, had higher amount of lipids, total minerals, phosphorus, silica, iron and magnesium in their leaves. Susceptible strains were high in reducing sugars and calcium. The leafhopper feeds preferably on lipids and proteins. It was concluded that the higher contents of minerals like silicon in resistant strain increase the osmotic pressure of the cell sap thereby adversely affecting the feeding ability of leafhoppers.

Singh and Atwal (1976) reported the higher contents of cellulose and calcium in the leaves of the resistant cotton variety than those in the susceptible varieties. The greater amount of total minerals in the leaves suggested that its cell sap had a higher osmotic pressure than that of the susceptible varieties.

Balasubramanian and Gopalan (1981) studied the mechanism of resistance of upland cotton to leaf hopper. Their studies revealed that the resistant variety, HB-69 contained more of total carbohydrates as compared to the susceptible PRS- 72 and the tolerant GS-23.

Plant epicuticular lipids are known to have significant role in modifying insect feeding and oviposition behaviour (Woodhead and Chapman, 1986).

Barroga and Bernardo (1993) reported that the cause of death of leafhoppers on resistant varieties may be largely the nutrient deficiency, rather than the presence of toxic materials in the plants. The deficiency can be due to the absence of some essential food nutrients or their inadequate amount.

Certain genotypes, in spite of being less hairy are resistant to leafhoppers (Singh *et al.,* 1972), perhaps because of the presence of some biochemicals in the leaves of host plants (Uthamasamy *et al.,* 1971, Singh *et al.,* 1972). Wide array of chemical substances including inorganic chemicals, primary metabolites, intermediary metabolites and secondary substances are known to render cultivars less suitable or unsuitable to a wide array of insect-pests (Dhaliwal and Arora 2003).

Sharma *et al.* (2009) and Barbehenn and Peter (2011) observed that tannins have a strong astringent taste and deleterious effect on phytophagous insects and affect the insect growth and development by binding to the proteins, reduce nutrient absorption efficiency and cause midgut lesions.

III MATERIAL AND METHODS

Field investigations were conducted at AICRP (Sunflower), Zonal Agricultural Research Station, Gandhi Krishi Vignana Kendra (GKVK), University of Agricultural Sciences and Main Research Station (MRS) Hebbal and Labarotary studies were conducted at Department of Agricultural Entomology and Department of Soil Science and Agricultural Chemistry, Bengaluru, during the years 2015-16 and 2016-17 in order to determine the morphological and biochemical basis of resistance to leafhopper (*Amrasca biguttula biguttula* Ishida.) in sunflower (*Helianthus annuus* L.). The materials used and the methodology adopted in carrying out these investigations are presented under appropriate headings in the following paragraphs.

3.1 Location of the experimental area

The experiments were laid out at the plots of All India Co- ordinated Research Project (Sunflower), ZARS, Hebbal and GKVK campuses of the University of Agricultural Sciences, Bengaluru, which is situated in the Eastern dry Agro-climatic zone of Karnataka state (India) with the altitude of 930m msl (13˚04’ 37” N, 77˚ 34’ 39.99” E). The annual rain fall ranges from 528mm to 1374mm with a mean of 915.8mm. Plots were homogeneous with respect to nutrient status. All other agronomic management practices for the field experiments were followed according to recommended package of practices (Anon., 2015).

3.1.1 Layout of Experiments

The field investigations were conducted both during *kharif and rabi* seasons of 2015-16 and 2016-17. The seeds of the sunflower genotypes were not treated with any pesticide, to facilitate natural infestation by leafhopper. The seeds of all the genotypes were sown in rows of 4 m and 4.2 m length with a spacing of 60 x 30 cm respectively.

3.2 Screening of sunflower germplasm entries, elite hybrids and their parental lines for their reaction to leafhopper and hopper burn injury.

In order to determine the sources of resistance to leafhopper and hopper burn injury, the germplasm lines, varieties, experimental hybrids and their parental lines were screened for their reaction during both *kharif* and *rabi* season of 2015-16 and 2016-17 under field conditions.

3.2.1 Screening during *Kharif* 2015

Totally sixty restorer lines, eleven germplasm lines, one variety, nine popular and released hybrids were screened under field conditions (Table 1) during *Kharif* 2015.

3.2.2 Screening during *Rabi* 2015

During *rabi* 2015, eleven varieties, two parental lines, five restorer lines, fourty five germplasm entries and ninty nine hybrids were screened under field conditions (Table 2).

3.2.3 Screening during *Kharif* 2016

Totally sixty four germplasm lines were screened during *kharif* 2016 under field conditions of ZARS, GKVK, Bengaluru (Table 3).

3.2.4 Screening during *Rabi* 2016

During *rabi* 2016, twenty four varieties, one parental line, thirteen restorer lines, twenty germplasm entries and thirty one hybrids were screened under field conditions (Table 4).

The seeds for the GMU entries for the field trial were obtained from the Indian Institute of Oilseeds Research, Hyderabad which were available at AICRP (Sunflower), ZARS, GKVK, Bengaluru.

These experiments were sown in unreplicated single rows at different dates during each of the four seasons during 2015-16 and 2016-17. The row length for each entry was either 4.0m or 4.2m in both seasons. Observations were recorded at 45 and 75 days after sowing (DAS). The screening experiment was conducted as per the package (Anon., 2015).

Table 1: List of sunflower restorer lines and germplasm entries screened against leafhopper during *Kharif* 2015

Location	**E-16, ZARS, GKVK**
Season	***Kharif 2015***
Entries	**81**
Date of sowing	**23/08/2015**
Design	**Unreplicated single row**
Row length	**4m**

Sl. No.	Entry No.	Sl. No.	Entry No.	Sl. No.	Entry No.	Sl. No.	Entry No.
1	RHA1001	22	RHA1022	42	RHA1042	62	EC734887 X NDCM52A
2	RHA1002	23	RHA1023	43	RHA1043	63	GMU775 X CMS 138A
3	RHA1003	24	RHA1024	44	RHA1044	64	GMU780 X CMS 17A
4	RHA1004	25	RHA1025	45	RHA1045	65	GMU762 X CMS 903A
5	RHA1005	26	RHA1026	46	RHA1046	66	GMU750 X CMS 903A
6	RHA1006	27	RHA1027	47	RHA1047	67	GMU743 X CMS 903A
7	RHA1007	28	RHA1028	48	RHA1048	68	GMU748 X CMS 903A
8	RHA1008	29	RHA1029	49	RHA1049	69	GMU 742 X CMS 903A
9	RHA1009	30	RHA1030	50	RHA1050	70	GMU 753 X CMS 903A
10	RHA1010	31	RHA1031	51	RHA1051	71	GMU 592 X CMS 903A
11	RHA1011	32	RHA1032	52	RHA1052	72	OPV3
12	RHA1012	33	RHA1033	53	RHA1053	73	KBSH 41
13	RHA1013	34	RHA1034	54	RHA1054	74	KBSH 44
14	RHA1014	35	RHA1035	55	RHA1055	75	KBSH 53
15	RHA1015	36	RHA1036	56	RHA1056	76	RSFH130
16	RHA1016	37	RHA1037	57	RHA1057	77	S-2017
17	RHA1017	38	RHA1038	58	RHA1058	78	KBSH 71
18	RHA1018	39	RHA1039	59	RHA1059	79	KBSH72
19	RHA1019	40	RHA1040	60	RHA1060	80	KBSH73
20	RHA1020	41	RHA1041	61	EC784877 X NDCM52A	81	KBSH74
21	RHA1021						

Table 2: List of sunflower restorer lines, germplasm entries, varieties and experimental hybrids screened against leaf hopper during *rabi* 2015

Location	**MRS, Hebbal**
Season	***Rabi* 2015**
Entries	**162**
Date of sowing	**13/11/2015**
Design	**Unreplicated single row**
Row length	**4m**

Sl. No.	**Entry No.**	**Sl. No.**	**Entry No.**	**Sl. No**	**Entry No.**	**Sl. No**	**Entry No.**	**Sl. No**	**Entry No.**	**Sl. No**	**Entry No.**
1	DRSF 108	28	IHT 238	55	IHT 753	82	IHT 971	109	RHA 284	136	GMU619
2	CMS 103 B	29	IHT 239	56	IHT 764	83	IHT 972	110	RHA 467	137	GMU620
3	EC-734844	30	IHT 240	57	IHT 775	84	IHT 975	111	RHA 469	138	GMU621
4	OPV 2	31	IHT 241	58	IHT 795	85	IHT 976	112	RH-95-C-1	139	GMU622
5	Morden	32	IHT 242	59	IHT 802	86	IHT 980	113	UASB 560	140	GMU623
6	KBSH 41	33	IHT 243	60	IHT 881	87	IHT 981	114	OPV 3	141	GMU624
7	KBSH 44	34	IHT 244	61	IHT 879	88	IHT 990	115	EC-734840	142	GMU625
8	S-207	35	IHT 245	62	IHT 878	89	IHT 995	116	EC734844	143	GMU626
9	RSFH 130	36	IHT 246	63	IHT 877	90	IHT 997	117	NCP 198	144	GMU627
10	RHA 93	37	IHT 247	64	IHT 848	91	IHT 1061	118	GMU 601	145	GMU628
11	GKVK-2	38	IHT 248	65	IHT 845	92	IHT 1089	119	GMU 602	146	GMU629
12	M-17R	39	IHT 249	66	IHT 843	93	NCP 22	120	GMU 603	147	GMU630
13	RHA 378	40	IHT 250	67	IHT 837	94	NCP28	121	GMU 604	148	GMU631
14	X-15WB	41	IHT 251	68	IHT 821	95	KBSH 53	122	GMU 605	149	GMU632
15	AHT 1	42	IHT 252	69	IHT 815	96	KBSH 71	123	GMU 606	150	GMU633
16	AHT 2	43	IHT 253	70	IHT 807	97	KBSH 72	124	GMU 607	151	GMU634
17	AHT 3	44	IHT 558	71	IHT 888	98	GMU 440	125	GMU 608	152	GMU635
18	AHT 4	45	IHT 591	72	IHT 891	99	GMU 520	126	GMU 609	153	GMU636
19	AHT 5	46	IHT 711	73	IHT 913	100	TCSH 1	127	GMU 610	154	GMU637
20	AHT 6	47	IHT 712	74	IHT 936	101	KBSH 1	128	GMU 611	155	GMU638
21	AHT 7	48	IHT 731	75	IHT 937	102	KBSH 73	129	GMU 612	156	GMU639
22	AHT 8	49	IHT 737	76	IHT 943	103	KBSH 74	130	GMU 613	157	GMU640
23	AHT 9	50	IHT 741	77	IHT 948	104	KBSH 75	131	GMU 614	158	GMU641
24	AHT 10	51	IHT 748	78	IHT 951	105	KBSH 76	132	GMU 615	159	GMU642
25	AHT 11	52	IHT 750	79	IHT 952	106	EC784877	133	GMU 616	160	GMU643
26	AHT 12	53	IHT 752	80	IHT 956	107	EC734887	134	GMU 617	161	GMU644
27	AHT13	54	IHT 753	81	IHT 960	108	E 17A	135	GMU 618	162	GMU645

Table 3: List of sunflower germplasm entries screened against leafhopper during *Kharif* 2016

Location	E-17B, ZARS, GKVK
Season	*Kharif* 2016
Entries	64
Date of sowing	11/08/2016
Design	Unreplicated single row
Row length	4.2m

Sl. No.	Entry No.	Sl. No.	Entry No.	Sl. No.	Entry No.	Sl. No.	Entry No.	Sl. No.	Entry No.
1	GMU 301	14	GMU 344	27	GMU 400	40	GMU 443	52	GMU 468
2	GMU 302	15	GMU 351	28	GMU 405	41	GMU 447	53	GMU 469
3	GMU 303	16	GMU 355	29	GMU 410	42	GMU 450	54	GMU 470
4	GMU 311	17	GMU 362	30	GMU 411	43	GMU452	55	GMU 474
5	GMU 313	18	GMU 363	31	GMU 413	44	GMU 454	56	GMU 475
6	GMU 321	19	GMU366	32	GMU 420	45	GMU 456	57	GMU 476
7	GMU 324	20	GMU 368	33	GMU 423	46	GMU 457	58	GMU 477
8	GMU 325	21	GMU 376	34	GMU 426	47	GMU458	59	GMU 478
9	GMU 326	22	GMU 378	35	GMU 428	48	GMU 459	60	GMU 479
10	GMU 327	23	GMU 379	36	GMU 433	49	GMU461	61	GMU 480
11	GMU 329	24	GMU 383	37	GMU 434	50	GMU463	62	GMU483
12	GMU 336	25	GMU 389	38	GMU 439	51	GMU 465	63	GMU 485
13	GMU 342	26	GMU 390	39	GMU 441	52	GMU 466	64	GMU 486

Table 4: List of sunflower germplasm entries, varieties, experimental hybrids and their parental lines screened against leaf hopper in *rabi* 2016

Location	E-16, ZARS, GKVK
Season	*Rabi* 2016
Entries	104
Date of sowing	06/11/2016
Design	Unreplicated single row
Row length	4m

Sl. No.	Entry No.	Sl. No.	Entry No.	Sl. No.	Entry No.	Sl. No.	Entry No.	Sl. No.	Entry No.
1	EC734844	22	UASB934	43	EC734877	64	AHT6	85	GMU605
2	EC734840	23	UASB932	44	RHA278	65	AHT7	86	GMU606
3	OPV3	24	UASB788	45	KBSH75	66	AHT8	87	GMU613
4	KBSH41	25	UASB790	46	RSFH130	67	AHT9	88	GMU614
5	KBSH44	26	UASB771	47	KBSH72	68	AHT10	89	GMU615
6	KBSH53	27	UASB560	48	KBSH76	69	AHT11	90	GMU616
7	KBSH71	28	NCP22	49	KBSH74	70	AHT12	91	GMU 617
8	GKVK2	29	NCP32	50	RHA-M-17-R	71	NCP198	92	GMU 618
9	GKVK1	30	NCP28	51	RH-95-C-1	72	EC734846	93	GMU 619
10	OPV2	31	RHA589	52	AHT13	73	IHT 238	94	GMU 620
11	RHA275	32	RHA857	53	CMS103B	74	IHT 239	95	RHA265
12	RHA630	33	RHA275	54	KBSH1	75	IHT 244	96	LTRR-83-273
13	EC734873	34	REC443	55	RHA469	76	IHT245	97	GPR135
14	EC734874	35	REC447	56	DRSF108	77	IHT246	98	OPV 6
15	RHA378	36	RHA272	57	RHA284	78	IHT247	99	RHA284
16	RHA589	37	RHA265	58	Morden	79	IHT248	100	Morden
17	RHA265	38	LTRR-83-273	59	AHT1	80	IHT249	101	IHT 240
18	RHA857	39	GPR135	60	AHT2	81	GMU601	102	IHT 241
19	RHA630	40	OPV 6	61	AHT3	82	GMU602	103	IHT 242
20	UASB929	41	OPV5	62	AHT4	83	GMU603	104	IHT 243
21	UASB933	42	OPV4	63	AHT5	84	GMU604		

Observations were recorded on the following parameters to assess the reaction of the entries: Sunflower genotypes to leafhopper infestation, which were screened in all the four seasons under field conditions.

3.2.1 Population of leafhopper

The leafhopper population (only nymphs) were recorded in each entry. Five plants of each entry were randomly selected and labelled for recording observations both at 45 and 75 DAS. The observations on nymphal population were recorded on two upper leaves, two middle leaves and two bottom leaves of the plant canopy in each plant that was labelled under each entry and later it was expressed as mean number per plant (*i.e.*, mean no./ six leaves/ plant) (Plate 1.)

3.2.2 Hopper burn injury grade

Under each genotype, the same set of five labelled plants which were observed for leafhopper population were also observed both at 45 and 75 DAS for assessing the hopper burn injury grade (Plate 2.)This was assessed in 0-5 scale as per the procedure given by Anon (2013) (Plate 3.) and later it was expressed as mean hopper burn injury grade per plant (Table 5.)

Table 5: Rating scale adopted for recording leaf hopper injury grade (Anon., 2013)

Rating scale	Characteristic feature/ Symptom
0	Free from leafhopper injury
1	Slight yellowing on edges of leaves upto 30%
2	Yellowing and curling upto 40% of leaves
3	Yellowing and curling upto 60% of leaves
4	Yellowing , curling upto 80% of leaves or 50% edge browning
5	Maximum yellowing, ‘cupping and curling of leaves upto 100% or complete browning

The data from all the screening trials in the different seasons (*Kharif* 2015, *Rabi* 2015, *Kharif* 2016 *and Rabi* 2016) were analyzed and relative grouping of entries was

Plate 1: Plants harbouring the leafhoppers underside of the leaves

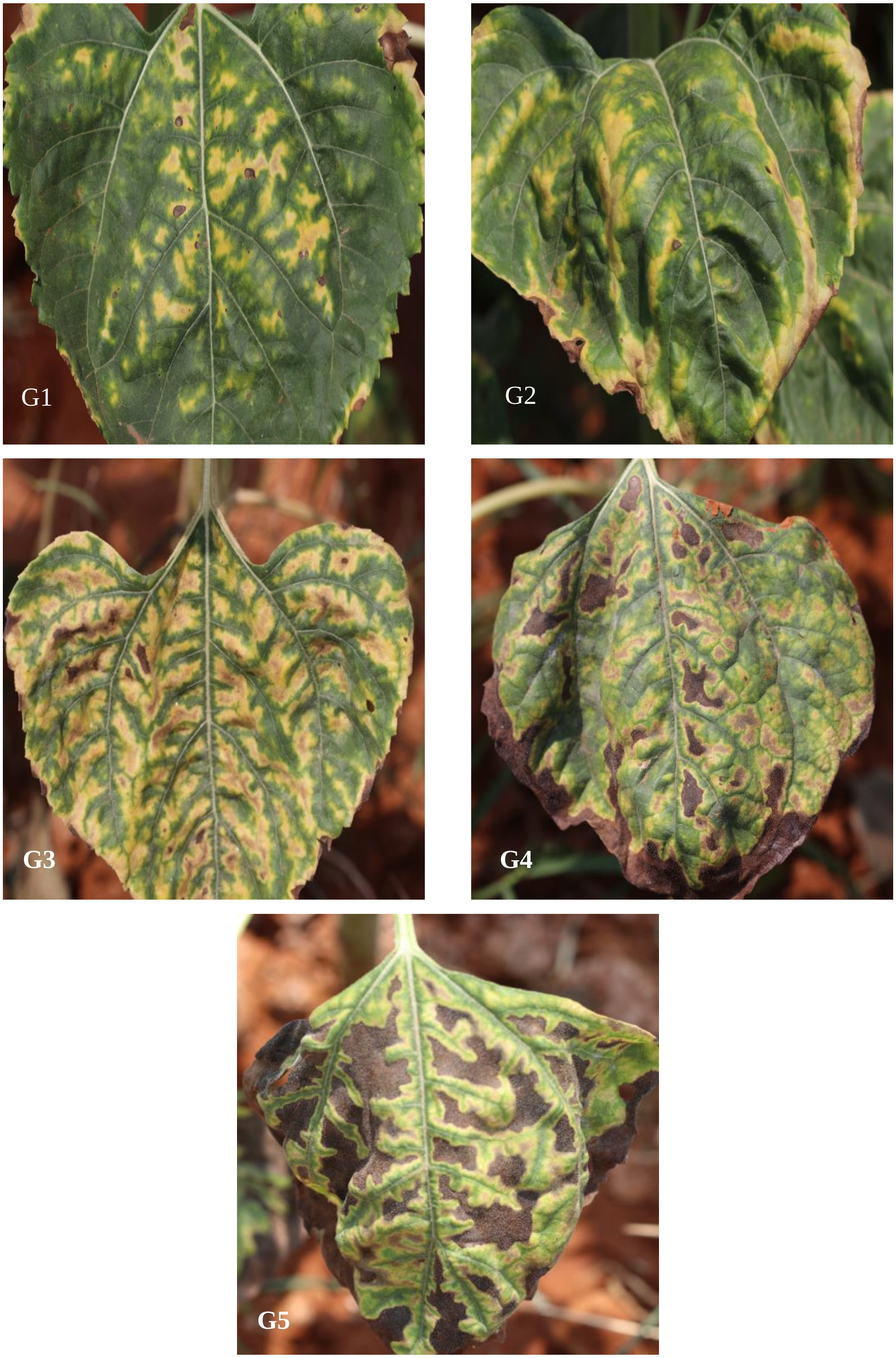


Plate 2: Leafhopper injury index grades (G1 to G5)

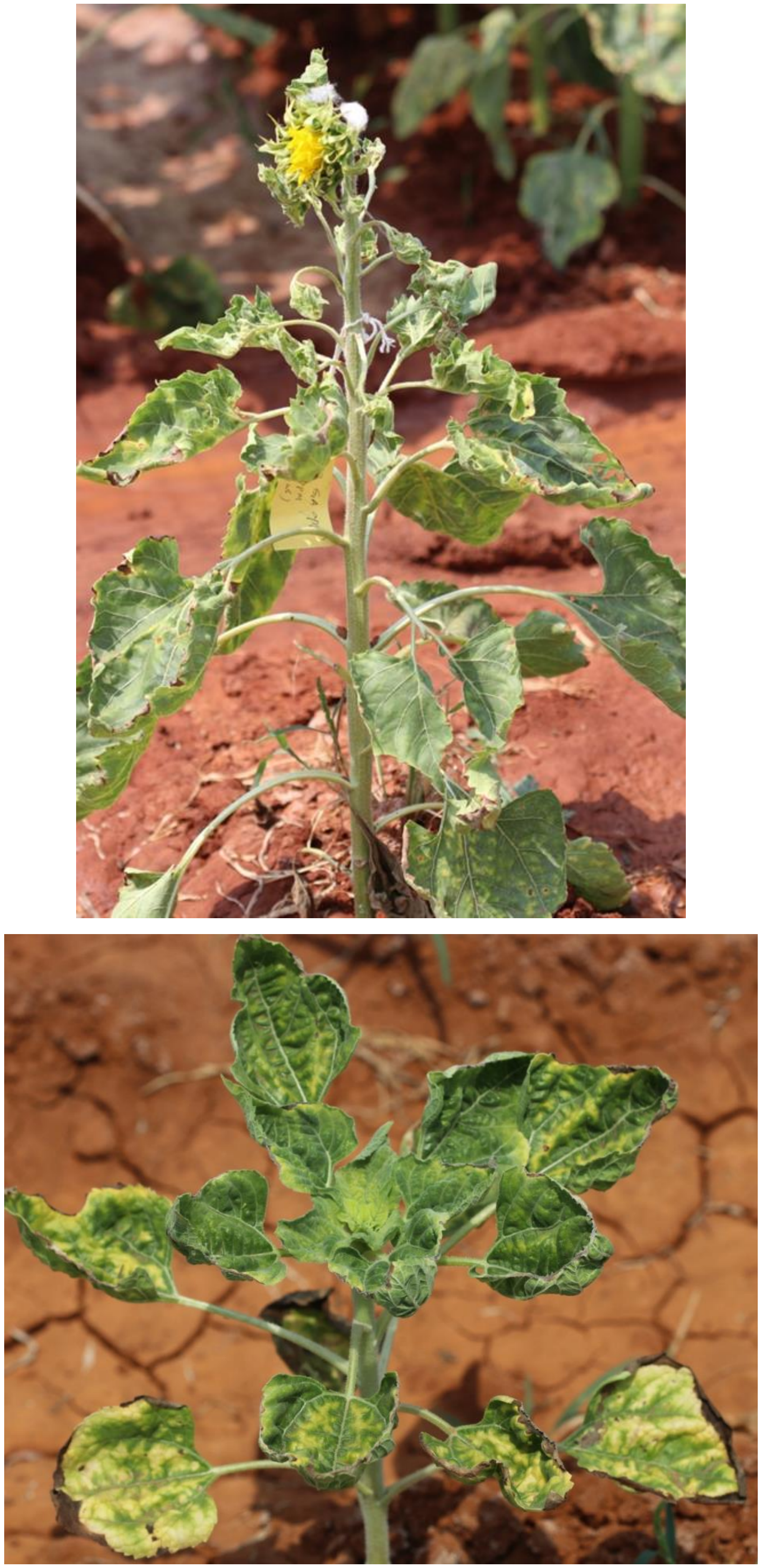


Plate 3: Plants showing the typical cupping symptoms to the reaction of leafhopper

made considering leafhopper population on different entries as well as overall leafhopper infestation during the cropping season. Based on the mean number of leafhoppers present per plant and leafhopper injury grade, the screened accessions were categorized as suggested by Kavitha and Reddy, 2012.

Leafhopper injury grade	Resistance category
0-1	R
2	MR
3	S
4-5	HS

NB: R: Resistant, MR: Moderately Resistant, S: Susceptible, HS: Highly susceptible

Due to the low population of leafhopper and negligible hopper burn injury grades in most entries during *Kharif* season of both 2015 and 2016, only *rabi* season data on leafhopper population and hopper burn injury grade were considered for categorization of resistant and highly susceptible entries.

Therefore, based on the incidence of the leafhopper and hopper burn injury grade during *rabi* season of both 2015 and 2016, the entries showing extreme reaction to the pest were short listed two categories *i.e.*, highly susceptible category and resistant category. They are as listed below:

I. Highly susceptible entries

1. DRSF 108
2. RHA 284
3. EC 734840
4. EC 734844
5. NCP 22
6. NCP28
7. KBSH 41
8. Morden
9. UASB 560

II. Resistant entries

1. RH-95-C-1
2. AHT 12
3. OPV 2
4. CMS 103 B
5. KBSH 53
6. KBSH 72
7. OPV3
8. NCP 198
9. KBSH 1
10. AHT 13

3.2.3 Artificial screening under glass house

Based on the data pertaining to the mean population of leafhopper and hopper burn injury grade recorded during 2015 and 2016 *rabi* field screening trials, about 19 entries showing extreme reaction to the hopper (*i.e.*, 10 resistant and 9 highly susceptible) were short listed into two categories.

Based on the data generated from the screening trial, these 19 entries were again screened under glass house conditions. Seeds of these 19 entries were planted in earthen or plastic pots (Plate 4.) 30-d-old test plants were infested with 10 adult males and 10 adult female leafhoppers (2 to 3 days age) and enclosed with cotton net cages When their progeny reached adulthood on all the entries, the insects in all the cages were counted and hopper burn injury was rated. Same procedure were followed at 60 days interval of test plant and took a leafhopper population counts and hopper burn injury grade to confirm the resistance and susceptibility in these nineteen entries.

Further, these 19 entries showing extreme reaction to the pest were utilized for determination of the morphological and biochemical basis of resistance to leafhoppers in sunflower.

A. Okra seedlings were maintained in plastic pots

B. Nymph population on bhendi leaf

C. Nymphal rearing on bhendi leaf in 3% agar

D. Young plants damaged due to leafhopper infestation

Plate 4: (A- D) Mass rearing of *Amrasca biguttula biguttula* on bhendi

3.3 Determination of morphological basis of resistance to green leafhoppers

During the course of this investigation, the morphological bases of resistance were determined by estimating the morphological features of selected genotypes at the Department of Agricultural Entomology, UAS, GKVK, Bengaluru. The present study has indicated that the distribution of the leafhopper in sunflower was maximum in the middle canopy, followed by the top canopy and least in the bottom canopy. Therefore, during this study, the trichome density and length were determined only in the top and middle level canopy of the test entries

3.3.1 Measurement of trichome density

The trichome density were measured in all the 19 genotypes of sunflower (comprising of 9 highly susceptible and 10 resistant entries) for which the leaf samples were collected from both top and middle portion of the plant, both at 45 and 60 DAS. Further, three leaf discs, each of 0.64 cm^2 area were used per leaf. Likewise two leaves from each plant and three sample plants from each entry were observed. Thus, the average trichome densities of the entries were calculated and it was expressed as no.of trichomes /0.64 cm^2 of the leaf area and trichome density were correlated with the leafhopper population.

Area of leaf disc = ð r^2,

Where, ð = 22/7 and r = radius of the leaf disc used for counting the trichomes.

ð = 3.142 x 0.452 = 0.64 cm^2

3.3.2 Measurement of trichome length

The trichome length were measured in all the 19 genotypes of sunflower (comprising of 9 highly susceptible and 10 resistant entries) for which the leaf samples were collected from both top and middle canopy of the plant, both at 45 and 60 DAS, by randomly observing three cross sections from each leaf and three trichomes per section were observed. Totally two leaves from top and two leaves from middle canopy of the sample plants were chosen for the observations. Likewise, three plants were observed from each entry. The observations were made by using a microscope. The stage and ocular micrometer was used for taking measurements and the trichome length was expressed in µm.

3.3.3 Leaf shape

Single leaf each from middle canopy of one randomly selected plant from each entry was taken and their lobe length and leaf length was measured with a scale. Lacination index was worked out for all five leaves based on the ratio of lobe length to leaf length. Leaf shape of each sunflower entries was determined by using lacination index and the entries were classified into different categories: broad, intermediate, narrow and lacinated leaves as per the methodology suggested by Arumugam and Muthukrishnan (1977).

Sl. No.	Leaf shape	Lacination Index Value
1.	Broad leaves	0.50-0.60
2.	Intermediate leaves	0.61-0.70
3.	Narrow leaves	0.71-0.80
4.	Lacinated leaves	0.81 and above

3.3.4 Shape of leaf lamina tip

The leaves that were used for above were used for observing the shape of leaf lamina tip based on visual observations.

3.3.5 Consistency of leaf lamina

The leaves that were used above were used for observing the consistency lamina tip based on visual observations and categorized into smooth and coarse.

3.3.6 Pigmentation of the petiole

The above same leaves were used for observing of the pigmentation of the petiole based on visual observations.

3.4 Determination of biochemical basis of resistance to sunflower leafhopper

The laboratory facilities at AICRP (Micronutrients), Department of Soil Science and Agricultural Chemistry, GKVK Bengaluru were utilized for this part of the investigation. For the determination of the biochemical factors imparting resistance against the leafhopper, the total soluble sugars, total soluble proteins and the total phenol contents were estimated at 45 and 60 days after sowing (DAS) in the leaf samples of the nine highly susceptible and ten resistant sunflower genotypes which had been identified and confirmed from the field and artificial screening trial. The leaves chosen for such biochemical analysis were sampled from the corresponding plants and subjected to biochemical analysis by following the methodology suggested by Sadasivam and Manickham (1991) with necessary modification(s).

3.4.1 Preparation of oven dried samples

The freshly collected leaf samples were dried at 60^0C to a constant weight in a hot-air oven. The samples were then powdered by using a pestle and mortar and the leaf powder was stored in sealed polyethylene covers at room temperature.

3.4.2 Estimation of total sugars

Reagents

Phenol reagent: 5g of redistilled phenol was dissolved in water and volume made upto 100 ml.

Standard glucose solution: Glucose stock solution containing 15 mg glucose/10 ml in water. This solution was diluted to 1:10 to obtain 150 μg glucose/ml working standard solution.

Sample extraction: 100mg of oven-dried leaf powder was used for extraction in 10 ml of 80% warm ethanol for one hour on a magnetic stirrer at room temperature. The extract was then centrifuged at 6000 rpm for 15 minutes. The supernatant was evaporated to dryness on a hot water bath and the residue was dissolved in 5 ml of distilled water. This alcohol free extract was used for the estimation of total soluble sugars (Dubois *et al.*, 1956).

Estimation: 0.1 ml of sample aliquot was diluted to 1ml with distilled water. 1ml of 5% phenol reagent and 5ml of 98% H_2SO_4 were added and incubated for 10 minutes and then placed in a water bath at 30^0C for 20 minutes. The absorbance was read at 490nm against the reagent blank using Hitachi U-2900 Spectrophotometer. A standard curve was constructed by using standard glucose in the range of 15-150 µg. The total sugar estimated was expressed as mg per gram of oven-dried sample.

3.4.3 Estimation of total soluble protein

Reagents used

Solution A: 20g of anhydrous sodium carbonate ($Na_2CO_3.2H_2O$) and 4g of sodium hydroxide were dissolved in 1000 ml of distilled water.

Solution B: 1 ml of 1.35% sodium potassium tartarate and 0.1 ml of 5.5% $CuSO_4.5H_2O$ were mixed together.

Solution C: 50 ml of solution A was mixed with 1 ml of solution B just before use.

Folin-Ciocalteu reagent (FCR): The commercial FCR was diluted 1:1 before use

Standard bovine serum albumin (BSA) solution: A stock BSA solution was prepared containing 2 mg BSA /ml in water. This solution was diluted 1:10 to obtain 200 µg BSA/ml working standard solution.

Extraction:

100 mg oven dried powdered sample was extracted in 10 ml of 0.1 M sodium phosphate buffer, pH 7.0, for one hour on a magnetic stirrer at room temperature. The extract was centrifuged at 10000 rpm for 20 minutes and the supernatant was used for the estimation of total soluble protein content. The protocol suggested by Lowry *et al*. (1951) was employed for this purpose.

Estimation:

A known volume of aliquot sample was made upto 1 ml with distilled water. To this 5 ml of solution C was added and mixed well. After 10 minutes, 0.5 ml of FCR was added and mixed immediately. The blue color developed was read at 660 nm after 30 minutes against reagent blank in colorimeter. A standard graph was constructed by using BSA solution as a standard in the range of 20-120 µg. The total soluble protein content was expressed as mg per gram oven dried sample.

3.4.4 Estimation of total phenols

Reagents used

Folin-Ciocalteu reagent: Commercial grade reagent was diluted 1:1 with water

20% Sodium carbonate solution: 20g of sodium carbonate (Na_2CO_3) was dissolved in water and made upto 100 ml

Standard catechol solution: A stock catechol solution was prepared containing 1 mg catechol /ml in water. This solution was diluted 1:10 to obtain 100 µg catechol /ml working standard solution

Extraction:

100 mg oven dried powdered sample was extracted in 10 ml of warm 80 extract which was centrifuged at 6000 rpm for 15 minutes. The supernatant was evaporated to dryness on a water bath and the residue was dissolved in 5 ml of distilled water. This alcohol free extract was used for the estimation of total phenols as per the methodology suggested by Malick and Singh (1980).

Estimation:

0.1 ml of aliquot sample was diluted to 3 ml with water and 0.5 ml of FCR was added and mixed. Exactly after 3 minutes, 2 ml of 20 per cent sodium carbonate solution was added and kept in boiling water bath for one minute. After cooling under running tap water, the absorbance was read at 650 nm, against the reagent blank in colorimeter. A standard graph was constructed by using catechol as a standard in the range of 20-100 µg. The total phenol content is expressed as mg per gram of oven-dried sample or per cent oven dried sample.

3.5 Statistical analysis

The following statistical methods were employed for analysis of data.

3.5.1 Mean

On the basis of individual plant observations, the mean for each character in all the populations were computed by dividing the number of observations to the total value.

3.5.2 Range

The minimum and maximum value on the basis of individual plant observations was used to indicate the range for a given character.

3.5.3 Standard deviation (SD)

Standard deviation shows how much variation or dispersion exists from the average. A low standard deviation indicates that the data points tend to be very close to the mean, whereas, high standard deviation indicates that the data points are spread out over a large range of values. The standard deviation is defined as the square root of the mean of the squared deviation of the individuals from their mean.

$$\text{Standard deviation (SD)} = \sqrt{variance}$$

3.5.4 Correlation analysis

Correlation analysis was done in excel using the WASP software. The test of significance for association between characters was done by comparing calculated ‘r’ values with table ‘r’ values at (n-2) error degrees of freedom, where n is the number of pairs of observations.

3.5.5 Standard error

Standard error was calculated by using the following formula.

$$SE = \frac{\text{Standard deviation}}{\sqrt{n}}$$

IV RESULTS AND DISCUSSION

Investigations pertaining to the screening of sunflower genotypes against *Amrasca biguttula biguttula* and basis of resistance to this pest were carried out during 2015-16 and 2016-17. The findings of those studies are furnished in this chapter.

4.1 Evaluation of sunflower germplasm entries, elite hybrids and their parental lines for their reaction to leafhopper infestation

Four hundred and eleven sunflower entries (*Helianthus annuus*) (including varieties, parental lines, elite and experimental hybrids and germplasm entries from Indian Institute of Oilseeds Research, Hyderabad, AICRP (sunflower), Zonal Agricultural Research Station (ZARS), Bengaluru were evaluated for their reaction to leafhopper (*Amrasca biguttula biguttula*) infestation in four different seasons at the ZARS ,University of Agricultural Sciences, GKVK, Bengaluru and also at Main Research Station, Hebbal, Bengaluru during 2015-16 and 2016-17.

Totally 81 entries were screened during *kharif* 2015 (August to October 2015), 162 entries were screened during *rabi* 2015 (November 2015 to January 2016), 64 entries were screened during *kharif* 2016 (August to October 2015) and 104 entries were screened during *rabi* 2016 (November 2015 to January 2016) and the data recorded on leafhopper population and hopper burn injury grade in each of the four trials during different seasons are discussed in the following pages.

4.1.1 Field screening of sunflower genotypes during *kharif* 2015

Eighty one entries were evaluated against leafhopper during *kharif* 2015 (August to October 2015) at ZARS, University of Agricultural Sciences, GKVK, Bengaluru (Table 6). The mean number of leafhopper nymphs per plant and hopper burn injury grade recorded on different sunflower entries at 45th DAS ranged from 0.00 to 1.33 and 0.00 to 1.00, respectively. At 75 DAS, mean number of leafhopper nymphs per plant and hopper burn injury grade recorded on different sunflower entries ranged from 0.00 to 1.83 and 0.00 to 2.00, respectively. The overall mean incidence of leafhopper population per plant during the season was 1.04 at 45 DAS and 1.24 at 75 DAS.

Table 6: Mean leafhopper population and hopper burn injury grade in different genotypes (*Kharif* 2015)

Sl. No.	Entry No.	45 DAS		75DAS	
		Mean no of leafhoppers/ plant	Hopper burn injury grade/plant	Mean no of leafhoppers/ plant	Hopper burn injury grade/ plant
1	**RHA1001**	0.83	0.00	1.33	1.00
2	**RHA1002**	0.50	0.00	0.83	0.00
3	**RHA1003**	0.00	0.00	0.50	1.00
4	**RHA1004**	0.66	0.00	0.83	2.00
5	**RHA1005**	1.33	1.00	1.50	2.00
6	**RHA1006**	0.66	0.00	1.33	1.00
7	**RHA1007**	0.50	0.00	0.66	0.00
8	**RHA1008**	0.00	1.00	0.83	1.00
9	**RHA1009**	0.33	0.00	1.00	1.00
10	**RHA1010**	0.83	1.0	1.66	2.00
11	**RHA1011**	0.00	0.00	0.50	0.00
12	**RHA1012**	0.50	0.00	0.66	1.00
13	**RHA1013**	0.00	1.00	1.00	0.00
14	**RHA1014**	0.66	0.00	0.83	0.00
15	**RHA1015**	0.00	1.00	1.16	1.00
16	**RHA1016**	0.50	0.00	0.83	0.00
17	**RHA1017**	0.50	0.00	0.66	0.00
18	**RHA1018**	0.33	0.00	1.33	1.00
19	**RHA1019**	0.83	1.00	1.16	1.00
20	**RHA1020**	1.16	1.00	1.00	0.00
21	**RHA1021**	1.00	0.00	1.50	2.00
22	**RHA1022**	0.00	0.00	0.50	0.00
23	**RHA1023**	0.16	0.00	1.00	1.00
24	**RHA1024**	0.83	1.00	0.66	0.00
25	**RHA1025**	0.50	1.00	0.83	0.00
26	**RHA1026**	0.66	0.00	1.33	1.00
27	**RHA1027**	0.83	1.00	1.16	2.00
28	**RHA1028**	0.33	0.00	1.00	0.00
29	**RHA1029**	1.16	0.00	1.66	2.00
30	**RHA1030**	0.66	0.00	1.33	1.00
31	**RHA1031**	1.00	1.00	1.00	0.00

Sl. No.	Entry No.	45 DAS		75DAS	
		Mean no of leafhoppers/ plant	Hopper burn injury grade/plant	Mean no of leafhoppers/ plant	Hopper burn injury grade/ plant
32	**RHA1032**	0.66	1.00	0.66	0.00
33	**RHA1033**	0.33	0.00	0.00	0.00
34	**RHA1034**	1.33	1.00	0.83	1.00
35	**RHA1035**	0.66	0.00	1.00	0.00
36	**RHA1036**	1.00	1.00	1.66	2.00
37	**RHA1037**	0.83	0.00	1.00	1.00
38	**RHA1038**	1.16	1.00	1.33	1.00
39	**RHA1039**	0.66	0.00	1.16	0.00
40	**RHA1040**	1.00	1.00	1.50	1.00
41	**RHA1041**	0.50	0.00	1.33	0.00
42	**RHA1042**	0.66	0.00	1.00	0.00
43	**RHA1043**	0.83	1.00	0.66	0.00
44	**RHA1044**	0.50	0.00	1.00	0.00
45	**RHA1045**	0.00	0.00	1.66	1.00
46	**RHA1046**	0.83	1.00	1.50	1.00
47	**RHA1047**	1.00	0.00	1.16	0.00
48	**RHA1048**	1.33	1.00	1.83	1.00
49	**RHA1049**	0.33	0.00	1.50	0.00
50	**RHA1050**	0.00	0.00	0.83	0.00
51	**RHA1051**	0.50	0.00	1.33	1.00
52	**RHA1052**	1.00	1.00	1.50	0.00
53	**RHA1053**	0.83	1.00	1.66	1.00
54	**RHA1054**	0.66	0.00	1.33	0.00
55	**RHA1055**	1.00	1.00	2.00	2.00
56	**RHA1056**	0.50	0.00	1.50	1.00
57	**RHA1057**	0.33	0.00	0.66	0.00
58	**RHA1058**	0.83	0.00	1.00	0.00
59	**RHA1059**	0.66	0.00	1.33	1.00
60	**RHA1060**	1.00	0.00	1.50	1.00
61	**EC784877 X NDCM52A**	1.33	1.00	1.50	1.00
62	**EC734887 X NDCM52A**	1.16	0.00	1.66	2.00

Sl. No.	Entry No.	45 DAS		75DAS	
		Mean no of leafhoppers/ plant	Hopper burn injury grade/plant	Mean no of leafhoppers/ plant	Hopper burn injury grade/ plant
63	GMU775 X CMS 138A	0.83	0.00	1.83	1.00
64	GMU780 X CMS 17A	0.66	1.00	1.33	1.00
65	GMU762 X CMS 903A	1.00	0.00	1.16	0.00
66	GMU750 X CMS 903A	1.33	0.00	1.50	1.00
67	GMU743 X CMS 903A	0.50	1.00	0.66	0.00
68	GMU748 X CMS 903A	0.00	0.00	1.33	1.00
69	GMU 742 X CMS 903A	0.66	0.00	0.50	0.00
70	GMU 753 X CMS 03A	1.00	0.00	0.33	0.00
71	GMU 592 X CMS 903A	0.00	1.00	0.83	0.00
72	OPV3	0.66	0.00	1.33	1.00
73	KBSH 41	0.50	1.00	1.50	1.00
74	KBSH 44	0.83	0.00	0.66	0.00
75	KBSH 53	0.16	0.00	1.00	0.00
76	RSFH130	1.16	1.00	1.50	1.00
77	S-2017	1.00	0.00	1.16	1.00
78	KBSH 71	0.66	1.00	1.00	0.00
79	KBSH72	0.83	0.00	1.16	1.00
80	KBSH73	1.00	0.00	1.00	0.00
81	KBSH74	0.00	0.00	0.83	1.00
Mean		**1.04**		**1.24**	
SEM±		**0.10**		**0.11**	
CD at P=0.05		**0.28**		**0.31**	

DAS: Days after sowing

Between the different entries there was no significant difference *w. r. t*. mean number of leafhoppers per plant both at 45 DAS and 75 DAS (0.28 and 0.31), respectively and the overall hopper burn injury grade ranged from 0.00 to 2.00. The overall incidence of the leafhopper and hopper burn injury grade during *kharif* 2015 trial was quiet low, hence due to low pest pressure, the entries could not be categorised as resistant or susceptible.

4.1.2 Field screening sunflower genotypes during *rabi* 2015

One hundred and sixty two entries were evaluated against leafhoppers during *rabi* 2015 (November 2015 to January 2016) at Main Research Station, Hebbal, Bengaluru (Table 7). The mean number of leafhopper nymphs per plant on different entries ranged from 0.50 to 2.66 at 45 DAS and hopper burn injury grade ranged from 0.00-2.00 At 75 DAS, the mean number of leafhopper nymphs per plant ranged from 0.66 to 5.66, with hopper burn injury grade of 1 to 5. The overall mean leafhopper incidence per plant on 162 entries during the season at 45 DAS and 75 DAS were 1.31 and 1.55, respectively.

Between the different entries there was no significant difference *w. r. t*. mean number of leafhoppers per plant both at 45 DAS and 75 DAS (0.20 and 0.32), respectively. However, based on hopper burn injury grade at 75 DAS, 10 sunflower entries were categorized as resistant, 101 as moderately resistant, 43 as susceptible and 9 as highly susceptible (Table 8). The sunflower crop enters seed filling stage during or after 75 DAS, therefore the data pertaining to the number of leaf hoppers per plant and hopper burn injury grade at 75 DAS was considered for categorizing the entries.

4.1.3 Field screening of sunflower genotypes during *kharif* 2016

Sixty four sunflower entries were evaluated against the leafhopper during *kharif* 2016 (August to October 2016) at ZARS, University of Agricultural Sciences, GKVK, Bengaluru (Table 9). The mean number of leafhopper nymphs per plant on different sunflower entries during this season, at 45 DAS, ranged from 0.00 to 1.16 and hopper burn injury grade ranged from 0.00 to 1.00. Similarly, at 75 DAS, the mean number of leafhopper nymphs per plant on different sunflower entries ranged 0.00 to 1.83 and hopper burn injury grade ranged from 0.00-2.00

Table 7: Mean leafhopper population and hopper burn injury grade in different genotypes (*Rabi* 2015)

Sl. No.	Entry No.	45 DAS		75DAS	
		Mean no of leafhoppers/ plant	Hopper burn injury grade/ plant	Mean no of leafhoppers/ plant	Hopper burn injury grade/ plant
1	DRSF 108	2.00	1.00	3.66	4.00
2	CMS 103 B	0.50	0.00	0.83	1.00
3	EC-734846	2.16	1.00	3.00	3.00
4	OPV 2	0.66	0.00	0.66	1.00
5	Morden	2.66	2.00	5.66	5.00
6	KBSH 41	2.33	1.00	4.66	5.00
7	KBSH 44	1.33	0.00	1.66	2.00
8	S-207	1.66	1.00	2.00	2.00
9	RSFH 130	1.50	0.00	1.33	1.00
10	RHA 93	1.16	0.00	2.33	1.00
11	GKVK-2	1.16	1.00	2.00	2.00
12	M-17R	1.00	0.00	2.16	1.00
13	RHA 378	1.33	0.00	2.33	1.00
14	X-15WB	1.50	1.00	2.16	2.00
15	AHT 1	1.00	0.00	1.33	1.00
16	AHT 2	1.33	1.00	2.16	1.00
17	AHT 3	1.66	2.00	3.00	4.00
18	AHT 4	1.50	0.00	2.00	1.00
19	AHT 5	1.83	1.00	3.50	3.00
20	AHT 6	1.00	0.00	1.50	2.00
21	AHT 7	2.00	1.00	2.83	3.00
22	AHT 8	1.66	1.00	2.33	1.00
23	AHT 9	1.33	1.00	1.50	1.00
24	AHT 10	1.16	0.00	1.33	1.00
25	AHT 11	1.66	1.00	2.83	2.00
26	AHT 12	0.66	0.00	0.83	1.00
27	AHT13	1.33	1.00	1.00	1.00
28	IHT 238	1.83	2.00	2.33	3.00
29	IHT 239	1.66	0.00	2.16	3.00
30	IHT 240	2.00	1.00	3.66	4.00
31	IHT 241	1.00	0.00	1.50	1.00
32	IHT 242	1.33	1.00	2.00	1.00
33	IHT 243	1.50	0.00	1.83	2.00
34	IHT 244	0.83	0.00	1.50	2.00
35	IHT 245	1.16	1.00	1.33	1.00
36	IHT 246	0.66	0.00	1.50	2.00
37	IHT 247	0.83	1.00	1.83	2.00
38	IHT 248	0.66	1.00	0.83	1.00
39	IHT 249	1.66	0.00	2.00	3.00
40	IHT 250	1.50	1.00	1.33	1.00

Sl. No.	Entry No.	45 DAS		75DAS	
		Mean no of leafhoppers/ plant	Hopper burn injury grade/ plant	Mean no of leafhoppers/ plant	Hopper burn injury grade/ plant
41	IHT 251	2.00	0.00	1.83	2.00
42	IHT 252	1.83	2.00	1.66	1.00
43	IHT 253	1.33	1.00	1.16	1.00
44	IHT 558	1.00	0.00	1.50	1.00
45	IHT 591	1.50	1.00	2.16	3.00
46	IHT 711	0.83	0.00	1.83	2.00
47	IHT 712	1.83	1.00	2.83	3.00
48	IHT 731	1.33	1.00	2.50	3.00
49	IHT 737	1.16	0.00	2.66	4.00
50	IHT 741	0.83	0.00	1.50	1.00
51	IHT 748	1.00	1.00	2.33	3.00
52	IHT 750	0.66	0.00	2.00	2.00
53	IHT 752	2.00	1.00	3.66	3.00
54	IHT 753	1.83	1.00	4.00	3.00
55	IHT 754	2.00	1.00	3.50	2.00
56	IHT 764	1.00	1.00	2.50	1.00
57	IHT 775	1.33	0.00	2.33	2.00
58	IHT 795	1.83	2.00	2.16	2.00
59	IHT 802	0.83	0.00	1.50	1.00
60	IHT 881	1.50	1.00	2.00	2.00
61	IHT 879	1.83	2.00	1.83	2.00
62	IHT 878	1.50	0.00	1.50	1.00
63	IHT 877	1.16	1.00	2.33	2.00
64	IHT 848	0.66	0.00	1.16	2.00
65	IHT 845	1.50	1.00	1.83	2.00
66	IHT 843	1.16	1.00	1.16	2.00
67	IHT 837	1.33	0.00	2.66	3.00
68	IHT 821	0.83	1.00	1.66	3.00
69	IHT 815	1.00	0.00	1.50	2.00
70	IHT 807	0.66	0.00	2.00	2.00
71	IHT 888	0.50	0.00	1.33	2.00
72	IHT 891	1.00	1.00	1.16	2.00
73	IHT 913	1.50	1.00	1.00	1.00
74	IHT 936	1.33	0.00	2.16	3.00
75	IHT 937	1.16	1.00	2.00	1.00
76	IHT 943	0.66	1.00	1.83	1.00
77	IHT 948	0.50	0.00	1.33	1.00
78	IHT 951	1.00	0.00	1.16	2.00
79	IHT 952	1.33	0.00	2.83	3.00
80	IHT 956	1.66	1.00	2.33	3.00
81	IHT 960	1.83	2.00	2.66	2.00
82	IHT 971	1.50	0.00	1.16	1.00
83	IHT 972	0.83	1.00	1.33	2.00

Sl. No.	Entry No.	45 DAS		75DAS	
		Mean no of leafhoppers/ plant	Hopper burn injury grade/ plant	Mean no of leafhoppers/ plant	Hopper burn injury grade/ plant
84	IHT 975	1.00	1.00	1.50	1.00
85	IHT 976	1.16	0.00	2.83	2.00
86	IHT 980	1.33	0.00	2.66	3.00
87	IHT 981	1.50	1.00	2.50	3.00
88	IHT 990	1.16	1.00	2.33	2.00
89	IHT 995	1.33	0.00	1.83	3.00
90	IHT 997	1.00	0.00	2.16	2.00
91	IHT 1061	0.66	0.00	1.66	1.00
92	IHT 1089	1.00	0.00	1.50	2.00
93	NCP 22	1.83	1.00	3.16	3.00
94	NCP28	2.16	1.00	3.50	4.00
95	KBSH 53	0.66	1.00	0.83	1.00
96	KBSH 71	1.50	0.00	2.00	2.00
97	KBSH 72	0.66	0.00	0.83	1.00
98	GMU 440	1.00	0.00	1.83	2.00
99	GMU 520	1.33	1.00	1.33	2.00
100	TCSH 1	0.83	0.00	1.33	2.00
101	KBSH 1	0.50	0.00	0.66	1.00
102	KBSH 73	1.50	0.00	1.83	2.00
103	KBSH 74	1.33	0.00	2.33	3.00
104	KBSH 75	1.50	1.00	1.83	1.00
105	KBSH 76	1.83	1.00	2.00	1.00
106	EC784877	1.66	1.00	2.33	2.00
107	EC734887	1.33	1.00	2.16	2.0
108	E 17A	1.50	0.00	1.33	1.00
109	RHA 284	1.83	0.00	3.16	4.00
110	RHA 467	1.50	0.00	2.00	3.00
111	RHA 469	1.33	1.00	1.83	2.00
112	RH-95-C-1	0.50	0.00	0.83	1.00
113	UASB 560	1.66	0.00	3.00	3.00
114	OPV 3	0.66	0.00	0.83	1.00
115	EC-734840	1.83	1.00	3.66	3.00
116	EC734844	1.66	1.00	3.50	4.00
117	NCP 198	0.66	0.00	1.33	1.00
118	GMU 601	1.00	0.00	1.83	3.00
119	GMU 602	1.33	0.00	2.33	3.00
120	GMU 603	1.16	0.00	2.66	4.00
121	GMU 604	1.50	1.00	2.00	1.00
122	GMU 605	1.66	1.00	3.00	2.00
123	GMU 606	1.33	0.00	2.50	1.00
124	GMU 607	1.50	1.00	2.16	2.00
125	GMU 608	0.83	1.00	2.00	1.00
126	GMU 609	1.16	1.00	2.33	2.00

Sl. No.	Entry No.	45 DAS		75DAS	
		Mean no of leafhoppers/ plant	**Hopper burn injury grade/ plant**	**Mean no of leafhoppers/ plant**	**Hopper burn injury grade/ plant**
127	GMU 610	1.00	0.00	2.66	2.00
128	GMU 611	1.33	1.00	2.83	2.00
129	GMU 612	1.66	0.00	2.66	1.00
130	GMU 613	2.16	1.00	2.16	2.00
131	GMU 614	1.33	0.00	1.83	1.00
132	GMU 615	1.50	1.00	1.50	2.00
133	GMU 616	1.33	0.00	1.83	2.00
134	GMU 617	2.00	0.00	3.00	1.00
135	GMU 618	1.83	0.00	2.33	2.00
136	GMU 619	1.66	1.00	2.16	1.00
137	GMU 620	1.33	1.00	2.83	3.00
138	GMU 621	1.50	1.00	2.66	2.00
139	GMU 622	1.00	0.00	2.50	1.00
140	GMU 623	1.33	0.00	1.83	2.00
141	GMU 624	1.50	1.00	2.16	2.00
142	GMU 625	1.16	0.00	2.00	3.00
143	GMU 626	1.83	1.00	1.83	1.00
144	GMU 627	2.16	1.00	1.50	2.00
145	GMU 628	1.33	1.00	1.66	2.00
146	GMU 629	0.66	0.00	2.16	3.00
147	GMU 630	1.50	0.00	2.33	2.00
148	GMU 631	1.33	1.00	2.00	1.00
149	GMU 632	1.00	0.00	2.50	1.00
150	GMU 633	1.33	0.00	2.16	2.00
151	GMU 634	1.50	0.00	2.33	2.00
152	GMU 635	1.33	1.00	2.83	3.00
153	GMU 636	1.16	1.00	2.66	2.00
154	GMU 637	0.83	0.00	2.50	1.00
155	GMU 638	0.66	0.00	1.50	1.00
156	GMU 639	1.50	0.00	1.33	1.00
157	GMU 640	1.00	1.00	1.83	2.00
158	GMU 641	1.83	1.00	1.66	2.00
159	GMU 642	2.16	1.00	1.50	1.00
160	GMU 643	2.00	0.00	2.33	3.00
161	GMU 644	1.83	0.00	2.16	2.00
162	GMU 645	1.66	1.00	2.50	4.00
Mean		**1.31**		**1.55**	
SEM±		**0.06**		**0.11**	
CD at P=0.05		**0.20**		**0.32**	

DAS: Days after sowing

Table 8: Categorization of sunflower genotypes for leaf hopper resistance based on mean population of leafhoppers and hopper burn injury grade (*Rabi* 2015)

Sl. No.	Resistance category	Name of the genotypes
1	**Resistant**	**RH-95-C-1, AHT 12, OPV 2,CMS 103 B, KBSH 53, KBSH 72, OPV3, NCP 198, KBSH 1, AHT 13 (10)**
2	**Moderately resistant**	KBSH 44, S-207, RSFH 130, RHA 93, GKVK-2, M-17R, AHT 1, AHT 2, AHT 4, AHT 6, AHT8, AHT9, AHT 10, IHT 241, IHT 242, IHT 243, IHT 245, IHT 246, IHT 247, IHT 248, IHT 250, IHT 252, IHT 253, IHT 558, IHT 711, IHT 741, IHT 750, IHT 764, IHT 775, IHT 795, IHT 802, IHT 881, IHT 879, IHT 878, IHT 877, IHT 848, IHT 845, IHT 843, IHT 815, IHT 807, IHT 888, IHT 891, IHT 913, IHT 937, IHT 943, IHT 948, IHT 951, IHT 960, IHT 971, IHT 972, IHT 975, IHT 976, IHT 990, IHT 997, IHT 1061, IHT 1089, KBSH 71, KBSH 73, KBSH 75, KBSH 76, GMU 440, GMU 520, TCSH1, EC78484877, EC 734887, E17A,RHA 469, GMU 601, GMU 604, GMU 606, GMU 607, GMU 608, GMU 609, GMU 612, GMU 613, GMU 614, GMU 615, GMU 616, GMU 617, GMU 618, GMU 619, GMU 621, GMU 622, GMU 623, GMU 624, GMU 626, GMU 627, GMU 628, GMU 630, GMU 631, GMU 633, GMU 634, GMU 636, GMU 637, GMU 639, GMU 640, GMU 641, GMU 642, GMU 644 **(101)**
3	**Susceptible**	EC734846, RHA 378, X15WB, AHT 3, AHT 5, AHT 7, AHT 11, IHT 238, IHT 239, IHT 240, IHT 249, IHT 251, IHT 591, IHT 712, IHT 731, IHT 731, IHT 737, IHT748, IHT 752, IHT 753, IHT 754, IHT 837, IHT 821, IHT 936, IHT 952, IHT 956, IHT 980,IHT 981,IHT 995, KBSH 74, RHA 467, GMU602,GMU 603, GMU 605, GMU610, GMU 611, GMU 620, GMU 625, GMU 629, GMU 632, GMU 635, GMU 643, GMU 645 **(43)**
4	**Highly susceptible**	**DRSF 108,RHA 284, EC 734840, EC 734844, NCP 22, NCP28, KBSH 41, Morden, UASB 560 (9)**

Table 9: Mean leafhopper population and hopper burn injury grade in different genotypes (*Kharif* 2016)

Sl. No.	Entry No.	45 DAS		75DAS	
		Mean no of leafhoppers/ plant	Hopper burn injury grade/plant	Mean no of leafhoppers/ plant	Hopper burn injury grade/ plant
1	GMU 301	0.83	0.00	1.16	1.00
2	GMU 302	0.66	0.00	1.33	1.00
3	GMU 303	1.00	1.00	1.50	1.00
4	GMU 311	0.83	1.00	1.16	0.00
5	GMU 313	0.66	0.00	1.00	0.00
6	GMU 321	0.50	0.00	0.66	0.00
7	GMU 324	0.83	1.00	1.00	1.00
8	GMU 325	0.50	0.00	0.66	0.00
9	GMU 326	0.83	1.00	1.00	1.00
10	GMU 327	0.66	0.00	1.33	1.00
11	GMU 329	1.16	1.00	1.50	2.00
12	GMU 336	0.66	0.00	0.83	0.00
13	GMU 342	0.66	0.00	1.00	0.00
14	GMU 344	0.83	1.00	0.83	0.00
15	GMU 351	1.00	1.00	1.16	1.00
16	GMU 355	0.00	0.00	0.83	0.00
17	GMU 362	0.33	0.00	1.50	1.00
18	GMU 363	0.50	0.00	1.66	1.00
19	GMU366	0.66	0.00	1.33	1.00
20	GMU 368	0.00	0.00	1.00	0.00
21	GMU 376	0.33	0.00	1.50	2.00
22	GMU 378	0.16	0.00	1.16	1.00
23	GMU 379	1.00	1.00	1.00	0.00
24	GMU 383	0.50	0.00	1.16	0.00
25	GMU 389	0.66	0.00	1.33	1.00
26	GMU 390	1.00	1.00	1.66	1.00
27	GMU 400	0.66	0.00	1.83	2.00
28	GMU 405	0.50	0.00	1.33	2.00
29	GMU 410	1.00	1.00	1.50	0.00
30	GMU 411	1.00	1.00	1.16	1.00
31	GMU 413	0.66	0.00	1.00	0.00
32	GMU 420	0.50	0.00	1.33	1.00
33	GMU 423	1.00	1.00	1.50	1.00

Sl. No.	Entry No.	45 DAS		75DAS	
		Mean no of leafhoppers/ plant	**Hopper burn injury grade/plant**	**Mean no of leafhoppers/ plant**	**Hopper burn injury grade/ plant**
34	GMU 426	0.66	0.00	0.83	0.00
35	GMU 428	1.00	1.00	1.33	0.00
36	GMU 433	0.33	0.00	1.83	1.00
37	GMU 434	0.16	0.00	1.16	1.00
38	GMU 439	0.00	0.00	1.50	2.00
39	GMU 441	0.33	0.00	1.33	1.00
40	GMU 443	1.00	1.00	1.00	0.00
41	GMU 447	0.66	0.00	1.33	0.00
42	GMU 450	0.83	1.00	1.16	1.00
43	GMU452	0.00	0.00	1.00	0.00
44	GMU 454	0.00	0.00	0.66	0.00
45	GMU 456	0.16	0.00	1.00	1.00
46	GMU 457	0.50	0.00	0.83	0.00
47	GMU458	0.33	0.00	1.33	1.00
48	GMU 459	0.66	0.00	0.50	0.00
49	GMU461	0.83	1.00	0.66	0.00
50	GMU463	0.66	0.00	1.00	1.00
51	GMU 465	0.50	0.00	1.50	1.00
52	GMU 466	0.33	0.00	1.16	1.00
53	GMU 468	0.50	0.00	1.00	0.00
54	GMU 469	0.16	0.00	0.66	1.00
55	GMU 470	1.00	1.00	1.00	0.00
56	GMU 474	0.66	0.00	1.16	0.00
57	GMU 475	0.83	1.00	1.00	1.00
58	GMU 476	0.50	0.00	0.00	0.00
59	GMU 477	1.00	1.00	1.16	1.00
60	GMU 478	0.83	1.00	1.50	1.00
61	GMU 479	0.50	0.00	1.00	0.00
62	GMU 480	0.33	0.00	0.66	0.00
63	GMU483	0.00	0.00	1.33	1.00
64	GMU 485	0.66	0.00	1.16	0.00
Mean		**1.01**		**1.24**	
SEM±		**0.10**		**0.12**	
CD at P=0.05		**0.29**		**0.34**	

DAS: Days after sowing

The overall mean leafhopper incidence on 64 entries screened during the season at 45 DAS and 75 DAS, were 1.01 and 1.24, respectively, which was very low. Between the different entries there was no significant difference *w. r. t.* mean number of leafhoppers per plant, both at 45 DAS (0.29) and 75 DAS (0.34), respectively (Table 9).

Therefore, due to low pest pressure during *kharif* 2016. Meaningful categorization of sunflower entries into resistant or susceptible categories was not possible for this season.

4.1.4 Field screening during *rabi* 2016

One hundred and four entries were evaluated against leafhoppers during *rabi* 2016 (November 2015 to January 2016) at ZARS, University of Agricultural Sciences, GKVK, Bengaluru (Table 10). The mean number of leafhopper nymphs per plant on the different entries ranged from 0.66 to 2.33 at 45 DAS and hopper burn injury grade ranged from 0.00-2.00 At 75 DAS, mean number of leafhopper nymphs per plant ranged from 0.83 to 5.33, with hopper burn injury grade per plant ranging between from 1.00 to 5.00 The overall mean leafhopper incidence per plant on the 104 entries screened during the season, at 45 DAS and 75 DAS, were 1.35 and 1.65, respectively.

Between the different entries there was no significant difference *w. r. t.* mean number of leafhopper nymphs per plant, both at 45 DAS and 75 DAS (0.38and 0.36), respectively. So, based on hopper burn injury grade per plant at 75 DAS, the 10 sunflower entries were categorized as resistant, 51 as moderately resistant, 34 as susceptible and 9 as highly susceptible (Table 11). The sunflower crop reaches seed filling stage during 75 DAS, in this context the data pertaining to number of leaf hoppers per plant and hopper burn injury grade at 75 DAS was considered for categorization of the entries.

Overall incidence of leafhopper per plant and hopper burn injury grade on the sunflower entries was highest during *rabi 20*16, followed by *rabi* 2015 seasons than during *kharif* 2015 and *kharif* 2016.

Table 10: Mean leafhopper population and hopper burn injury grade in different genotypes (*Rabi* 2016)

Sl. No.	Entry No.	45 DAS		75DAS	
		Mean no of leafhoppers/ plant	Hopper burn injury grade/ plant	Mean no of leafhoppers/ plant	Hopper burn injury grade/ plant
1	EC734844	2.33	1.00	4.33	4.00
2	EC734840	2.16	1.00	3.66	4.00
3	OPV3	1.00	0.00	1.33	1.00
4	KBSH41	2.00	0.00	4.16	4.00
5	KBSH44	1.00	0.00	1.83	3.00
6	KBSH53	0.83	0.00	1.00	0.00
7	KBSH71	1.83	1.00	2.33	2.00
8	GKVK2	1.16	1.00	1.83	2.00
9	GKVK1	1.50	0.00	2.66	2.00
10	OPV2	1.00	0.00	0.83	1.00
11	RHA275	1.66	1.00	2.50	3.00
12	RHA630	1.33	0.00	2.00	2.00
13	EC734873	1.33	0.00	2.66	3.00
14	EC734874	1.16	1.00	2.33	3.00
15	RHA378	1.50	0.00	2.16	2.00
16	RHA589	1.66	1.00	2.83	3.00
17	RHA265	1.33	0.00	2.16	2.00
18	RHA857	1.50	1.00	2.83	3.00
19	RHA630	1.00	0.00	1.33	1.00
20	UASB929	1.33	1.00	2.16	2.00
21	UASB933	1.66	2.00	3.00	3.00
22	UASB934	1.50	0.00	2.00	2.00
23	UASB932	1.83	1.00	3.50	3.00
24	UASB788	1.00	0.00	1.83	2.00
25	UASB790	2.00	1.00	2.83	3.00
26	UASB771	1.66	1.00	2.33	2.00
27	UASB560	2.16	2.00	3.50	4.00
28	NCP22	1.83	1.00	3.00	5.00
29	NCP32	1.16	1.00	3.16	2.00
30	NCP28	2.33	1.00	3.50	4.00
31	RHA589	1.50	0.00	1.83	2.00
32	RHA857	1.33	0.00	2.33	3.00
33	RHA275	1.16	0.00	2.66	2.00
34	REC443	1.50	1.00	2.00	2.00

Sl. No.	Entry No.	45 DAS		75DAS	
		Mean no of leafhoppers/ plant	Hopper burn injury grade/ plant	Mean no of leafhoppers/ plant	Hopper burn injury grade/ plant
35	REC447	1.66	1.00	3.00	3.00
36	RHA272	1.33	0.00	2.50	2.00
37	RHA265	1.50	1.00	2.16	2.00
38	LTRR-83-273	0.83	1.00	2.00	2.00
39	GPR135	1.16	1.00	2.33	3.00
40	OPV 6	1.50	0.00	2.66	2.00
41	OPV5	1.33	1.00	2.83	3.00
42	OPV4	1.66	0.00	2.66	2.00
43	EC734877	1.33	1.00	2.16	2.00
44	RHA278	1.33	0.00	1.83	1.00
45	KBSH75	1.50	1.00	2.83	2.00
46	RSFH130	1.16	0.00	2.33	2.00
47	KBSH72	1.33	1.00	1.00	1.00
48	KBSH76	1.66	1.00	3.16	3.00
49	KBSH74	1.16	1.00	2.83	2.00
50	RHA-M-17-R	1.33	0.00	2.66	2.00
51	RH-95-C-1	0.83	0.00	1.33	1.00
52	AHT 13	1.00	1.00	1.16	1.00
53	CMS103B	0.83	0.00	1.50	1.00
54	KBSH1	1.00	1.00	2.50	1.00
55	RHA469	1.50	1.00	2.16	3.000
56	DRSF108	2.16	1.00	3.83	4.00
57	RHA284	1.83	0.00	4.00	4.00
58	Morden	2.33	1.00	5.33	4.00
59	AHT1	1.00	0.00	2.16	2.00
60	AHT2	1.33	1.00	2.16	3.00
61	AHT3	1.66	2.00	3.00	3.00
62	AHT4	1.50	0.00	2.00	2.00
63	AHT5	1.83	1.00	2.66	3.00
64	AHT6	1.00	0.00	1.50	2.00
65	AHT7	2.00	1.00	2.83	3.00
66	AHT8	1.66	1.00	2.33	2.00
67	AHT9	1.33	1.00	2.00	2.00
68	AHT10	1.16	0.00	2.16	3.00
69	AHT11	1.60	1.00	2.83	2.00
70	AHT12	0.66	0.00	1.00	1.00
71	NCP198	1.33	1.00	2.00	1.00

Sl. No.	Entry No.	45 DAS		75DAS	
		Mean no of leafhoppers/ plant	**Hopper burn injury grade/ plant**	**Mean no of leafhoppers/ plant**	**Hopper burn injury grade/ plant**
72	EC734846	1.66	1.00	2.16	3.00
73	IHT 238	1.33	1.00	2.83	3.00
74	IHT 239	1.50	1.00	2.66	2.00
75	IHT 240	1.00	0.00	2.50	3.00
76	IHT 241	1.33	0.00	1.83	2.00
77	IHT 242	1.50	1.00	2.16	2.00
78	IHT 243	1.16	0.00	2.00	3.00
79	IHT244	1.83	1.00	3.00	2.00
80	IHT245	2.16	1.00	2.16	2.00
81	IHT246	1.33	1.00	2.50	2.00
82	IHT247	1.16	0.00	2.16	3.00
83	IHT248	1.50	0.00	2.33	2.00
84	IH 249	1.33	1.00	2.00	3.00
85	GMU601	1.16	0.00	2.50	2.00
86	GMU602	1.33	0.00	2.16	2.00
87	GMU603	1.50	0.00	2.33	2.00
88	GMU604	1.33	1.00	2.83	3.00
89	GMU605	1.16	1.00	2.66	2.00
90	GMU606	1.50	0.00	2.50	3.00
91	GMU607	1.33	0.00	2.00	2.00
92	GMU608	1.50	0.00	2.33	2.00
93	GMU609	1.33	1.00	1.83	2.00
94	GMU610	1.16	0.00	1.83	3.00
95	GMU611	1.33	1.00	2.00	2.00
96	GMU612	1.50	0.00	1.83	2.00
97	GMU613	1.16	0.00	2.66	2.00
98	GMU614	1.16	1.00	2.16	3.00
99	GMU 615	1.33	0.00	1.66	2.00
100	GMU616	1.33	1.00	2.33	2.00
101	GMU 617	1.66	0.00	2.00	3.00
102	GMU 618	1.50	1.00	2.66	3.00
103	GMU 619	1.33	1.00	2.16	2.00
104	GMU 620	1.66	1.00	1.83	2.00
Mean		**1.35**		**1.65**	
SEM±		**0.14**		**0.12**	
CD at P=0.05		**0.38**		**0.36**	

DAS: Days after sowimg

Table 11: Categorization of sunflower genotypes for leafhopper resistance based on mean population of leafhoppers and hopper burn injury grade (*Rabi* 2016)

Sl. No.	Resistance category	Name of the genotypes
1	**Resistant**	**RH-95-C-1, AHT 12, OPV 2,CMS 103 B, KBSH 53, KBSH 72, OPV3, NCP 198, KBSH 1, AHT 13 (10)**
2	**Moderately resistant**	KBSH 71, GKVK-2, GKVK- 1 RHA 630, RHA 378, RHA 265, UASB 929, UASB934, UASB788, UASB 771, NCP 32, RHA 589, RHA 275, REC 443, RHA 272, RHA 272, RHA 265, LTRR-83-273, OPV-6, OPV-4, EC734877, KBSH 75, RSFH130, KBSH 74, RHA- M-17R, KBSH1, AHT 1,AHT 4, AHT 6, AHT8, AHT9, AHT 11, NCP 198, IHT 239, IHT 241, IHT 242, IHT 244, IHT 245, IHT 246, IHT 248, GMU 611, GMU 612, GMU 613, GMU 615, GMU 616, GMU 609, GMU 612, GMU 613, GMU 614, GMU 619, GMU 620 **(51)**
3	**Susceptible**	KBSH 44, RHA 275, EC734873, EC734874, RHA 589, RHA 857, UASB 933, UASB 932, UASB 790, RHA 857, REC 447, GPR 135, OPV 5, KBSH 73, KBSH 76, RHA 469, AHT 2, AHT 3, AHT 5, AHT 7, AHT 10, EC73846, IHT 238, IHT 240, IHT 243, IHT 247, IHT 249, GMU604,GMU 606, GMU610, GMU 614, GMU 617, GMU 618 **(34)**
4	**Highly susceptible**	**DRSF 108, RHA 284, EC 734840, EC 734844, NCP 22, NCP28, KBSH 41, Morden, UASB 560 (9)**

Therefore, data from the field conducted during trials *rabi* 2015 and *rabi* 2016 were utilized for categorizing the entries by considering the hopper burn injury grade as well as the overall mean leafhopper infestation. The entries were hence categorized as Resistant, Moderately Resistant, Susceptible and Highly Susceptible for *rabi* 2015 and *rabi* 2016 seasons and the entries categorized as resistant and highly susceptible (extreme cases) were utilized for intensive screening under glass house conditions (Table 12a & b) (Plate 5a & b and 6)

Out of 162 entries evaluated in *rabi* 2015, 10 entries were grouped as “Resistant”, 101 entries as “Moderately resistant”, 43 entry as “Susceptible” and 9 entries under “Highly Susceptible” group.

Out of 104 entries evaluated during *rabi* 2016, 10 entries were classified as “Resistant”, 51 entries as “Moderately resistant”, 34 entries as “Susceptible”, 9 entries as “Highly Susceptible” (Table 12a &b). The 10 resistant entries and 9 highly susceptible entries were most consistent in their reaction to the pest. Therefore, these 19 entries were shortlisted and taken forward for intensive screening under artificial conditions (glass house) for further studies.

In the four field trials conducted, it was observed that, in all the susceptible entries there was a significant increase in leafhopper number and hopper burn injury per plant with the advancement of the stage of the crop. In general, it was observed that the incidence of leafhopper increased with the age of the crop. That was probably due the multiplication of the pest with progress of time and also could be due to the proliferation of the foliage with the enhanced growth of the plant/ biomass.

The changes in the pest density in four season’s entries could be ascribed to the change in time of screening and location of the plot. The wide variation in hopper burn injury on various germplasm entries in four seasons clearly indicated the variation among the lines in their degree of resistance to the leafhopper.

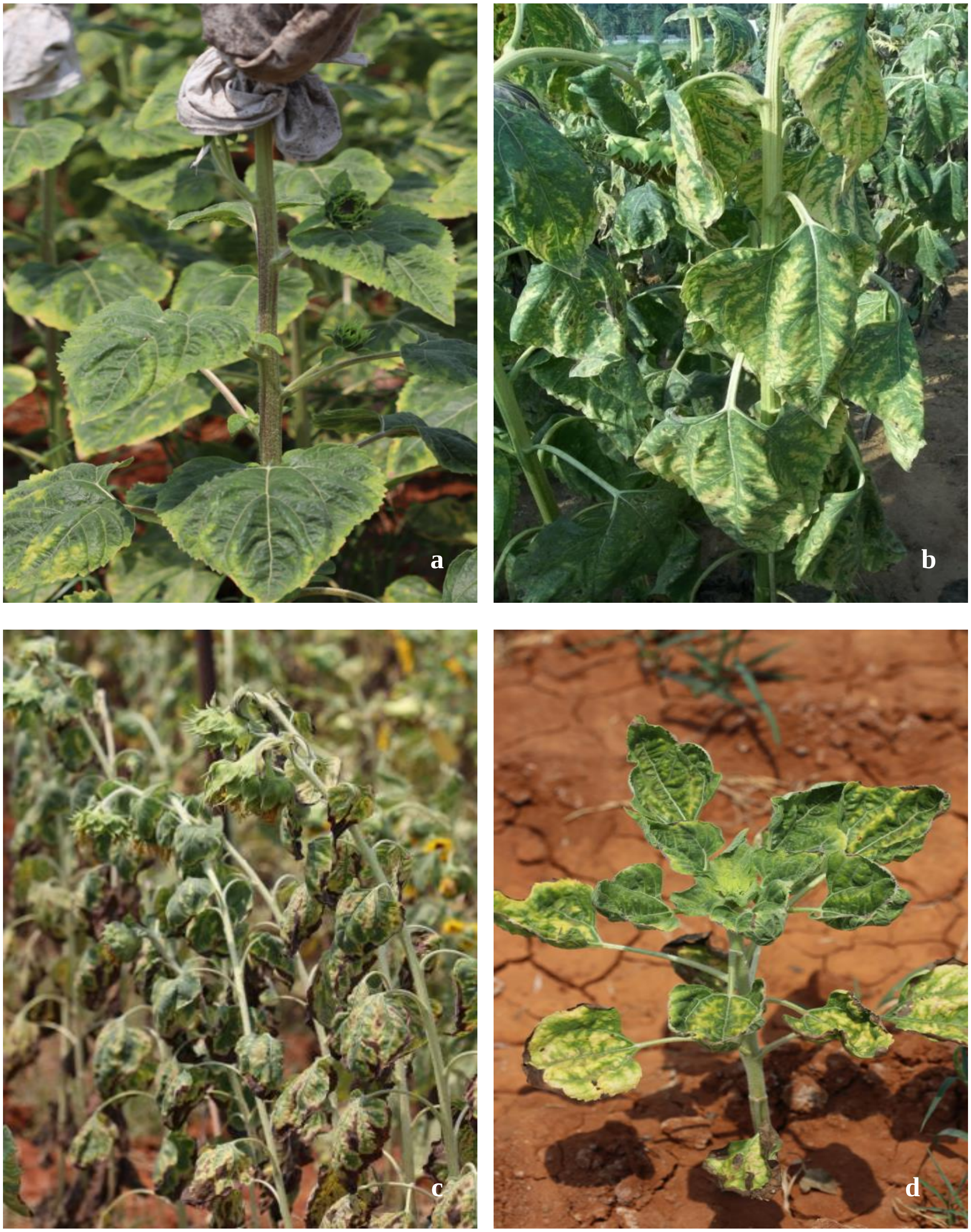


Plate 5(a): Reaction of susceptible sunflower entries *i.e.* (a) IC0506027, (b) EC0306728, (i) IC0506118, (j) POL-6 to the leafhopper infestation

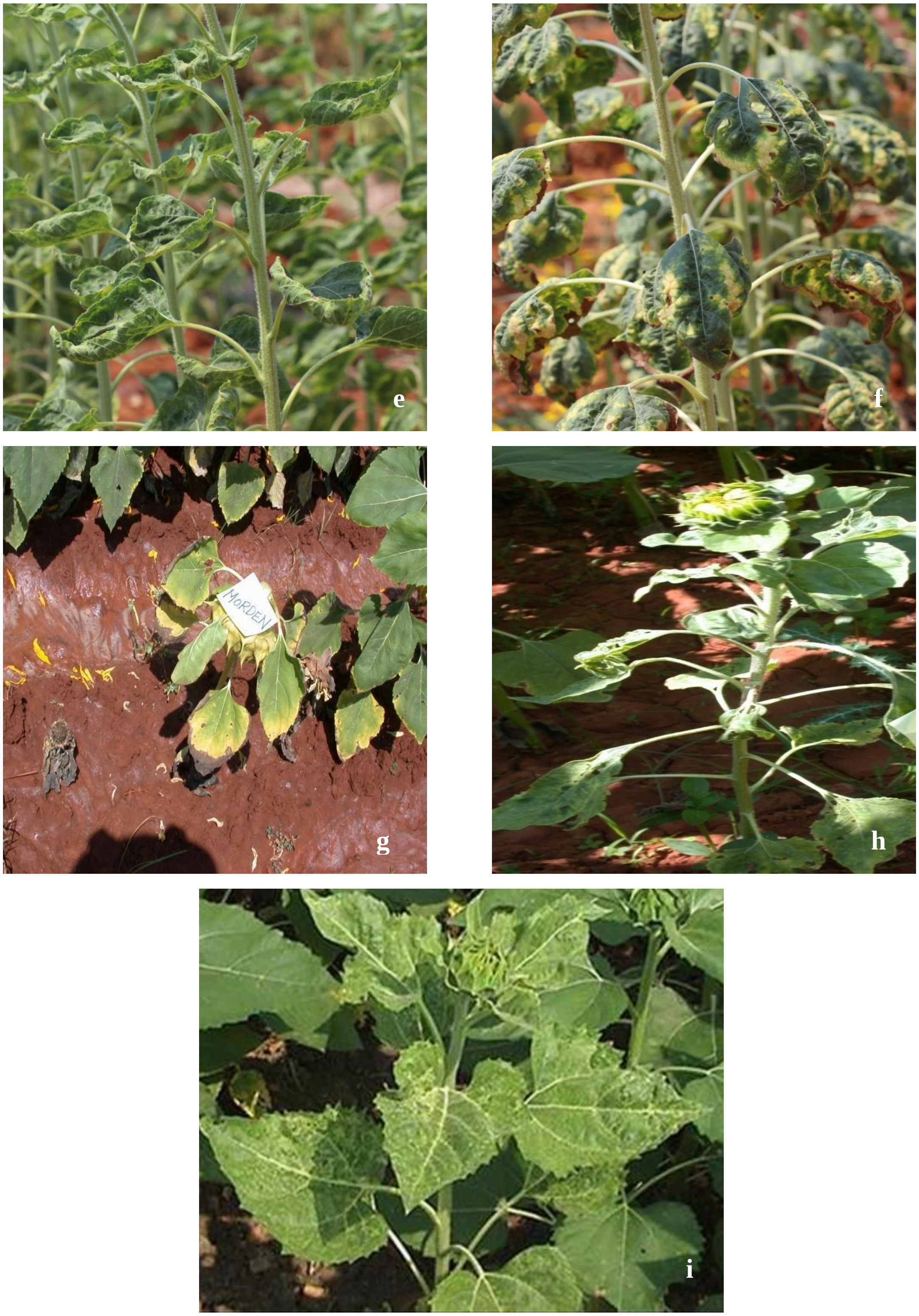


Plate 5(b): Reaction of susceptible sunflower entries *i.e.* (e) IC0506027, (f) EC0306728, (g) IC0506118, (h) POL-6, (i) POL-7 to the leafhopper infestation

Plate 6: Reaction of resistant sunflower entries *i.e.* (a) KBSH 53 (b) CMS 103B to the leafhopper infestation

Table 12a: Short listed resistant entries based on field screening of rabi 2015 and 2016

Sl. No.	Entries	*Rabi 2015*				*Rabi 2016*			
		Mean no of leafhoppers/ plant		Hopper burn injury grade		Mean no of leafhoppers/ plant		Hopper burn injury grade	
		45 DAS	75 DAS	45 DAS	75 DAS	45 DAS	75 DAS	45 DAS	75 DAS
1	RH-95-C-1	0.50	0.83	0.00	1.00	0.83	1.33	0.00	1.00
2	AHT 12	0.66	0.83	0.00	1.00	0.66	1.00	0.00	1.00
3	OPV 2	0.66	0.66	0.00	1.00	1.00	0.83	0.00	1.00
4	CMS 103 B	0.50	0.83	0.00	1.00	0.83	1.50	0.00	1.00
5	KBSH 53	0.66	0.83	1.00	0.00	1.33	1.00	0.00	0.00
6	KBSH 72	0.66	0.83	0.00	1.00	1.33	1.00	1.00	1.00
7	OPV3	0.66	0.83	0.00	1.00	1.00	1.33	0.00	1.00
8	NCP 198	0.66	1.33	1.00	1.00	1.33	2.00	1.00	1.00
9	KBSH 1	0.50	0.66	0.00	1.00	1.00	2.50	1.00	1.00
10	AHT 13	1.33	1.00	1.00	1.00	1.00	1.16	1.00	1.00
	Mean	**0.67**	**0.86**			**1.03**	**1.36**		
	SD±	**0.24**	**0.19**			**0.23**	**0.52**		

Table 12b: Short listed highly susceptible entries based on field screening in rabi 2015 and 2016

Sl. No.	Entries	***Rabi* 2015**				***Rabi* 2016**			
		Mean no of leaf hoppers/ plant		Hopper burn injury grade		Mean no of leaf hoppers/ plant		Hopper burn injury grade	
		45 DAS	75 DAS	45 DAS	75 DAS	45 DAS	75 DAS	45 DAS	75 DAS
1	DRSF 108	2.00	3.66	1.00	4.00	2.16	3.83	1.00	4.00
2	RHA 284	1.83	3.16	0.00	4.00	1.83	5.33	0.00	4.00
3	EC 734840	1.83	3.66	1.00	3.00	2.16	3.66	1.00	4.00
4	EC 734844	1.66	3.50	1.00	4.00	2.33	4.33	1.00	4.00
5	NCP 22	1.83	3.16	1.00	3.00	1.83	3.00	1.00	5.00
6	NCP28	2.16	3.50	1.00	4.00	2.33	3.50	1.00	4.00
7	KBSH 41	2.33	4.66	1.00	5.00	2.00	4.16	1.00	4.00
8	Morden	2.66	5.66	2.00	5.00	2.33	5.33	1.00	4.00
9	UASB 560	1.66	3.00	0.00	3.00	2.16	3.50	2.00	4.00
	Mean`	**1.99**	**3.77**			**2.12**	**4.07**		
	SD±	**0.33**	**0.85**			**0.19**	**0.81**		

DAS: Days after sowing

The results of the present investigation pertaining to the field screening were similar to the reports of Fick (1978), Nagaraju *et al.* (2004), Anonymous (2006, 2007 and 2008) who screened several entries against leafhoppers, by the same methodology, however, their results cannot be compared with the present investigation as the entries/cultivars used by them differ and so also the seasonal variations.

The present finding of sunflower are in accordance with Deshmukh and Akhare (1979) who screened, for three years 1975-77 at Akola for the response of early and dwarf genotypes of sunflower to leafhopper, *A. biguttula biguttula*, It was found that Cernianka-66 exhibited lesser leafhopper population on them indicating that the two varieties were comparatively resistant to the leafhopper. Similarly, Bhat and Virupakshappa (1993) screened some germplasm lines against leafhoppers in sunflower and the entries No. 771, 775, 892, 1009, 1035, 1042, 1407, 1055, 1134, 702 R, KBSH-8, BSH-1 S- 55, EC-61039 and 35811 either supported comparatively lower population or did not express cupping symptoms compared to susceptible genotypes.

The results were in line with that of Suganthy and Uma (2011) who screened the promising germplasm entries of sunflower for confirmation of their reaction to leafhoppers, Results revealed that all the five germplasm entries *viz*., GMU 407, GMU 415, GMU 424, GMU 473 and GMU 493 were promising to the key pests of sunflower. GMU 473 recorded the maximum of 5.0 thrips and 3.0 *S. litura* larvae per plant with the defoliation of 25 per cent as against 7 and 0 per cent defoliation in the checks, Morden and TCSH 1, respectively. GMU 424 recorded the maximum of 0.4 leafhoppers per plant as against 28 and 19 hoppers per plant in Morden and TCSH 1, respectively and also screening under glasshouse condition revealed that GMU 473 recorded the maximum injury grade of 0.5 for leafhopper as against 3.5 and 2.2 in the checks Morden and TCSH 1, respectively. GMU 415 and GMU 493 recorded the lowest grade of 0.1. Similarly, Hyacinth and Selvanarayanan (2011) screened 112 accessions of sunflower under field conditions in two seasons at Tamilnadu, for their resistance against leafhopper, (*A. biguttula biguttula*). In the first season, four accessions *viz*., KBSH 1, AHT 14, GK 2002 and GMU 698 harboured the least population whereas in the second season, the accession KBSH 1 proved to be promising.

Furthermore the present findings are corroborated by Balasubramanian and Gopalan (1981) who assessed the different sunflower genotypes against the leafhopper *(A. biguttula biguttula*). Ashfaq and Aslam (2001a) screened out the different genotypes of sunflower on the leaf base, similarly Mandal and Dash (2003) screened out fifteen sunflower genotypes under the field conditions against *A. biguttula biguttula* among ten five were resistant. The present findings are in conformity with those of Anon., (2002), Sarwan and Dhillon (2014) and Anon., (1999) who all reported the leafhopper on the sunflower.

Since, Rana and Sheoran (2004) reported that the leafhopper population ranged from a minimum of 2 on HSFH 848 to a maximum of 4 per plant on KBSH 1. This result is similar to the present findings, whereas, Bhat and Virupakshappa (1993) observed some hybrids such as KBSH 8 and KBSH 1 recorded the least damage. Morden recorded the highest leafhopper population at both 45 and 75 DAS (2.66 and 5.66 per plant), respectively. Results pertaining to Morden tally with the present findings.

4.1.5 Spatial distribution pattern of leafhopper in sunflower crop canopy.

Germplasm entries of sunflower were screened for evaluating their resistance potential against *A. biguttula biguttula* and the same set of entries were used for studying canopy distribution pattern in sunflower.

4.1.5.1 *Kharif* 2015

There were significant differences between the populations of leafhoppers within the crop canopy at both 45 DAS (CD=0.054) and 75 DAS (CD=0.061), maximum pest population was recorded in the middle canopy (1.95/ plant and 2.60/plant) of the plant followed by the top (1.49/ plant and 1.14/ plant) and least population was found at the bottom canopy (0.56/ plant and 1.50/plant) (Table 13).

4.1.5.2 *Rabi* 2015

There was significant difference between the population of leafhopper within the crop canopy at both 45 DAS (CD=0.071) and 75 DAS (CD=0.42). Leafhopper population

(45 DAS and 75 DAS) was highest in the middle (3.58/plant and 5.78/plant), followed by top (2.95/plant and 4.66/plant) and least in the bottom (1.5/plant and 2.11/plant), respectively. However, there was no significant difference between top and middle crop canopy at 75 DAS (Table 13).

4.1.5.3 *Kharif* 2016

There is significant difference between the population of leafhopper within the crop canopy at both 45 DAS (CD=0.064) and 75 DAS (CD=0.08). Maximum leafhopper population was recorded in the middle canopy (1.81/ plant and 2.69/ plant) followed by the top (1.32/ plant and 2.69/ plant) canopy respectively. However, there was no significant difference between top and middle level canopy at 75 DAS (Table 14).

4.1.5.4 *Rabi* 2016

There was significant difference between the population of leafhopper within the crop canopy at both 45 DAS (CD=0.065) and 75 DAS (CD=0.36). Leafhopper density was highest in the middle (3.77/plant and 6.37/plant), followed by top canopy (3.33/plant and 5.16/plant) and least was recorded in the bottom canopy (1.46/plant and 2.77/plant) respectively (Table 14).

The vertical distribution of leafhopper in the plant revealed that bottom level of the plant less preferred compared to middle and top level canopy of plants of different ages (Table 13 &14). The relative preference of the leafhopper to middle and lower levels of canopy could keep changing in certain occasions. The results also indicated that there was variation in population density among the growth stages of sunflower between 45 to 75 DAS and within plant, middle canopy leaves appears to be more suitable for nymphs to stay or for the multiplication owing to the superior nutritional quality. These finding however, do not agree with those of Jayaramaiah and Jagadish (1996) where, in case of *Myzus nicotianae* Blackman in tobacco probably due to differences in the host plant and pest species involved.

Nevertheless, it indicates that middle level canopy is the most preferred site in sunflower for colonization by leafhopper.

Table 13: Spatial distribution pattern of leafhopper in sunflower crop canopy during *kharif* and *rabi* of 2015

	Crop canopy											
	***Kharif* 2015**						***Rabi* 2015**					
	45days			**75days**			**45days**			**75days**		
	Bottom	**Middle**	**Top**	**Bottom**	**Middle**	**Top**	**Bottom**	**Middle**	**Top**	**Bottom**	**Middle**	**Top**
Mean leafhoppers per leaves	0.56 (0.87a)	1.95 (1.19c)	1.49 (1.09b)	1.14 (1.01a)	3.00 (1.40c)	2.6 (1.32b)	1.5 (1.08a)	3.58 (1.49c)	2.95 (1.37b)	2.11 (1.19a)	5.78 (1.81b)	4.66 (1.65b)
±SD	0.66	1.12	1.06	0.89	1.22	1.15	1.31	1.48	1.52	1.63	2.48	1.89
SE.M±	**0.019**			**0.022**			**0.032**			**0.15**		
CD at P=0.05	**0.054**			**0.061**			**0.071**			**0.42**		

Table 14: Spatial distribution pattern of leafhopper in sunflower crop canopy during *Kharif* and *rabi* of 2016

	Crop canopy											
	***Kharif* 2016**						***Rabi* 2016**					
	45days			**75days**			**45days**			**75days**		
	Bottom	**Middle**	**Top**	**Bottom**	**Middle**	**Top**	**Bottom**	**Middle**	**Top**	**Bottom**	**Middle**	**Top**
Mean leafhoppers per leaves	0.44 (0.84a)	1.81 (1.17c)	1.32 (1.05b)	0.96 (0.96a)	3.12 (1.42b)	2.69 (1.34b)	1.46 (1.07a)	3.77 (1.53c)	3.33 (1.45b)	2.77 (1.22a)	6.37 (1.41b)	5.16 (1.87c)
±SD	0.55	0.99	0.98	0.91	1.11	1.07	1.21	1.10	1.25	1.46	2.22	1.82
SEM±	**0.023**			**0.03**			**0.023**			**0.13**		
CD at P=0.05	**0.064**			**0.08**			**0.065**			**0.36**		

NB: Figures in the parenthesis are $\sqrt{x+0.50}$ transformed values

The present findings are contradictory to those of Mahto (1990) who revealed that at lower canopy level of sunflower , leafhopper was significantly more in number than other two levels. He did not find significant difference in nymphal population between middle and upper leaves. In okra, Senapati and Khan (1978) found that the younger leaves (top canopy) were significantly more preferred than the older leaves by *A. biguttula biguttula*. In case of potato, leafhopper *Emposca fabae* Harris was reported to have distinct preference for middle leaves. The higher preference by leafhopper for lower canopy level in sunflower in earlier findings and mid levels canopy preference that of in potato and younger leaves in okra, all could be attributed to variations and nutrient levels differing in each case.

4.1.6 Artificial screening of entries under the glass house during *rabi* 2016

A total of 19 entries (10 Resistant and 9 highly susceptible) shortlisted from both screening trails conducted during *rabi* 2015 and *rabi* 2016 which represented two contrasting groups *w.r.t* their reaction to leafhopper infestation were taken for this study. These 19 entries were further subjected to artificial screening under glasshouse conditions during *rabi* 2016 at glass house of the Department of Plant Pathology, University of Agricultural Sciences, Bengaluru, to ascertain their consistent reaction to leafhopper under high pest pressure (Table 15).

The number of leafhopper nymphs and hopper burn injury grade per plant on 19 sunflower entries under artificial screening, at 45 DAS ranged from 0.00 (OPV 3) to 33 (Morden) and 0.00 (OPV3) to 2.00 (Morden) respectively. At 60 DAS, the number of leafhopper nymphs and hopper burn injury grade ranged from 0.00 (RH- 95-C-1, OPV 2, CMS 103 B) to 26.0 (Morden) and 0.00 (RH-95-C-1, AHT 12, OPV 2, CMS 103B, OPV3, NCP 198, KBSH 1 and AHT 13) to 4.00 (RHA 284, EC 734840,NCP 22, KBSH 41 and Morden) (Table 15).

In the 10 resistant entries (RH-95-C-1, AHT 12, OPV 2, CMS 103 B, KBSH 53, KBSH 72, OPV3, NCP 198, KBSH 1, AHT 13) the number of leafhopper nymphs and hopper burn injury grade per plant ranged from 0.00 to 10.0 and 0, respectively, at 45th

Table 15: Leafhopper population build up following artificial infestation of *A. biguttula biguttula* at different plant ages on sunflower entries

A. Resistant entries

Entries	No of hoppers released at 30 DAS	Plant age				
		No of nymphs			Hopper burn injury grade	
		45 DAS	60 DAS	Mean	45 DAS	60 DAS
RH-95-C-1	20	4.00	0.00	**2.00**	0	0
AHT 12	20	7.00	4.00	**5.50**	0	0
OPV 2	20	8.00	0.00	**4.00**	0	0
CMS 103B	20	6.00	0.00	**3.00**	0	0
KBSH 53	20	5.00	3.00	**4.00**	0	1
KBSH 72	20	9.00	1.00	**5.00**	0	1
OPV 3	20	0.00	2.00	**1.00**	0	0
NCP 198	20	9.00	3.00	**6.00**	0	0
KBSH 1	20	10.0	2.00	**6.00**	0	0
AHT 13	20	5.00	0.00	**2.50**	0	0
Mean		**6.30**	**1.50**			

B. Highly susceptible entries

Entries	No of hoppers released at 30 DAS	Plant age				
		No. of nymphs			Hopper burn injury grade	
		45 DAS	60 DAS	Mean	45 DAS	60 DAS
DRSF 108	20	22.0	16.0	19.0	0	3
RHA 284	20	18.0	13.0	15.5	1	4
EC 734840	20	17.0	9.00	13.0	1	4
EC 734844	20	24.0	19.0	21.5	0	3
NCP 22	20	19.0	22.0	20.5	0	4
NCP 28	20	26.0	16.0	21.0	1	3
KBSH 41	20	24.0	16.0	20.0	0	4
Morden	20	33.0	26.0	29.5	2	4
UASB 560	20	21.0	24.0	22.5	0	3
Mean		**22.60**	**17.88**			

DAS: Days after sowing

DAS. At 60th DAS, the number of leafhopper nymphs per plant and hopper burn injury grade ranged from 0.00 to 4.0 and 0 to 1respectively (Table15)

The number of leafhopper nymphs and hopper burn injury grade on the nine highly susceptible sunflower entries (DRSF 108, RHA 284, EC 734840, EC 734844, NCP 22, NCP28, KBSH 41, Morden and UASB 560) during at 45th DAS ranged from 17.00 to 33.00 and 0.00 to 2.00, respectively. At 60th DAS, the number of leafhopper nymphs per plant and hopper burn injury grade ranged from 9.00 to 26.00 and 3 to 4, respectively (Table 15).

4.2 Determination of morphological basis of resistance

A total of 19 entries (10 Resistant and 9 highly susceptible) harbouring different levels of leafhopper infestation were studied separately for variations in the pigmentation of petiole, shape of lamina tip and consistency of lamina, lacination index, trichome density and trichome length by recording the observations at 45 and 60 days after sowing

4.2.1 Pigmentation of petiole

Perusal of the Table 16 indicates that all the ten resistant and nine susceptible entries exhibited green petiole, none of the entries had purple pigmented petiole. It indicated that there was no relationship between the pigmentation of the petiole and leafhopper infestation in the 19 sunflower entries.

4.2.2 Shape of the lamina tip

All the ten resistant and nine susceptible entries were having no association with the shape of the lamina tip. Leafhopper population on these nineteen entries was independent of the shape of lamina tip. All the nineteen entries exhibited pointed lamina tip (Table 16).

4.2.3 Lamina consistency

Two types of lamina consistency were observed in the entries *i,e*. coarse and smooth. Totally seven out of the ten resistant entries exhibited coarse lamina, whereas seven out of the nine susceptible entries exhibited smooth lamina (Table 16). It indicated that the close association of leafhopper resistance has got with lamina consistency.

4.2.4 Lacination index

The lacination index was calculated on all nineteen entries. Out of ten resistant entries, seven resistant entries recorded the lacination indices ranging between 0.70- 0.80 *i.e.,* narrow leaves. Similarly, nine susceptible entries recorded different lacination index ranging from 0.51 to 0.84, this indicated different shape of leaves *i.e.*, broad leaves, intermediate leaves and narrow leaves respectively, which did not have much bearing on leafhopper resistance (Table 16).

Studies to determine the relationship between colour of petiole, shape and consistency of lamina with reference to the incidence of leafhopper and hopper burn injury revealed that both petiole pigmentation (Green Vs Purple) and shape of the lamina (Pointed *Vs* Rounded tip) did not seem to have any relationship with the incidence of the leafhopper and hopper burn injury. However, among the two types of laminar consistency observed (Coarse Vs Smooth), majority of resistant entries possessed coarse lamina, whereas, majority of the susceptible entries exhibited smooth lamina. Out of ten resistant entries, seven resistant entries recorded the lacination index which ranged from 0.70-0.84 *i.e.,* narrow leaves. Similarly, nine susceptible entries recorded different lacination index which ranged from 0.51 to 0.84, this indicated that existence of different shape of leaves *i.e.*, broad leaves, intermediate leaves and narrow leaves. Similar type of studies by Kadapa *et al*., (1988) indicated that leaf toughness serves as a limiting factor in population build up of certain sucking pests. Thus, in the present study, leaf coarseness of the leafhopper resistant sunflower genotypes might have discouraged the leafhopper infestation and subsequent development of hopper burn injury. The present findings are almost in agreement with that of Seetharam and Ravikumar (2003), who reported that smooth (soft) leaves of sunflower were associated with susceptibility to sucking pests.

Table 16: Petiole colour, shape of the lamina tip, consistency of lamina and lacination index in leafhopper resistant and susceptible genotypes

A) Resistant entries

Sl. No.	Entries	Pigmentation of the petiole	Shape of the lamina tip	Consistancy of the lamina	Lacination index (cm)
1	RH-95-C-1	Green	Pointed tip	Smooth	0.74
2	AHT 12	Green	Pointed tip	Coarse	0.84
3	OPV 2	Green	Pointed tip	Smooth	0.73
4	CMS 103B	Green	Pointed tip	Coarse	0.74
5	KBSH 53	Green	Pointed tip	Coarse	0.77
6	KBSH 72	Green	Pointed tip	Coarse	0.70
7	OPV 3	Green	Pointed tip	Smooth	0.64
8	NCP 198	Green	Pointed tip	Coarse	0.53
9	KBSH 1	Green	Pointed tip	Coarse	0.75
10	AHT 13	Green	Pointed tip	Coarse	0.66
				Mean	**0.71**

B) Highly susceptible entries

Sl. No.	Entries	Pigmentation of the petiole	Shape of the lamina tip	Consistancy of the lamina	Lacination index(cm)
1	DRSF 108	Green	Pointed Tip	Smooth	0.51
2	RHA 284	Green	Pointed Tip	Smooth	0.59
3	EC 734840	Green	Pointed Tip	Coarse	0.84
4	EC 734844	Green	Pointed Tip	Coarse	0.76
5	NCP 22	Green	Pointed Tip	Smooth	0.80
6	NCP 28	Green	Pointed Tip	Smooth	0.72
7	KBSH 41	Green	Pointed Tip	Smooth	0.68
8	Morden	Green	Pointed Tip	Smooth	0.71
9	UASB 560	Green	Pointed Tip	Smooth	0.69
				Mean	**0.70**

In the present study, the thickness of leaf lamina showed positive and significant correlation with the leafhopper population. The present finding can be comparble with that of Taylo and Bernardo (1995), who reported that leaf thickness and number of primary branches did not show significant variation in the resistant and susceptible genotypes.

4.2.5 Trichome Density

The trichome density in the ten resistant entries (Table 17, Fig. 1) ranged between 183.64 to 235.30/0.64cm^2 (mean=208.43±17.04) and 163.13 to 211.84/0.64 cm^2 (mean=189.57±16.51) at 45 DAS and 60 DAS, respectively. There was no significant difference between the density of trichomes at 45 DAS and 60 DAS (0.95), whereas in nine susceptible entries (Table 17, Fig. 1), it ranged between 106. 32 to 194.26/0.64cm^2 (mean=145.94±34.33) and 89.23 to 169.79/0.64cm^2 (mean=137.36±30.93) at 45 DAS and 60 DAS, respectively. In this case also there was no significant difference between the entries *w.r.t* the density of trichomes (0.77) at 45 DAS and 60 DAS.

A similar trend was observed by Parnell *et al.*, (1949) wherein, the trichome density and their angles of insertion contributed towards leafhopper resistance in cotton. The present findings can be compared with that of by the Naqvi (1975) who reported that trichome density showed the negative correlation with the population of leafhopper *(A. biguttula biguttula)* on the brinjal crop**.** The present observations are in consistency with that of Mahal *et al*. (1993a) who found opposite relationship among appearance of nymphs and hair density of leaves. Correspondingly, Taylo and Bernardo (1995) found that emergence of leafhopper showed negative and significant correlation with hair density. The present results somewhat similar those of Sikka *et al.* (1966), Lokesh and Singh (2005) who found that hair density on the veins in relation to oviposition showed a negative and significant correlation.

4.2.6 Trichome Length

In the ten resistant entries (Table 17, Fig. 1) trichome length ranged between 20.12 to 27.87µm (mean = 23.05±2.37) and 20.14 to 27.84 µm (mean = 23.07±2.36) at

45th DAS and 60th DAS, respectively. Whereas, in the nine susceptible entries it ranged between 17.68 to 27.31 µm (mean = 21.73±3.38) (Table 17, Fig. 1) and 17.70 to 27.34 (mean = 21.75±3.38) at 45th DAS and 60th DAS, respectively. There was no significant difference *w.r.t* trichome length during 45th and 60th DAS in all the nineteen entries.

The findings of Seetharam and Ravikumar (2003) wherein hairiness (trichomes) are linked to resistance to sucking pests in sunflower are agreeable with the present findings. A similar trend was observed by Parnell *et al*., (1949) wherein, the trichome length and their angles of insertion contributed towards leafhopper resistance in cotton. Further, Ramey (1962) observed that dense pubescence confers resistance to thrips in cotton, similarly in case of Cassava (Schoonhoven, 1974). The multivariate analysis pertaining to thrips vector, SND and trichome length showed that the mean of all the above variables are significantly different from each other (P=0.01). The present study can be compared with that of Gaikwad *et al.* (1991) who reported the different morpho-physical plant characters and their correlation in the leaves of brinjal. The present findins can be compared with that of Lit and Bernardo (1990) who reported significant and negative linear correlation among hair length, number of primary branches, and density of leaf hairs and causes larval liking and reduced adult oviposition on the brinjal plants. The present study is in consistency with that of Mahal *et al*. (1993a) who found the opposite relationship among appearance of nymphs and hair.

4.2.7 Correlation between trichome density, incidence of leafhoppers and hopper burn injury grade

Simple correlation (Table 18) between trichome density and incidence of leafhopper and hopper burn injury revealed that, in the resistant entries, the trichome density was significantly and positively correlated with the leafhopper population (r = 0.271**) whereas, with the hopper burn injury grade (r = -0.032**) trichome density was significantly and negatively correlated. However, the correlation between the incidence of the leafhopper with hopper burn injury grade was positive, but not significant (r = 0.181) in the resistant entries.

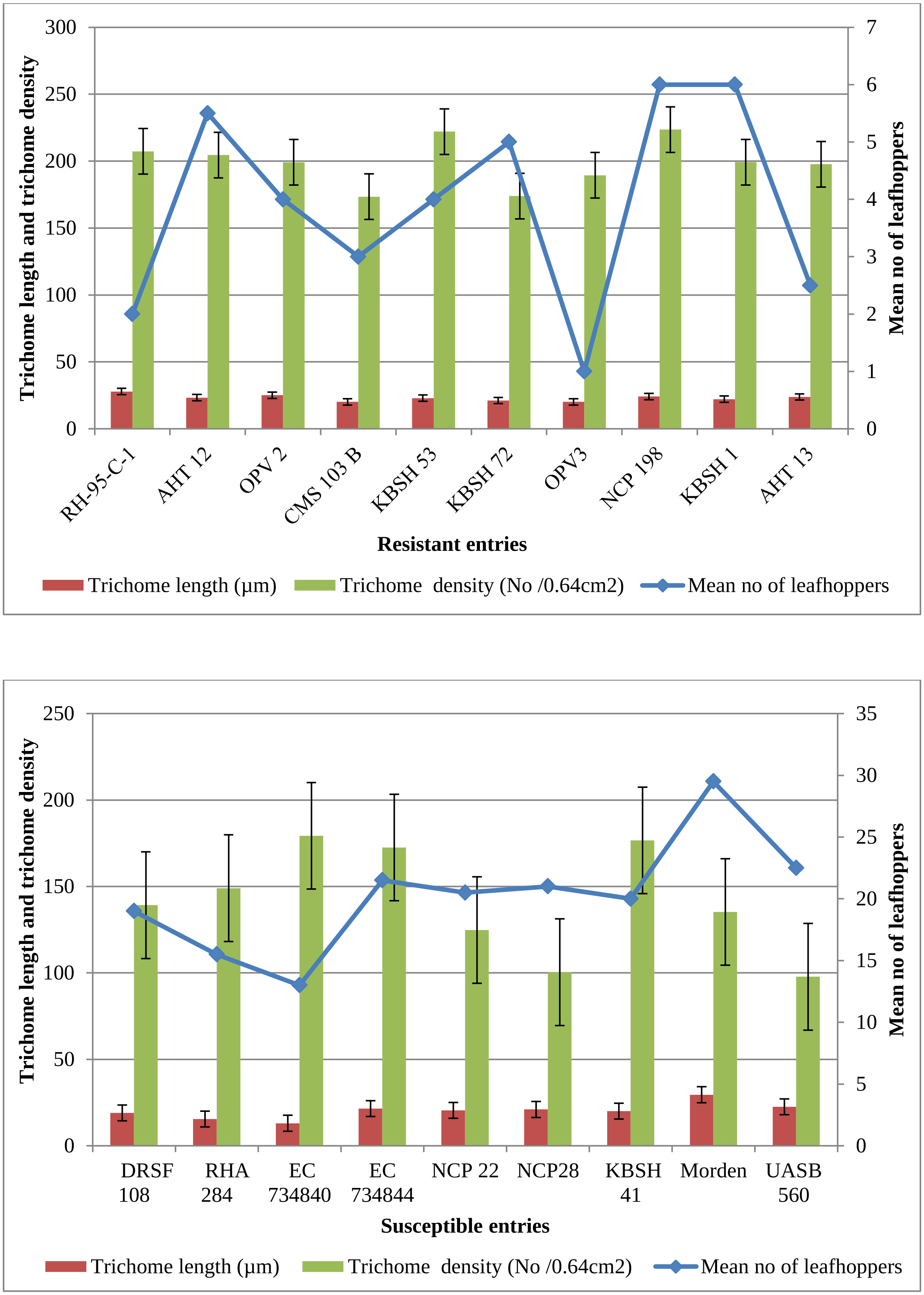


Fig. 1: Trichome density and trichome length in relation to the incidence of leafhopper

In susceptible entries, trichome density was significantly and negatively correlated with the leafhopper population (r = -0.412**) whereas, with the hopper burn injury grade (r = -0.184) trichome density was non significant and negatively correlated. However, the correlation between the incidence of the leafhopper with hopper burn injury grade was positive, but not significant (r = 0.109).

4.2.8 Correlation between trichome length, incidence of leafhoppers and hopper burn injury grade

Studies to determine the influence of trichome length on the population of leafhopper and hopper burn injury grade in the 10 resistant entries (Table 19) revealed that the trichome length was non significantly and negatively correlated with the incidence of both the leafhopper (r = -0.007) and hopper burn injury grade (r = -0.236) but this relationship was non significant (0.181). In the nine susceptible entries trichome length was significantly and negatively correlated with the leafhopper population (r = -0.603**), whereas with the hopper burn injury (r = 0.216) trichome length was non significantly and positively correlated. However, the correlation between the incidence of the leafhopper with hopper burn injury grade was positive, but not significant (r = 0.109).

The present findings are in conformity with that of Ramey (1962) in cotton. In an earlier study, greater trichome density and length in resistant sunflower genotypes might have inhibited the thrips vector infestation and indirectly contributed towards lower incidence of SND in the resistant genotypes. Correlation between the incidence of the thrips vector and that of SND was positive, but not significant (r = 0.362). This agrees with the findings of Meenakshi (2006), who also observed a non-significant positive relationship between thrips vector and SND incidence. The amount of resistance imparted by the host plants to *A. biguttula biguttula* is related to morphological characters like hair density on midrib and lamina, thickness of cortex and diameter of midrib vein as in cotton and hair density in okra (Batra and Gupta 1970 and Yadav *et al*., 1967).

Table 17: Leaf trichome density and length in selected sunflower entries at different growth stages

A) Resistant entries

Entries	**Trichome density (No /0.64cm^2)**			**Trichome length (µm)**		
	45 DAS	**60 DAS**	**Mean**	**45 DAS**	**60 DAS**	**Mean**
RH-95-C-1	210.35	204.21	207.28	27.87	27.84	27.85
AHT 12	211.58	197.46	204.52	23.21	23.42	23.31
OPV 2	210.34	187.85	199.09	25.10	25.12	25.11
CMS 103B	183.64	163.13	173.38	20.12	20.14	20.13
KBSH 53	232.16	211.84	222.00	22.89	22.84	22.86
KBSH 72	184.42	163.43	173.92	21.12	21.16	21.14
OPV 3	197.56	181.30	189.43	20.16	20.14	20.15
NCP 198	235.30	211.74	223.52	24.13	24.14	24.13
KBSH 1	210.11	188.35	199.23	22.12	22.15	22.13
AHT 13	208.90	186.45	197.67	23.78	23.80	23.79
Mean	**208.43**	**189.57**		**23.05**	**23.07**	
SD±	**17.04**	**16.51**		**2.37**	**2.36**	
F	**0.95**	**NS**		**0.99**	**NS**	

B) Highly susceptible entries

Entries	**Trichome density (No /0.64cm^2)**			**Trichome length (µm)**		
	45 DAS	**60 DAS**	**Mean**	**45 DAS**	**60 DAS**	**Mean**
DRSF 108	146.22	132.11	139.17	17.68	17.70	17.69
RHA 284	154.84	143.21	149.03	27.31	27.34	27.32
EC 734840	194.26	164.32	179.29	25.62	25.64	25.63
EC 734844	175.24	169.79	172.52	24.34	24.37	24.35
NCP 22	129.70	119.85	124.78	18.81	18.79	18.80
NCP 28	107.34	93.41	100.38	19.36	19.38	19.37
KBSH 41	187.23	166.12	176.68	22.32	22.31	22.31
Morden	112.31	158.21	135.26	19.08	19.05	19.06
UASB 560	106.32	89.23	97.78	21.08	21.20	21.14
Mean	**145.94**	**137.36**		**21.73**	**21.75**	
SD±	**34.33**	**30.93**		**3.38**	**3.38**	
F	**0.77**	**NS**		**0.99**	**NS**	

DAS: Days after sowing

Table 18: Correlation between trichome density, incidence of leafhopper and hopper burn injury grade

Sl. No.	Category	Resistant entries		Highly susceptible entries	
		Leafhopper (No)	Hopper burn injury grade	Leafhopper (No)	Hopper burn injury grade
1	Leafhopper (No)	1.000	0.181	1.000	0.109
2	Hopper burn injury grade	0.181	1.000	0.109	1.000
3	Trichome density	0.271**	-0.032**	-0.412**	-0.184

** Significance at 1%

Table 19: Correlation between trichome length, incidence of leafhopper and hopper burn injury

Sl. No.	Category	Resistant entries		Highly susceptible entries	
		Leafhopper (No)	Hopper burn injury grade	Leafhopper (No)	Hopper burn injury grade
1	Leafhopper (No)	1.000	0.181	1.000	0.109
2	Hopper burn injury grade	0.181	1.000	0.109	1.000
3	Trichome length	-0.007	-0.236	-0.603**	0.216

** Significance at 1%

Table 20: Correlation between resistant and susceptible entries *w.r.t.* trichome density and trichome length

Sl. No.	Category	Trichome density		Trichome length	
		Resistant entries	Susceptible entries	Resistant entries	Susceptible entries
1	Resistant entries	1.000	-0.139	1.000	-0.250
2	Susceptible entries	-0.139	1.000	-0.250	1.000

The present findings are similar with those of Jayaraj and Sellammal, 1988; Jenkins, 1989 and Watson, 1989. In cotton, the insect resistance is associated with various morphological traits. There are certain morphological characteristics in cotton such as hairiness (glabrous v/s hairy), leaf shape (okra v/s normal) and the presence or absence of nectar-producing glands on leaves or flowers make the plants less attractive to pests, this can reduce their survival or growth. Hairiness is one of the important easily recognizable insect resistant trait in cotton. In numerous species there is a negative correlation between the trichome density and insect feeding, oviposition responses and the nutrition of larvae. Specialized hooked trichomes may impale adults or larvae as well. Hairiness has been reported to have resistance against the sucking insect pests of cotton. Similarly, Tidke and Sane (1962) established a correlation between hairiness of leaf and leafhopper population in cotton genotypes which was further confirmed by Ali *et al.* (1995b). The degree of leafhopper resistance has definite correlation with the pilosity of the plant. The more tufted types were less prone to leafhopper attack. On the relative importance of the characteristics of hairiness studied, length of hair seemed to be of prime importance, closely followed by density of hair on lamina whereas, hair on the midrib did not seem to play any role in resistance to pest. Length of hair, with higher hair density on the lamina was considered to be the best selection index in breeding resistance to leafhopper attack (Sikka *et al.*, 1966).

The present experimental results are similar with those of Sajjad *et al.* (2004) who evaluated eighteen cotton cultivars against *A. devastans*. The cultivars, CRIS-82 and MNH-536 were severely infested by *A. devastans*. The lowest seasonal infestation was recorded for CRIS-467 and CRIS-134. The cultivars with the greatest hair density were resistant to leafhopper, whereas the cultivars with the lowest hair density were susceptible to leafhopper. Hair length had no significant effect on the population of leafhopper.

4.2.9 Correlation between resistant and susceptible entries *w. r. t* trichome density and trichome length

The correlation between resistant and susceptible entries *w.r.t* trichome density and trichome length was negative and non significant (Table 20.)

4.3 Biochemical analysis of sunflower entries screened for leafhopper infestation

Leaves from the 19 entries having extreme reactions to leafhopper infestation were sampled (at 45 and 60 days after planting) and analyzed separately for different biochemical constituents like, total sugars, total proteins and total phenols by following the standard procedures. The results of these biochemical analyses are presented below.

4.3.1 Total Soluble protein (TSP) content in relation to the incidence of leafhopper

The results on total soluble protein content at 45 and 60 DAS are presented in (Table 21, Fig. 2)

At 45 Days After Sowing (DAS):

Total soluble protein content in the ten resistant genotypes ranged between 4.65 to 5.75 mg/g (mean = 5.08±0.32), whereas the total soluble protein content in the nine susceptible entries ranged between 4.82 to 5.50 mg/g (mean = 5.16±0.29).

At 60 DAS:

In the ten resistant genotypes, total soluble protein content ranged between 5.22 to 6.27 mg/g, (mean = 5.56±0.31), whereas the total soluble protein content in the nine susceptible entries ranged between 5.40 to 6.10 mg/g (mean = 5.70±0.24).

There was no significant difference between total soluble protein content at 45th and 60th DAS, in both resistant and susceptible entries (0.93) and (0.62).

Mean total soluble protein:

The pooled mean of the two observations (*i.e.,* 45 and 60DAS) indicated that the total soluble protein content was marginally higher in the resistant entries (mean =

5.70±0.24mg/100mg) when compared to the susceptible entries (mean = 5.32±0.28 mg/g).

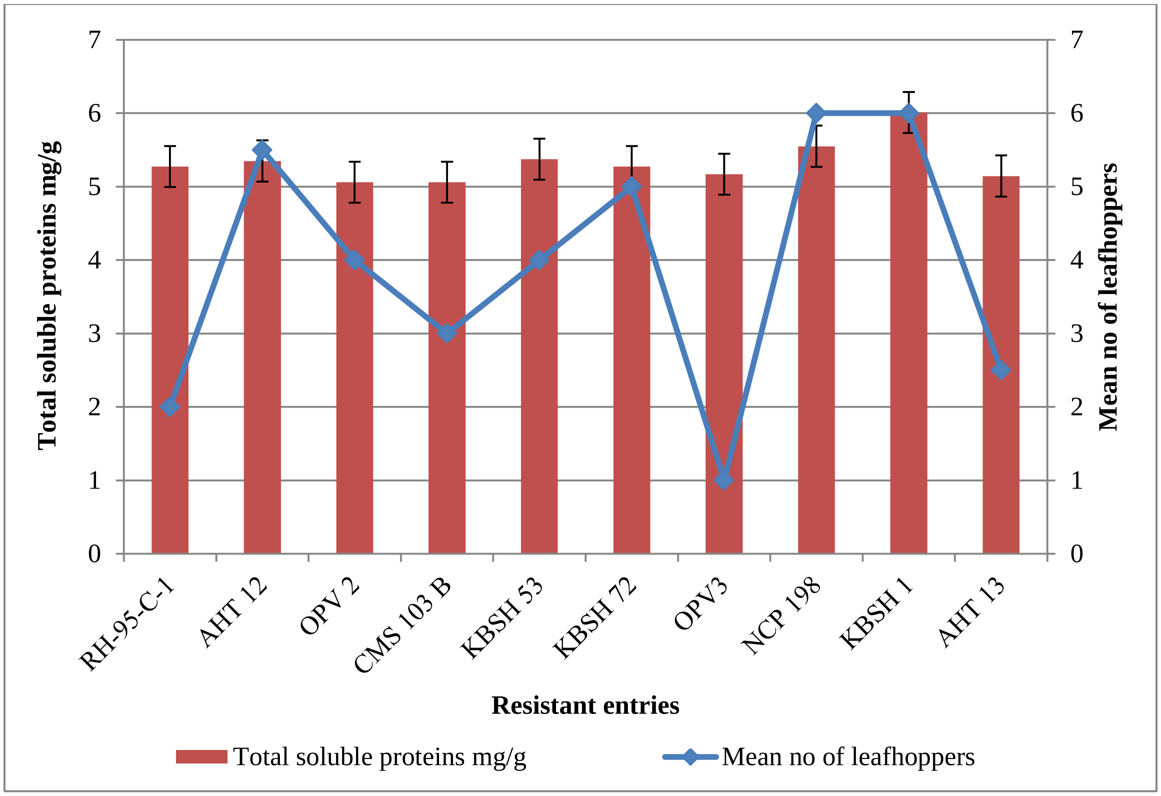
These results are in lined with (Chakravorthy and Sahni, 1972; Balasubramanian and Gopalan, 1981; Bhat *et al.*, 1981a; Thimmaiah *et al*., 1992). The cotton varieties susceptible to pests or diseases have been found to contain higher amount of protein. Higher content of soluble proteins in susceptible strains (22.53 mg) as compared to leafhopper resistant cotton strains (18mg/g fresh leaf) was reported by Bhat *et al*. (1981b). Presence of lower quantity of protein was related with resistance of rice varieties to BPH (Sujatha *et al*., 1987). A similar trend has been observed during the present investigations also.

The present findings can be compares with that of Uthamasamy (1980) who reported that different minerals showed various responses towards population fluctuations of the leafhopper. The present studies are not in conventionality with that of Singh (1988), who found that the effect of protein was less significant on the prevalence of *A. biguttula biguttula.* While Singh and Agarwal (1988) found that highly susceptible varieties contained considerably high amounts of protein as compared to resistant varieties. These results are conformed by Singh and Taneja (1989) who found the positive correlation between protein content of host plants and the oviposition of leafhopper.

Correlation between total soluble protein and incidence of leafhopper:

The perusal of the table 22 revealed that the total soluble protein was non significantly and positively correlated with the incidence of the leafhopper. However, at 45th (r = 0.499*), 60th DAS (r = 0.658*) and the pooled mean total soluble protein (r = 0.653*) was positively and significantly correlated with leafhopper incidence in resistant entries.

In susceptible entries, at 45th (r = -0.150), 60th DAS (r = -0.228) and the pooled mean, the total soluble protein (r = -0.199) was negatively and not significantly correlated with leafhopper incidence in resistant entries



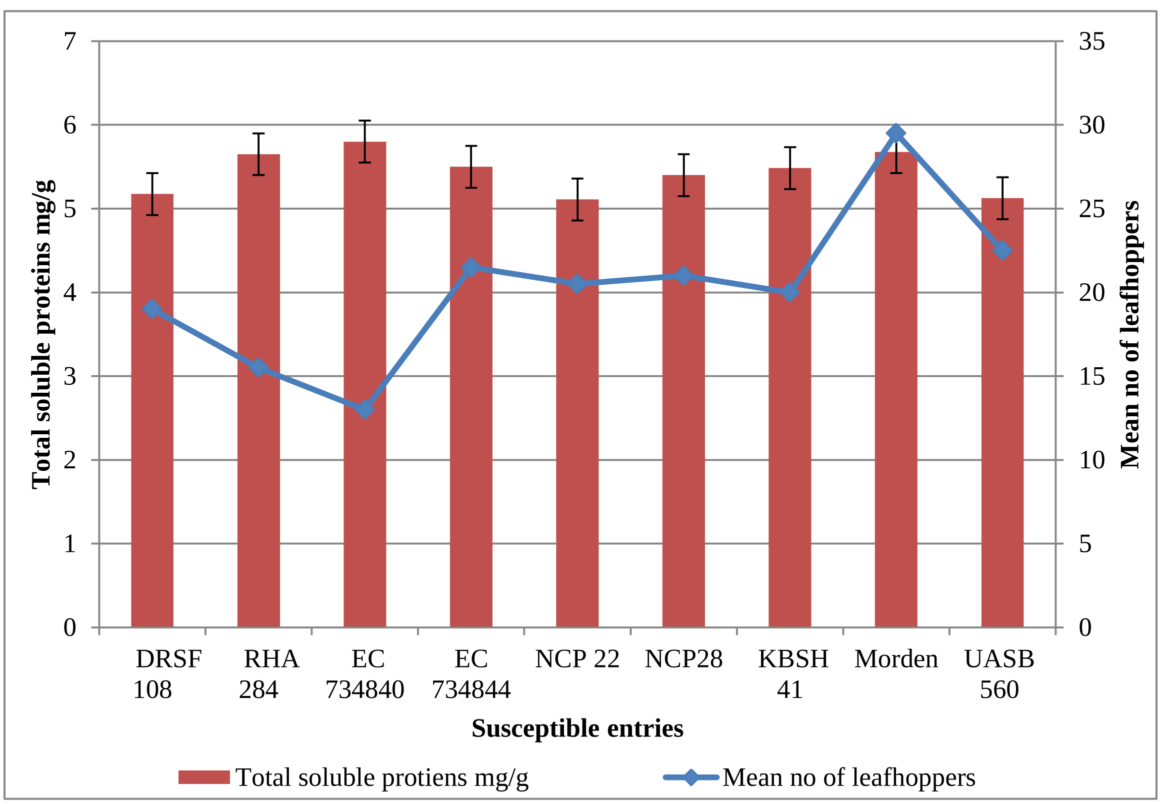


Fig. 2: Total soluble proteins in relation to the incidence of leafhopper

Table 21: Total soluble protein content (mg/g) in leaves of selected sunflower entries at different growth stages

Sl. No.	Resistant entries	Total soluble protein			Susceptible entries	Total soluble protein		
		45 DAS	60 DAS	Pooled mean		45 DAS	60 DAS	Pooled mean
1	RH-95-C-1	5.15	5.40	5.27	DRSF 108	4.95	5.40	5.17
2	AHT 12	5.25	5.45	5.35	RHA 284	5.40	5.90	5.65
3	OPV 2	4.65	5.47	5.06	EC 734840	5.50	6.10	5.80
4	CMS 103B	4.90	5.22	5.06	EC 734844	5.35	5.65	5.50
5	KBSH 53	5.25	5.50	5.37	NCP 22	4.82	5.40	5.11
6	KBSH 72	4.75	5.80	5.27	NCP 28	4.95	5.85	5.40
7	OPV 3	4.82	5.52	5.17	KBSH 41	5.35	5.62	5.48
8	NCP 198	5.30	5.80	5.55	Morden	5.45	5.90	5.67
9	KBSH 1	5.75	6.27	6.01	UASB 560	4.75	5.50	5.12
10	AHT 13	5.07	5.22	5.14				
	Mean	**5.08**	**5.56**	**5.32**		**5.16**	**5.70**	**5.43**
	SD±	**0.32**	**0.31**	**0.28**		**0.29**	**0.24**	**0.25**
	F	**0.93**	**NS**			**0.62**	**NS**	

DAS: Days after sowing

Table 22: Correlation between total soluble protein and incidence of leafhopper and hopper burn injury grade

Sl. No.	Category	Resistant entries		Highly susceptible entries	
		Leafhopper (No)	Hopper burn injury grade	Leafhopper (No)	Hopper burn injury grade
1	**Leafhopper (No)**	1.000	0.181	1.000	0.109
2	**Hopper burn injury grade**	0.181	1.000	0.109	1.000
3	**Protein at 45 DAS**	0.499*	-0.144	-0.150	0.634*
4	**Protein at 60 DAS**	0.658*	0.142	-0.228	0.741*
5	**Pooled mean**	0.653*	-0.004	-0.199	0.732*

* Significance at 5%

Correlation between total soluble protein and incidence of hopper burn injury grade:

In resistant entries, the correlation between total soluble protein and hopper burn injury grade (Table 22) was negatively correlated and non significant at 45th DAS (r = -0.144) and non significant and positively correlated at 60th DAS (r = 0.142). The correlation between hopper burn injury grade and total soluble protein was non significant and positive at 60 DAS. The pooled mean of the two observations at 45th and 60^{th} DAS showed that, the hopper burn injury grade was non significantly and negatively correlated with the total soluble protein (r = -0.004).

In susceptible entries, the correlation between total soluble protein and hopper burn injury grade (Table 22) was positively correlated and significant at 45th DAS (r = 0.634*) and 60th DAS (r = 0.741*) The pooled mean of the two observations at 45th and 60^{th} DAS showed that, the hopper burn injury grade was significant and positively correlated with the total soluble protein (r = 0.732*).

The above findings are almost in agreement with the results of Chakravorthy and Sahni (1972); Balasubramanian and Gopalan (1981) and Bhat *et al*, (1981) who opined that cotton varieties susceptible to pests or diseases contain higher amount of protein.

4.3.2 Total Soluble Sugar (TSS) content in relation to the incidence of leafhopper and hopper burn injury grade

The results pertaining to the estimation of TSS content at 45 and 60 DAS in the 19 entries are presented in Table 23, Fig. 3.

At 45 DAS:

TSS content in the ten resistant genotypes ranged between 5.00 to 7.10mg/g, (mean = 6.33±0.56), whereas the TSS content in the 10 susceptible entries ranged between 6.90 to 8.15 mg/g (mean = 7.57±0.45).

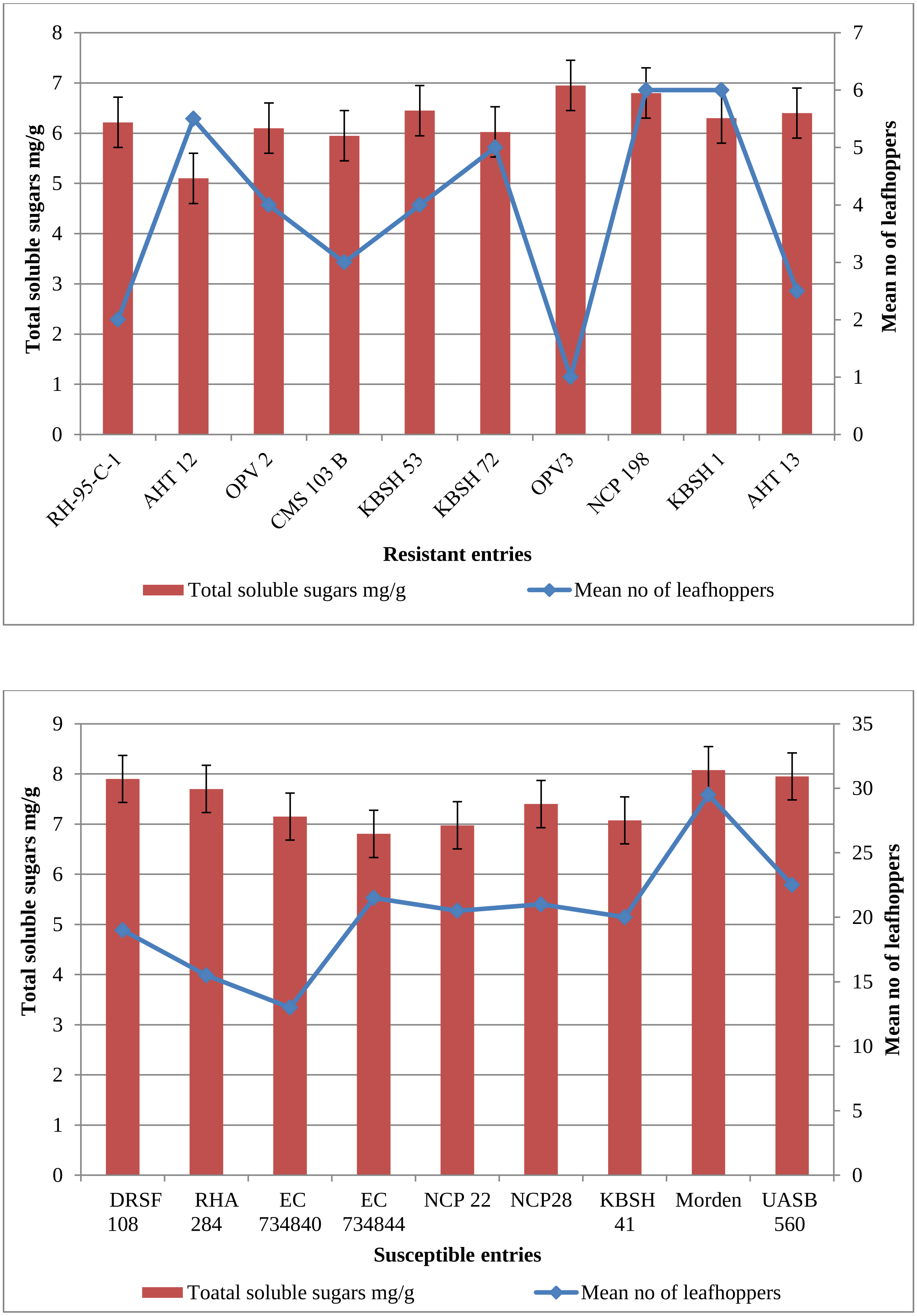


Fig. 3: Total soluble sugars in relation to the incidence of leafhopper

At 60 DAS:

In the ten resistant genotypes, TSS ranged between 5.20 to 6.80mg/g, (mean = 6.12±0.46), whereas the total soluble sugar content in the 9 susceptible entries ranged between 6.71 to 8.00 mg/g (mean = 7.32 ± 0.49). There was no significant difference between total soluble sugar content at 45^{th} and 60^{th} DAS in both resistant and susceptible entries (0.55) and (0.80), respectively.

Mean TSS:

The pooled mean of the two observations (*i.e.*, 45 and 60DAS) indicated that the TSS content was higher in the susceptible entries (mean = 7.44±0.49 mg/g) when compared to the resistant entries (mean = 6.22±0.50 mg/g).

In similar investigations, pest susceptible cotton genotypes had higher levels of sugars, whereas the resistant genotypes had comparatively lower levels of sugars (Thimmaiah, 1992; Chandrashekara, 1994). Similarly, leafhopper resistant cotton cultivars had lower content of reducing sugars as compared to the susceptible strains. (Singh *et al*., 1971; Mohan Kumar and Venugopal, 1999). Samal *et al*. (1982) and Dharma Reddy and Mishra (1995) reported less total soluble sugars in BPH resistant rice cultivars as compared to the susceptible ones. Balasubramanian and Gopalan (1981) found that susceptible genotype contain the minor amount of reducing sugars as compared to resistant genotype. Singh (1988) negatively correlated the *A. biguttula biguttula* incidence in leaves of resistant genotypes due to the total and non reducing sugars.

Correlation between total soluble sugar and incidence of leafhopper

The perusal of the (Table 24) revealed that at 45 DAS (r = -0.361), 60 DAS (r = -0.310) and the pooled mean of total soluble sugars (r = -0.340) was non significantly and negatively correlated with leafhopper incidence in the resistant entries.

Table 23: Total soluble sugar content (mg/g) in leaves of selected sunflower entries at different growth stages

Sl. No	Resistant entries	Total soluble sugar			Susceptible entries	Total soluble sugar		
		45 DAS	60 DAS	Pooled mean		45 DAS	60 DAS	Pooled mean
1	RH-95-C-1	6.32	6.11	6.21	DRSF 108	8.00	7.80	7.90
2	AHT 12	5.00	5.20	5.10	RHA 284	7.90	7.50	7.70
3	OPV 2	6.30	5.90	6.10	EC 734840	7.40	6.90	7.15
4	CMS 103B	6.10	5.80	5.95	EC 734844	6.90	6.71	6.80
5	KBSH 53	6.60	6.30	6.45	NCP 22	7.15	6.80	6.97
6	KBSH 72	6.15	5.90	6.02	NCP 28	7.50	7.30	7.40
7	OPV 3	7.10	6.80	6.95	KBSH 41	7.15	7.00	7.07
8	NCP 198	6.90	6.70	6.80	Morden	8.15	8.00	8.07
9	KBSH 1	6.40	6.20	6.30	UASB 560	8.00	7.90	7.95
10	AHT 13	6.50	6.30	6.40				
	Mean	**6.33**	**6.12**	**6.22**		**7.57**	**7.32**	**7.44**
	SD±	**0.56**	**0.46**	**0.50**		**0.45**	**0.49**	**0.47**
	F	**0.55**	**NS**			**0.80**	**NS**	

DAS: Days after sowing

Table 24: Correlation between total soluble sugars and incidence of leafhopper and hopper burn injury grade

Sl. No.	Category	Resistant entries		Highly susceptible entries	
		Leafhopper (No)	Hopper burn injury grade	Leafhopper (No)	Hopper burn injury grade
1	**Leafhopper (No)**	1.000	0.181	1.000	0.109
2	**Hopper burn injury grade**	0.181	1.000	0.109	1.000
3	**Sugars at 45th DAS**	-0.361	0.035	0.456*	0.159*
4	**Sugars at 60th DAS**	-0.310	-0.024	0.511*	0.006*
5	**Pooled mean**	-0.340	0.009	-0.304*	-0.228*

*Significance at 5%

In susceptible entries, both at 45 DAS (r = 0.456*) and 60th DAS (r = 0.511*), the total soluble sugars was significantly and positively correlated with the incidence of the leafhopper and the pooled mean of total soluble sugars (r = -304*) was negatively and significantly correlated with leafhopper incidence.

Correlation between total soluble sugars and hopper burn injury grade

In resistant entries, the correlation between total soluble sugar and hopper burn injury grade (Table 24) was positively correlated but it was non significant at 45th DAS (r = 0035), whereas 60th DAS (r = -0.024) the correlation between hopper burn injury and total soluble sugars was non significant and negative. The pooled mean of the two observations at 45th and 60th DAS showed that, the hopper burn injury was non significant and positively correlated with the total soluble sugars (r = -0.009).

In susceptible entries, the correlation between total soluble sugars and hopper burn injury (Table 24) was positively correlated and significant at 45th DAS (r = 0.159*) and 60th DAS (r = 0.006*). The pooled mean of the two observations at 45th and 60th DAS showed that, the hopper burn injury was significant and negatively correlated with the total soluble sugars (r = -0.228*).

Negative association of sugars with seed cotton yield indicated that higher sugar content makes the plant parts more palatable to insects (Mundas, 1992).Mustard aphid population showed significant positive correlation with sugar content, indicating that higher amounts of sugar was needed for better survival of the aphid, providing better nutritional condition for its growth and development and thus sugar content in plants was generally associated with susceptibility (Sachan and Sachan, 1991). These observations of earlier workers are in close agreement with the present findings.

4.3.3 Total phenol content in relation to the incidence of leafhopper and hopper burn injury

The results *w.r.t* the estimation on TSS content at 45 and 60 DAS are furnished in Table 25, Fig. 4.

At 45 DAS:

Total phenol content in the ten resistant genotypes ranged between 2.30 to 2.90 mg/g (mean = 2.57±0.18), whereas total phenol content in the nine susceptible entries ranged between 1.25 to1.80 mg/g (mean = 1.53±0.21).

At 60 DAS:

Total phenol content in the ten resistant genotypes ranged between 2.60 to 3.25 mg/g (mean = 2.86 ±0.26), whereas the total phenol content in the nine susceptible entries ranged between 1.40 to 2.20 mg/g (mean = 1.75 ±0.30). There was no significant difference between total soluble phenol content at 45th and 60th DAS in both resistant and susceptible entries (0.075) and (0.45).

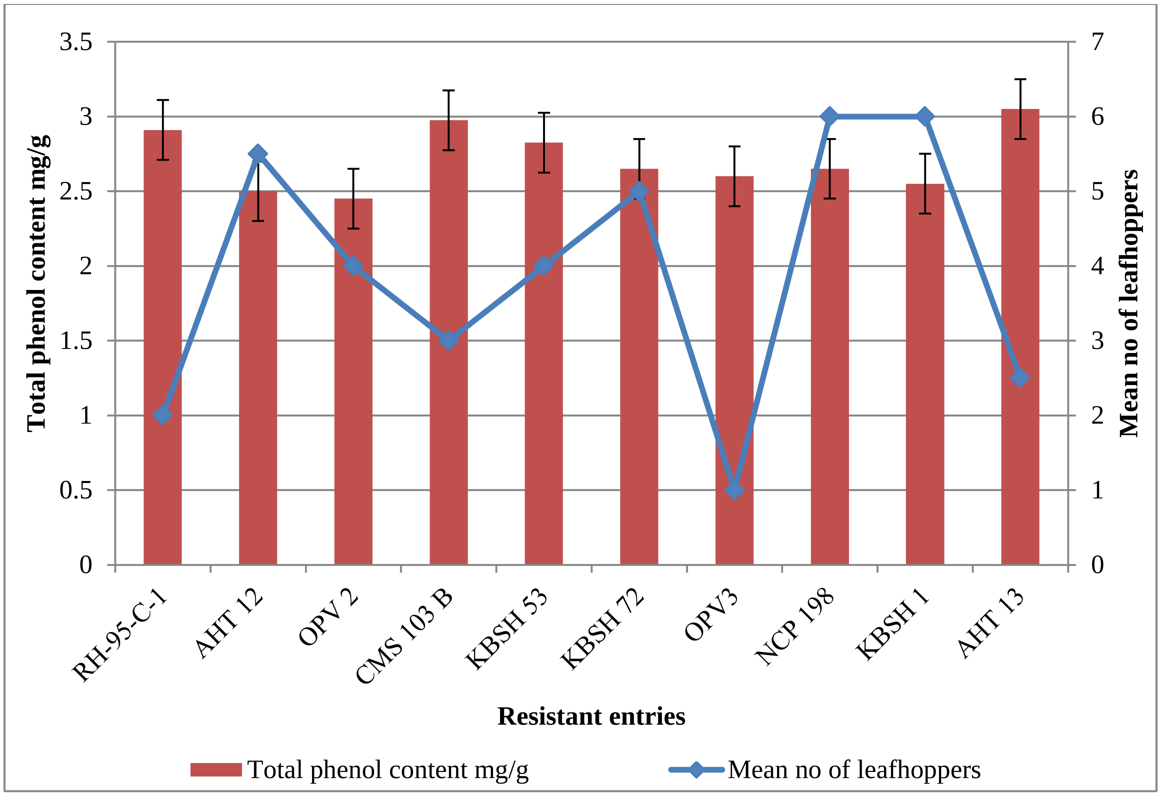
Mean total phenol content:

The pooled mean of the two observations recorded at 45th and 60th DAS indicated that the total phenol content was higher in the resistant entries (mean = 2.71±0.20) when compared to the susceptible entries (mean = 1.64±0.25).

Higher phenolic content is associated with lower damage by *Scirtothrips dorsalis* in chilli (Manoj, 1994). BPH resistant rice varieties had high content of phenols in comparison to the susceptible ones (Peraiah *et al*., 1982). Chhabra *et al*. (1993) reported higher content of total phenols in blackgram genotypes, showing resistance to whitefly and leafhoppers. Kotireddy (1971) reported that rice cultivars resistant to *Pyricularia oryzae* Cav. contained more total phenols than the susceptible variety. At Coimbatore, restorer lines RHA587 and RHA3376 were free from necrosis disease and both the entries *i.e.*, RHA587 (57.9, 140.2 and 228mg/100g) and RHA3376 (68.1, 120.1, 192.4 mg /100g) recorded high total phenol content at vegetative, flowering and maturity stages, respectively (Anon., 2007).

Correlation between total phenol content and incidence of the leafhopper

The study table 26 revealed that the total phenol was non significantly and negatively correlated at 45 DAS (r= -0.196), 60 DAS (r= -0.655) and the mean of the two



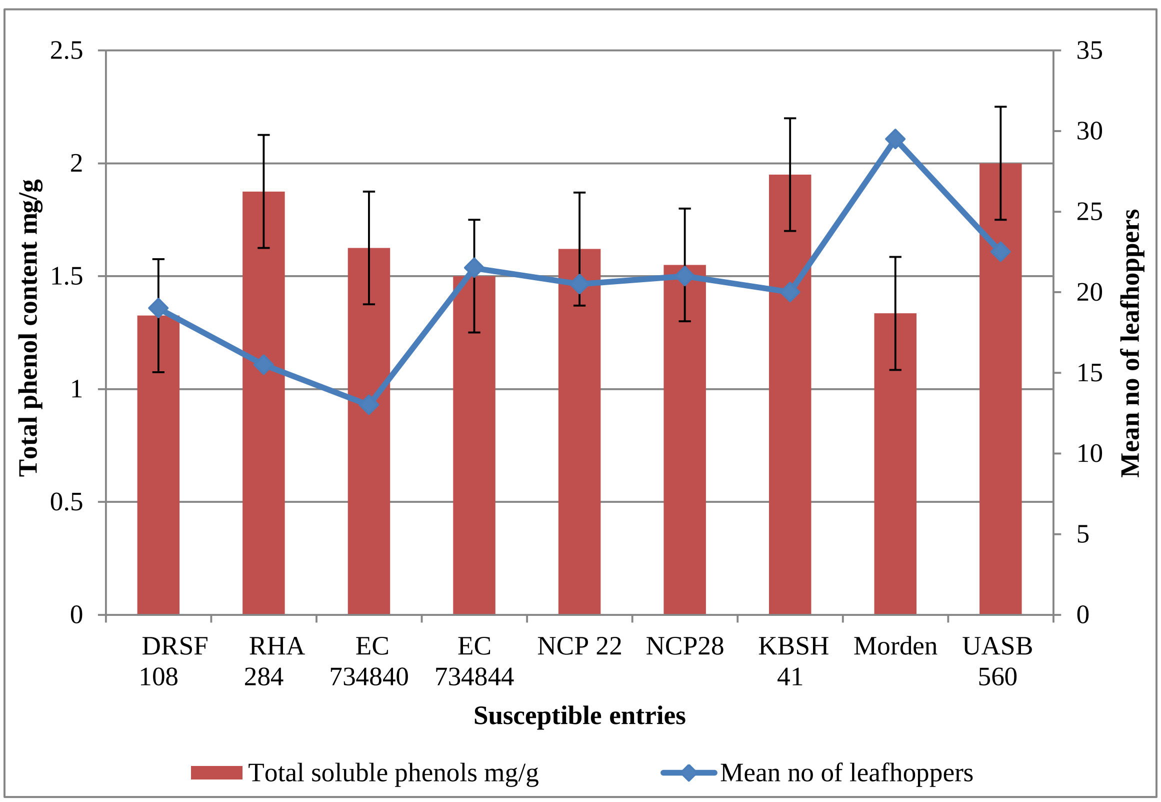


Fig. 4: Total phenol content in relation to the incidence of leafhopper

Table 25: Total phenol content (mg/g) in leaves of selected sunflower entries at different growth stages

Sl. No.	Resistant entries	Total soluble protein			Susceptible entries	Total soluble protein		
		45 DAS	60 DAS	Pooled mean		45 DAS	60 DAS	Pooled mean
1	RH-95-C-1	2.60	3.22	2.91	DRSF 108	1.25	1.40	1.32
2	AHT 12	2.40	2.60	2.50	RHA 284	1.65	2.10	1.87
3	OPV 2	2.30	2.60	2.45	EC 734840	1.55	1.70	1.62
4	CMS 103B	2.70	3.25	2.97	EC 734844	1.40	1.60	1.50
5	KBSH 53	2.80	2.85	2.82	NCP 22	1.70	1.54	1.62
6	KBSH 72	2.50	2.80	2.65	NCP 28	1.40	1.70	1.55
7	OPV 3	2.40	2.80	2.60	KBSH 41	1.80	2.10	1.95
8	NCP 198	2.60	2.70	2.65	Morden	1.25	1.42	1.33
9	KBSH 1	2.50	2.60	2.55	UASB 560	1.80	2.20	2.00
10	AHT 13	2.90	3.20	3.05				
	Mean	**2.57**	**2.86**	**2.71**		**1.53**	**1.75**	**1.64**
	SD±	**0.18**	**0.26**	**0.20**		**0.21**	**0.30**	**0.25**
	Fcal	**0.075**	**NS**			**0.45**	**NS**	

DAS: Days after sowing

Table 26: Correlation between total phenol content and incidence of leafhopper and hopper burn injury grade

Sl. No.	Category	Resistant entries		Highly susceptible entries	
		Leafhopper (No)	Hopper burn injury grade	Leafhopper (No)	Hopper burn injury grade
1	**Leafhopper (No)**	1.000	0.181	1.000	0.109
2	**Hopper burn injury grade**	0.181	1.000	0.109	1.000
3	**Phenols at 45th DAS**	-0.196	0.223*	-0.061	-0.151
4	**Phenols at 60th DAS**	-0.655	-0.941*	-0.155	-0.485*
5	**Pooled mean**	-0.503	0.054*	-0.655	-0.210*

*Significance at 5%

observations (r= - 0.503) in resistant entries. In susceptible entries, the total phenol was non significantly and negatively correlated at 45th (r= -0.061) at 60th (r= -0.155) and also *w.r.t* the pooled the mean of the two observations (r= - 0.655).

Correlation between total phenol content and hopper burn injury grade

In the ten resistant entries, correlation between total phenol and incidence of hopper burn injury grade (Table 26) revealed that it was significantly and positively correlated at 45th DAS (r = 0.223*). However, at the 60th DAS (r = -0.941*) the correlation between hopper burn injury grade and total phenol content was significant and negative. The pooled mean of the two observations recorded at 45th and 60th DAS showed that, hopper burn injury was significantly and positively correlated with total phenol content of the genotypes (r = 0.054*).

In nine susceptible entries correlation between total phenol and incidence of hopper burn injury grade (Table 26) revealed that, it was negatively correlated at 45th DAS, but, this relationship was non significant (0.151). However at the 60th DAS (r = -0.485*) the correlation between hopper burn injury grade and total phenol content was significant and negative. The pooled mean of the two observations recorded at 45th and 60th DAS showed that, hopper burn injury grade was significantly and negatively correlated with total phenol content of the genotypes (r = -0.210*).

The present findings are supported by the reports of earlier workers, *viz.,* Sachan and Sachan (1991) who found a significant negative correlation between the aphid population and phenol content of mustard cultivars indicating that higher amounts of phenol was responsible for low aphid population, while, Baruah and Dutta (1994) reported a negative association between the total phenolics and the incidence of *Riptortus lineasis* on greengram. Similarly, Malik *et al*. (1995) reported that the polyphenol content in linseed showed a negative correlation (r = - 0.87) with bud fly infestation.

The concentration of biochemical compounds in the leaf tissue, namely protein, sugars and phenolic compounds, also influence leafhopper infestation. Changes in the concentration of these constituents may exert marked influence on the physiology of the plant, which in turn influence further leafhopper infestation

Chemical constituents of leaves such as total sugars, non reducing sugars, tannins, silica and moisture content and pH were negatively correlated with leafhopper (*A. biguttula biguttula*) density in okra (Singh *et al.,* 1988). Lipid, total phosphorus, silica, iron and magnesium content of leaves was positively correlated whereas calcium, potash and non reducing sugars in leaves were negatively correlated with level of resistance to leafhopper, *A. biguttula biguttula* (Singh *et al*., 1972). Taking clue from these earlier works, it is possible that sunflower germplasm lines have differed substantially in chemical constituents of the leaf or morphological characteristics of leaves or both.

Correlation between resistant entries and susceptible entries *w.r.t.* total soluble protiens, total soluble sugars and total phenol content.

The correlation between resistant and susceptible entries *w.r.t.* total soluble protein, total soluble sugars and total phenol content was negative and non significant (Table 27).

Table 27: Correlation between resistant entries and susceptible entries *w. r. t.* total soluble protiens, total soluble sugars and total phenol content

Sl. No.	Category	Total soluble protien		Total soluble sugars		Total phenol content	
		Resistant entries	Susceptible entries	Resistant entries	Susceptible entries	Resistant entries	Susceptible entries
1	**Resistant entries**	1.000	-0.449	1.000	-0.026	1.000	-0.480
2	**Susceptible entries**	-0.449	1.000	-0.026	1.000	-0.480	1.000

V SUMMARY

Investigations on the host plant resistance to leafhopper, *Amarasca bigiuttula biguttula* Ishida. (Hemiptera : Cicadellidae) on sunflower (*Helianthus annuus* L.) with special reference to the determination of morphological and biochemical basis of resistance was carried out in the Departments of Agricultural Entomology, SS&A and AICRP (Sunflower), University Agricultural Sciences, Bengaluru during the period 2015-16 to 2016-17. The salient findings of these investigations are briefly summarized below.

In four cropping seasons (*kharif* 2015, *rabi* 2015, *kharif* 2016 *and rabi2*016), totally four hundred and eleven sunflower entries (including varieties / parental lines /hybrids/gremfour plasm lines) were screened for their reaction to leafhopper infestation.

The overall incidence of leafhopper per six leaves and hopper burn injury grade recorded in Sunflower entries was more during *rabi 20*16 followed by *rabi* 2015 seasons and it was very low during *kharif* 2015 and 2016. Therefore, data from the screening trials of *rabi* 2015 and *rabi* 2016 were considered and the entries showing extreme reaction (*i.e.,* resistant and highly susceptible) were taken forward for intensive screening under glass house conditions under high pest pressure.

Totally 19 entries (*i.e.*, 10 resistant and 9 highly susceptible) were shortlisted and subjected to artificial screening during *rabi 2017* to ascertain consistent reaction of these entries for leafhopper infestation.

The number of leafhopper nymphs and hopper burn injury grade per plant on 19 sunflower entries under glass house conditions at 45th DAS ranged from 0.00 (OPV 3) to 33 (Morden) and 0 to 2, respectively. At 60th DAS the number of leafhopper nymphs and hopper burn injury grade per plant ranged from 0.00 (RH- 95-C-1, OPV 2, CMS 103 B) to 26.0 (Morden) and 0 to 4 respectively, which confirmed the resistant reaction of the ten entries and highly susceptible nature of the nine entries.

The spatial distribution of the leafhopper studied on sunflower entries during two different phenological stages of the crop (45 and 75 DAS) revealed that the leafhopper confined maximum population to the middle portion of the plant canopy, followed by top portion during both growth stages in the level canopy of sunflower.

Artificial screening of the 19 shortlisted entries under high pest pressure revealed that, the 10 resistant entries (RH-95-C-1, AHT 12, OPV 2,CMS 103 B, KBSH 53, KBSH 72, OPV3, NCP 198, KBSH 1 and AHT 13) the number of leafhopper nymphs per plant and hopper burn injury grade ranged from 0.00 to 10.0 and 0 respectively at 45^{th} DAS. At 60^{th} DAS the number of leafhopper nymphs/plant and hopper burn injury grade per plant ranged from 0.00 to 4.0 and 0 to1respectively.

In contrast to this, the number of leafhopper nymphs/ per plant and hopper burn injury grade on nine highly susceptible entries (DRSF 108, RHA 284, EC 734840, EC 734844, NCP 22, NCP28, KBSH 41, Morden and UASB 560) at 45^{th} DAS ranged from 17.00 to 33.00 and 0 to 2, respectively. At 60^{th} DAS, the number of leafhopper nymphs per plant and hopper burn injury grade ranged from 9.00 to 26.00 and 3 to 4, respectively.

The 19 entries when subjected to morphological revealed that the petiole pigmentation (Green and Purple) and shape of the lamina tip (Pointed and Rounded tip) did not seem to have any bearing on the leafhopper infestation and hopper burn injury grade. However, majority of leafhopper resistant entries possessed coarse lamina, whereas, majority of the susceptible entries exhibited smooth lamina. Thus, leaf coarseness of the leafhopper resistant sunflower genotypes might have discouraged the leafhopper infestation and subsequent development of hopper burn symptoms.

Trichome density was higher in the 10 leafhopper resistant entries ($208.43 \pm 17.04/0.64 cm^2$) and ($189.57 \pm 16.51/0.64 cm^2$) at 45^{th} and 60^{th} DAS, respectively. When compared to the 9 susceptible entries at 45^{th} and 60^{th} DAS ($145.94 \pm 34.33/0.64 cm^2$) ($137.36 \pm 30.93/0.64 cm^2$) respectively, clearly indicating that the trichome density was greater in the resistant entries when compared to susceptible entries. Similarly, the trichome length was marginally greater in the 10 resistant entries at 45^{th} and 60^{th} DAS

(23.05± 2.37 µm) and (23.07± 2.36 µm) when compared to the 9 susceptible entries (21.73±3.38 µm) and (21.75±3.38 µm) at 45th DAS and 60th DAS respectively.

Trichome density was significantly positively correlated with the leafhopper population (r = 0.271**) and significantly negatively correlated with the hopper burn injury grade (r = -0.032**). However, the correlation between the leafhopper infestation with hopper burn injury grade was positive, but not significant (r = 0.181) in the resistant entries. Meanwhile, in susceptible entries, trichome density was significantly and negatively correlated with the leafhopper population (r = -0.412**) and non significant negative correlation existed between hopper burn injury (r = -0.184) trichome density. However, the correlation between the leafhopper infestation and hopper burn injury was positive, but not significant (r = 0.109).

Similarly, trichome length on the incidence of leafhopper and hopper burn injury in the 10 resistant entries revealed that the trichome length was non significant and negatively correlated with the incidence of both the leafhopper (r = -0.007) and hopper burn injury(r = -0.236) and hopper burn injury but this relationship was non significant (0.181). In the 9 susceptible entries, trichome length was significantly and negatively correlated with the leafhopper population (r = -0.063**). Whereas, hopper burn injury grade (r = 0.216) with trichome length However, the correlation was non significant and positively correlated between the leafhopper infestation with hopper burn injury grade was positive, but not significant (r = 0.109).

Thus, greater trichome density and length in the resistant sunflower genotypes might have inhibited the leafhopper infestation to a greater extent and indirectly contributed towards lower incidence of hopper burn injury.

Biochemical basis of resistance in the 19 entries showing two extreme reactions was analysed, the total soluble protein content in the 10 resistant genotypes was marginally lower at 45th DAS, (5.08±0.32) and 60th DAS (5.56±0.31), as compared to the nine susceptible entries at, 45DAS (5.16 ± 0.29) and 60DAS (5.70±0.24). The pooled mean of observations recorded at 45th and 60th DAS indicated that total soluble protein content was marginally higher in the susceptible entries (mean = 5.32±0.28 mg/100mg) when compared to the resistant entries (mean = 5.70±0.24mg/100mg). Thus, no clear relationship could be derived between the incidences of leafhopper, hopper burn injury grade *w.r.t* the total soluble protein content of the sunflower genotypes.

The total soluble protein was non significantly and positively correlated with the incidence of the leafhopper. However, at 45th (r = 0.499*), 60th DAS (r = 0.658*) and the pooled mean the total soluble protein (r = 0.653*) was positive to and significantly correlated with leafhopper incidence in resistant entries, In susceptible entries, at 45th (r = -0.150), 60th DAS (r = -0.228) and the pooled mean the total soluble protein content (r = -0.199) was negatively and not significantly correlated with leafhopper incidence in resistant entries

In resistant entries, the correlation between total soluble protein and hopper burn injury was negatively correlated and non significant at 45th DAS (r = -0.144) and 60th DAS (r = 0.142). The correlation between hopper burn injury grade and total soluble protien was non significant and positive. The pooled mean of the two observations at 45th and 60th DAS showed that, the hopper burn injury grade incidence was non significant and negatively correlated with the total soluble protein (r = -0.004). In susceptible entries, the correlation between total soluble protein and hopper burn injury positively correlated and significant at 45th DAS (r = 0.634*) and 60th DAS (r = 0.741*) The pooled mean of the two observations at 45th and 60th DAS showed that, the hopper burn injury was significant and positively correlated with the total soluble protein (r = 0.732*).

The total soluble sugar (TSS) content was relatively lower in the ten resistant genotypes both at 45 DAS (6.12 ± 0.46 mg/100 mg) and 60 DAS (6.12 ± 0.46 mg/100 mg) as compared to the nine susceptible genotypes at 45DAS (7.57± 0.49 mg/100 mg) and 60DAS (7.32 ± mg/ 100 mg). The pooled mean of the two observations (*i.e.*, 45 and 60DAS) indicated that the TSS content was higher in the susceptible entries (7.44±0.49mg/100mg) when compared to the resistant entries (6.22±0.50 mg/100mg).

The total soluble sugars were significantly and positively correlated with the incidence of the leafhopper. However in resistant entries, at 45th (r = -0.361), 60th DAS (r = -0.310) and the pooled mean total soluble sugars (r = -0.340) was not significantly and negatively correlated with leafhopper incidence. In susceptible entries, at 45th (r = 0.456*), 60th DAS (r = 0.511*), that the total soluble sugars was significantly and positively correlated with the incidence of the leafhopper and the pooled mean total soluble sugars (r = -304*) was negative and significantly correlated with leafhopper incidence.

In the resistant entries, the correlation between total soluble sugar and hopper burn injury was positively correlated and non significant at 45th DAS (r = 0.035) whereas 60th DAS (r = -0.024) the correlation between hopper burn injury and total soluble sugars was non significant and negative. The pooled mean of the two observations at 45th and 60th DAS showed that, the hopper burn injury was non significant and positively correlated with the total soluble sugars (r = -0.009). In susceptible entries, the correlation between total soluble sugars and hopper burn injury was positively correlated and significant at 45th DAS (r = 0.159*) and 60th DAS (r = 0.006*). The pooled mean of the two observations at 45th and 60th DAS showed that, the hopper burn injury was significant and negatively correlated with the total soluble sugars (r = -0.228*).

The total phenol content in the 10 resistant genotypes was higher at 45 DAS (2.570±0.18) and at 60 DAS (2.86±0.26), when compared with the total phenol content in the nine susceptible entries at 45DAS (1.53 ± 0.21) and 60DAS (1.75±0.30). The pooled mean of two observations recorded at 45th and 60th DAS indicated that the total phenol content was higher in the resistant entries (mean = 2.71±0.20) when compared to the susceptible entries (mean = 1.64±0.25).

The total phenol was negatively correlated at 45th (r= -0.196), 60th (r= -0.655) and in case of the mean of the two observations (r= - 0.503) in resistant entries. In susceptible entries, the total phenol was negatively correlated at 45th (r= -0.061) at 60th (r= -0.155) and in the case of the mean of the two observations (r= - 0.655).

In resistant entries, correlation between total phenol and incidence of hopper burn injury grade revealed that, it was positively correlated at 45^{th} DAS, but, this relationship was significant (r = 0.223*). However at the 60th DAS (r = -0.941*) the correlation between hopper burn injury grade and total phenol content was significant and negative. The pooled mean of the two observations recorded at 45^{th} and 60th DAS showed that, hopper burn injury was significantly and positively correlated with total phenol content of the genotypes (r = 0.054*). In susceptible entries correlation between total phenol and incidence of hopper burn injury revealed that, it was negatively correlated at 45^{th} DAS, but, this relationship was non significant (0.151). However at the 60th DAS (r = -0.485*) the correlation between hopper burn injury incidence and total phenol content was significant and negative. The pooled mean of the two observations recorded at 45^{th} and 60th DAS showed that, hopper burn injury was significantly and positively correlated with total phenol content of the genotypes (r = -0.210*).

The wide variation present in the sunflower genotypes can be exploited in the resistance breeding programmes in sunflower, particularly for leafhopper.

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Mysore J. Agric. Sci., 51 (2) : 271-275, 2017

Field Evaluation of Sunflower (*Helianthus annuus* L.) Genotypes for their Reaction to Green Leaf Hopper, *Amrasca biguttula biguttula* (Ishida) (Hemiptera : Cicadellidae) infestation

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Abstract

One hundred and sixty two sunflower (*Helianthus annuus* L.) accessions were screened under field conditions at the Main Research Station (MRS), Hebbal, Bengaluru, during *Rabi* season of 2015 for their reaction to leaf hopper, *Amrasca biguttula biguttula* Ishida infestation. The results revealed that, the ten accessions *viz*., RH-95-C-1, AHT 12, OPV 2, CMS 103 B, KBSH 53, KBSH 72, OPV3, NCP 198, KBSH 1 and AHT 13 showed resistance reaction, whereas, DRSF 108, RHA 284, EC 734840, EC 734844, NCP 22, NCP28, KBSH 41, Morden and UASB 560 were found to be highly susceptible. Among the remaining accessions, 101 accessions were moderately resistant and 43 accessions were in the susceptible category. The spatial distribution of the leafhopper studied on sunflower entries during two different phenological stages of the crop (45 and 75 DAS) revealed that the leafhopper confined maximum population to the middle portion of the plant canopy, followed by top portion during both growth stages in the level canopy of sunflower.

Keywords: *Amrasca biguttula biguttula, helianthus annuus,* field screening, resistance, canopy distribution

In Sunflower (*Helianthus annuus* L.) the work for the development ofinsect resistant cultivar / hybrid in particular reference to sucking pests, is still in its infancy. It is an elite oilseed crop of our country with high quality edible oil and wider adaptability and occupies an area of 7.21 lakh hectares with a production of 4.99 lakh tonnes and a productivity of 692 kg / ha. However, Karnataka occupies first position in India by accounting for an area of 3.84 lakh ha, a production of 1.93 lakh tonnes and productivity of 503 kg / ha (Anon., 2013). Although sunflower crop has the yield potential of 2.0 to 2.5 tonnes / ha under favourable conditions, its mean productivity levels are quiet low in India, mainly due to several biotic and abiotic stress factors. Among the bioticfactors, the attack of insect pests is the major limiting factor in its successful cultivation.

Of the 251 insect and acarine species that have been recorded on sunflower at the global level (Rajamohan, 1976), insect pests like Capitulum borer, *Helicoverpa armigera* (Hub.); Green semilooper, *Thysanoplusia orichalcea* (Fab.); Bihar hairy caterpillar, *Spilarctia obliqua* (Walker); tobacco caterpillar, *Spodoptera litura* (Fab.); cabbage semilooper, *Trichoplusia ni* (Hub.) and leaf hopper, *Amrasca biguttula biguttula* were considered to be of major economic importance in India (Basappa, 1995; Jagadish *et al*., 2004).

Leafhoppers, *A. biguttula biguttula* (Homoptera : Cicadellidae) are the important sucking pests of sunflower in India (Rana and Sheoran, 2004). Both nymphs and adults suck the plant sap and their severe infestation leads to curling of leaves and the characteristic "hopper burn" symptom. Crop loss due to insect pests in sunflower varies from region to region. As a result of severe outbreak of seedling pests, the plant stand of sunflower crop could be reduced by more than 30 per cent (Basappa and Bhat, 1998). The leaf hopper alone causes crop loss ranging from 18.5 to 46.3 per cent in Maharashtra (Anon., 1979).

Many insecticides are being used to control the pest complex of sunflower, which pose health and environmental hazards. Plant resistance is a potential alternate management strategy to reduce such pest damage, since it is eco-friendly, cost effective and can be integrated with cultural and biological control measures (Chirumamilla *et al*., 2010).

Since host plant resistance can be effectively exploited and utilized against sucking pests (Saritha *et al*., 2008), the present investigation was undertaken to screen sunflower germplasm for resistance against leaf hopper under field conditions.

Material and Methods

The study was conducted at Main Research Station, Hebbal, Bengaluru, Karnataka falls under the eastern dry Agro-climatic zones of Karnataka state during *Rabi* season 2015. The experiment was sown on Nov. 13, 2015 in unreplicated rows of 4 m length.

The experiment was initiated in order to determine the sources of resistance to leaf hopper population, of which 162 germplasm lines and experimental hybrids were screened under field conditions for their reaction to the leaf hopper. Observations on mean leaf hoppers per plant and hopper burn injury were recorded on 45th and 75th DAS. All agronomic practices were followed as per the Package of Practices, UAS, Bengaluru (Anon., 2015).

For recording leaf hopper population, five plants of each entry were randomly selected and labelled for recording observations both at 45 and 75 DAS. The observations were recorded on two upper leaves, two middle leaves and two bottom leaves of plant canopy and later it was expressed as mean number per plant (*i.e.*, mean no. / six leaves / plant). Both nymphs and adults were counted.

Hopper burn injury was recorded on the same five labelled plants in each entry following a 0 to 5 scale (Anon, 2013) and expressed as mean injury grade per plant.

Based on the leaf hopper injury grade, the accessions were categorised as detailed below. In that ten entries were categorised as resistant and nine entries were highly susceptible. Germplasm entries of sunflower were screened for evaluating their resistance potential against *A. biguttula biguttula* and the same set of entries were used for studying canopy distribution pattern of sunflower by counting the number of leaf hoppers at two top, two middle and two bottom leaves.

Leaf hopper injury grade	Resistance category*
0-1	R
2	MR
3	S
4-5	HS

Note: R: Resistant, MR: Moderately Resistant, S: Susceptible, HS: Highly susceptible

Results and Discussion

The results revealed that mean population of leaf hoppers ranged from 0.50 to 2.66 and 0.83 to 5.66 the infestation at 45 DAS and 75 DAS, respectively, across the different genotypes and hopper burn injury grade ranged from 0.00-1.80 and 0.40-4.60 at 45 DAS and 75 DAS, respectively.

Based on the observations ten accessions *viz.*, RH-95-C-1, AHT 12, OPV 2,CMS 103 B, KBSH 53, KBSH 72, OPV3, NCP 198, KBSH 1and AHT 13 had relatively lower leaf hopper population (< 1.0 hopper / plant) and hopper burn injury grade (0-1) than other accessions and were grouped as resistant, whereas, nine accessions *viz.*,DRSF 108, RHA 284, EC 734840, EC 734844, NCP 22, NCP28, KBSH 41, Morden and UASB 560 recorded the highest mean populations (>3 hoppers / plant) and hopper burn injury scale (>3 injury grade) and based on the mean injury grade these entries were rated as highly susceptible. Among the remaining accessions, 101 accessions were rated as moderately resistant and 43 accessions were rated as susceptible (Table I). Rana and Sheoran (2004) reported that the hopper population ranged from a minimum of 2 on HSFH 848 to a maximum of 4 per plant on KBSH 1. This result was contradictory with the present findings whereas, Bhat and Virupakshappa (1993) observed some hybrids such as KBSH 8 and KBSH 1 recorded the least damage. Morden recorded the highest leaf hopper population at both 45 and 75 DAS (2.66 and 5.66 per plant), respectively. Suganthy and Uma (2011) reported a maximum of 28 hoppers per plant in Morden and they consider Morden as susceptible check.

The present investigation has revealed that the genotypes RH-95-C-1, AHT 12, OPV 2,CMS 103 B,

TABLE 1

Categorization of sunflower genotypes for leafhopper resistance based on mean population of leafhoppers and hopper burn injury grade

Resistance category	Name of the genotypes
Resistant	RH-95-C-1, AHT 12, OPV 2,CMS 103 B, KBSH 53, KBSH 72, OPV3, NCP 198, KBSH 1, AHT 13 (10)
Moderately resistant	KBSH 44, S-207, RSFH 130, RHA 93, GKVK-2, M-17R, AHT 1, AHT 2, AHT 4, AHT 6, AHT8, AHT9, AHT 10, IHT 241, IHT 242, IHT 243, IHT 245, IHT 246, IHT 247, IHT 248, IHT 250, IHT 252, IHT 253, IHT 558, IHT 711, IHT 741, IHT 750, IHT 764, IHT 775, IHT 795, IHT 802, IHT 881, IHT 879, IHT 878, IHT 877, IHT 848, IHT 845, IHT 843, IHT 815, IHT 807, IHT 888, IHT 891, IHT 913, IHT 937, IHT 943, IHT 948, IHT 951, IHT 960, IHT 971, IHT 972, IHT 975, IHT 976, IHT 990, IHT 997, IHT 1061, IHT 1089, KBSH 71, KBSH 73, KBSH 75, KBSH 76, GMU 440, GMU 520, TCSH1, EC78484877, EC 734887, E17A,RHA 469, GMU 601, GMU 604, GMU 606, GMU 607, GMU 608, GMU 609, GMU 612, GMU 613, GMU 614, GMU 615, GMU 616, GMU 617, GMU 618, GMU 619, GMU 621, GMU 622, GMU 623, GMU 624, GMU 626, GMU 627, GMU 628, GMU 630, GMU 631, GMU 633, GMU 634, GMU 636, GMU 637, GMU 639, GMU 640, GMU 641, GMU 642, GMU 644 (101)
Susceptible	EC734846, RHA 378, X15WB, AHT 3, AHT 5, AHT 7, AHT 11, IHT 238, IHT 239, IHT 240, IHT 249, IHT 251, IHT 591, IHT 712, IHT 731, IHT 731, IHT 737, IHT748, IHT 752, IHT 753, IHT 754, IHT 837, IHT 821, IHT 936, IHT 952, IHT 956, IHT 980,IHT 981,IHT 995, KBSH 74, RHA 467, GMU602,GMU 603, GMU 605, GMU610, GMU 611, GMU 620, GMU 625, GMU 629, GMU 632, GMU 635, GMU 643, GMU 645 (43)
Highly susceptible	DRSF 108,RHA 284, EC 734840, EC 734844, NCP 22, NCP28, KBSH 41, Morden, UASB 560 (9)

KBSH 53, KBSH 72, OPV3, NCP 198, KBSH 1 and AHT 13 are resistant to *A. biguttula biguttula* by virtue of recording both relatively lower pest population and injury grade. Thus, the 19 entries (having extreme reactions to leaf hopper) (Table II) will be subjected to further tests both under field and artificial conditions, to confirm the resistance and susceptibility so that, it will help in further determination of morphological and biochemical basis for leaf hopper resistance in sunflower.

The results of the present investigation pertaining to the field screening were similar to the reports of Nagaraju *et al.* (2004), Anonymous (2006, 2007 and 2008) who screened several entries against leafhoppers, by the same methodology, however, their results cannot be compared with the present investigation as the entries / cultivars used by them differ and so also the seasonal variations.

Spatial distribution pattern of leafhopper in sunflower crop canopy

There was significant difference between the population of leafhopper within the crop canopy at both 45^{th} DAS (CD=0.071) and 75^{th} DAS (CD=0.42). During *rabi* 2015, leafhopper population (45^{th} DAS and 75^{th} DAS)was highest in the middle (3.58 / plant and 5.78 / plant), followed by top (2.95 / plant and 4.66 / plant) and least in the bottom (1.5 / plant and 2.11 / plant) at 45^{th} DAS and at 75^{th} DAS, respectively. However, there was no significant difference between top and middle crop canopy at 75 DAS (Table III). These finding however, do not agree with those of Jayaramaiah and Jagadish (1996) in case of *Myzus nicotianae* in tobacco probably due to differences in the host plant and pest species involved. Nevertheless, it indicates that middle level canopy is the most preferred site in sunflower for colonization by leafhopper.

TABLE II

Entries showing resistance and high susceptibility short listed for further studies.

A. Resistant entries

Entries	Mean no of leafhoppers / plant		Hopper burn injury grade	
	45 DAS	75 DAS	45 DAS	75 DAS
RH-95-C-1	0.50	0.83	0.20	1.00
AHT 12	0.66	0.83	0.00	0.80
OPV2	0.66	0.66	0.00	1.00
CMS 103 B	0.50	0.83	0.20	0.60
KBSH 53	0.66	0.83	1.00	0.60
KBSH 72	0.66	0.83	0.00	1.00
OPV3	0.66	0.83	0.40	0.40
NCP 198	0.66	1.33	0.00	1.00
KBSH 1	0.50	0.66	0.80	0.60
AHT 13	1.33	1.00	1.00	1.00
B. Highly susceptible entries				
DRSF 108	2.00	3.66	1.20	3.40
RHA 284	1.83	3.16	0.80	4.00
EC 734840	1.83	3.66	1.80	4.20
EC 734844	1.66	3.50	1.60	3.20
NCP 22	1.83	3.16	1.00	2.80
NCP28	2.16	3.50	0.60	3.00
KBSH 41	2.33	4.66	1.00	4.40
Morden	2.66	5.66	1.40	4.60
UASB 560	1.66	3.00	1.20	3.60

TABLE III

Spatial distribution pattern of leafhopper in sunflower crop canopy

	45 days			75 days		
	Bottom	Middle	Top	Bottom	Middle	Top
Mean leafhoppers per leaves	1.5 (1.08a)	3.58 (1.49c)	2.95 (1.37b)	2.11 (1.19a)	5.78 (1.81b)	4.66 (1.65 b)
±SD	1.31	1.48	1.52	1.63	2.48	1.89
SEM±		**0.032**			**0.15**	
CD at P=0.05		**0.071**			**0.42**	

The present findings are contradictory to those of Mahto (1990) who revealed that at lower canopy level of sunflower , leafhopper was significantly more in number than other two levels. He did not find significant difference in nymphal population between middle and upper leaves.

The overall incidence of leafhopper per six leaves and hopper burn injury grade recorded in sunflower during *rabi* 2015. Totally 19 entries (*i.e.,* resistant and 9 highly susceptible) were shortlisted and subjected to artificial screening to ascertain consistent reaction of these entries for leafhopper infestation. The spatial distribution of the leafhopper studied on sunflower entries during two different phenological stages of the crop (45 and 75 DAS) revealed that the leafhopper confined maximum population to the middle portion of the plant canopy, followed by top portion during both growth stages in the level canopy of sunflower.

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(*Received :* May, 2017 *Accepted :* June, 2017)

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P R Yadav <jexpzool@gmail.com> Fri, Jul 14, 2017 at 7:04 PM
To: Soumya Shettar <soumyashettar23@gmail.com>

Dear Madam,

I am pleased to inform you that your paper on Evaluation of Sunflower Genotypes for Resistance to Leafhopper (Amarsca biguttula biguttula Ishida.) and Its Distribution in Crop Canopy by Soumya Shettar, Jagadish, K. S., Srinivasa Reddy, K.M., Shadakshari, Y.G. and Subbarayappa, C. T has been accepted for publication in J Exp Zool India. Your paper will appear in Vol. 20, No.2, July 2017.

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Yours;

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On Mon, Jun 26, 2017 at 1:32 PM, Soumya Shettar
[Quoted text hidden]

EVALUATION OF SUNFLOWER GENOTYPES FOR RESISTANCE TO LEAFHOPPER (*AMARSCA BIGUTTULA BIGUTTULA* ISHIDA.) AND ITS DISTRIBUTION IN CROP CANOPY

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ABSTRACT

Host plant resistance is a potential alternate management strategy to reduce pest damage, since it is eco-friendly, cost effective and economic alternative to chemical control of leafhopper (*Amarsca biguttula biguttula* Ishida). Therefore twenty four varieties, one parental line, thirteen restorer lines, twenty germplasm entries and thirty one hybrids were sown on 6th november 2016 in unreplicated single rows of row length 4m each. Two leaves each at basal, middle and top level of canopy was examined at 75 days after sowing for leafhoppers number and hopper burn injury. Out of 104 entries screened, ten entries were recorded very less number of leafhopper and hopper burn injury in the range of 0.66-1.00 and 0.4 -1.0 respectively. While nine lines were highly susceptible with highest leafhopper load (3.50-5.66 per plant) and hopper burn injury (3.20-4.60 per plant). Distribution of leafhopper was maximum in the middle canopy (6.37±2.2 per plant) followed by that in the top canopy (5.16±1.82 per plant) and least in the bottom canopy (2.77±1.46 per plant) indicating that insecticidal sprays or release of biocontrol agents should be directed mainly towards middle and top level canopy for effective management of leafhopper. The results imply that, the 10 entries having very less leafhopper population and hopper burn injury proved as good source of leafhopper resistance.

Key words: sunflower, leafhopper, resistance

Introduction

In India, sunflower (*Helianthus annuus* L.) production is hindered due to susceptibility of crop to various biotic and abiotic stresses. Among the biotic stresses leafhopper (*Amrasca biguttula biguttula* Ishida: Cicadellidae: Hemiptera) poses a major challenge causing considerable reduction in the yield. The nymphs and adults suck the plant sap mainly from the lower surface of leaves and inject toxic saliva into the plant tissue at the time of feeding, resulting into phytotoxic symptoms known as "Hopper burn". As a result yellowing, browning, bronzing, cupping and withering, necrosis of leaves occur and ultimately, the leaves shed prematurely. Crop loss due to insect pests in sunflower varies from region to region. As a result of severe outbreak of seedling pests, the plant stand of sunflower crop could be reduced by more than 30 per cent (Basappa and Bhat, 1998). There are reports of leafhopper alone causing crop loss ranging from 18.5 to 46.3 per cent in Maharashtra (Anon., 1979).among various approaches to manage this pest, host plant resistance is reliable and economical. Efforts by plant breeders to develop varieties/ hybrids with inbuilt tolerance to leafhopper are constrained by narrow genetic base of cultivated sunflower. Therefore, it becomes imperative to screen the available germplasm for resistance to the leafhopper particularly in the context of integrated pest management.

Earlier workers have demonstrated that the germplasm entries- 771, 775,892, 1009,1035,1042, 1407,1134,702R, KBSH-8, BSH-1, S-55, EL-61039, 75268 M, 77195, 110737 and 35811 were promising against leafhopper; EC-93442was promising against white fly and EC-101287 and EC-68414 were promising against thrips, either by supporting comparatively lesser population or not expressing the cupping symptoms as compared to the susceptible ones as indicated by Bhat and Virupakshappa (1993).further entries 364, 1147, 16022, 1139, 90, 777, 1136, 1426, 38, 212, 226, 367, 702, 145, 776, 702, 9, 90, 26, 238, 342, 1089, 25, 342, J375, 2306, 1602, showed promise against leafhopper, entries- 364, 1139, 873, 1394, 91, 88, 179, 109, 216, 212, 366, 377-1 were promising against other pests as reported by Anonymous (2000).

Distribution pattern of sucking pests varies from crop to crop and it is pest specific, particularly in the tobacco aphid, *Myzus nicotianae* where aphid density was highest in the top, one third portion of tobacco canopy followed by middle one third and it was least in the bottom one-third of the plant as indicated by the work of Jayaramaiah and Jagadish (1996.)

With this background in mind germplasm entries of sunflower were screened for evaluating their resistance potential against *A. biguttula biguttula* and further its canopy distribution pattern studied in the same trail.

Material and Methods

One hundred four germplasm entries of sunflower were supplied by Indian institute if oilseed research, Hyderabad were sown on 6th November 2016, at ZARS, GKVK, University of Agricultural Sciences, Bengaluru in unreplicated single rows of row length 4m each (Table 1.)

The experiment was initiated in order to determine the sources of resistance to leaf hopper population, of which 104 germplasm entries were screened under field conditions for their reaction to the leaf hopper (Table 2). All the agronomic practices were followed as per the Package of Practices, UAS, Bengaluru (Anon., 2015).These two observations were recorded on 45 and 75 DAS.

Table 1. List of sunflower genotypes screened against leaf hopper.

Location	**ZARS, GKVK**
Season	***Rabi* 2016**
Entries	**104**
DAS	**06/11/2015**
Design	**Unreplicated single rows**
Row length	**4m**

Observations were recorded on the following two parameters to assess the reaction of the entries:

i. Population density counts

The leafhopper population (both nymphs and adults) were recorded in each entry. Five plants of each entry were randomly selected and labelled for recording observations both at 45 and 75 DAS. The observations were recorded on two upper leaves, two middle leaves and two bottom leaves of plant canopy and later it was expressed as mean number per plant (*i.e.*, mean no. / six leaves/ plant).

ii. Hopper burn injury grade:

The same five plants which were observed for leaf hopper population were again observed both at 45 and 75 DAS for recording leaf hopper injury grade, which was assessed in 0-5 scale as per the procedure given by Anon (2013) and later it was expressed as mean injury grade per plant

Rating scale adopted for recording leaf hopper injury grade as per Anon. 2013.

Rating scale	Characteristics
0	Free from leaf hopper injury
1	Slight yellowing on edges of leaves upto 30%
2	Yellowing and curling upto 40% of leaves
3	Yellowing and curling upto 60% of leaves
4	Yellowing , curling upto 80% of leaves or 50% edge browning
5	Maximum yellowing, ‘cupping and curling of leaves upto 100% or complete browning

Based on the mean number of leaf hoppers present per plant and leaf hopper injury grade, the screened accessions were categorized as detailed below:

Leaf hopper number / plant	Leaf hopper injury grade	Resistance category
0-1	0-1	R
1-2	2	MR
2-3	3	S
Above 3	4-5	HS

NB: R: Resistant, MR: Moderately Resistant, S: Susceptible, HS: Highly susceptible

Results and Discussion

The sunflower crop attains maturity during 75 DAS, in this context the data pertaining to number of leaf hoppers per plant and hopper burn injury grade at 75 DAS was considered for drawing conclusions. The results showed that the leafhopper number and hopper burn injury per plant was in the range of 0.00 to >3.00 and 0-5 (Table 2). Based on the observations, the 104 germplasm lines were categorized into four infestation ranges, namely, zero and 0-1 (resistant), 1 to 2 and 2 (moderately resistant), 2-3 and 3 (susceptible) and >3 and 4-5 (highly susceptible).

Based on the observations ten accessions *viz***.,** RH-95-C-1, AHT 12, OPV 2,CMS 103 B, KBSH 53, KBSH 72, OPV3, NCP 198, KBSH 1 and AHT 13 had relatively lower leaf hopper population (< 1.0 hopper/ plant) and hopper burn injury grade (0-1) than other accessions and were grouped as resistant , whereas, nine accessions *viz.*, DRSF 108, RHA 284, EC 734840, EC 734844, NCP 22, NCP28, KBSH 41, Morden and UASB 560 recorded the highest mean populations (> 3 hoppers/ plant) and hopper burn injury scale (>3 injury grade) and based on the mean injury grade these entries were rated as highly susceptible. Among the remaining accessions, 51 accessions were rated as moderately resistant and 34accessions were rated as susceptible (Table 3). Since, Rana and Sheoran (2004) reported that the leafhopper population ranged from a minimum of 2 on HSFH 848 to a maximum of 4 per plant on KBSH 1. This result was contradictory with the present findings whereas, Bhat and Virupakshappa (1993) observed some hybrids such as KBSH 8 and KBSH 1 recorded the least damage. Morden recorded the highest leafhopper population at both 45 and 75 DAS (2.66 and 5.66 per plant), respectively. Suganthy and Uma (2011) reported a maximum of 28 hoppers per plant in Morden and they consider Morden as susceptible check.

The distribution patter of leafhopper in crop canopy (Table 3.) showed maximum population in the middle level canopy (6.37/ plant) as compared to the top (5.16/ plant) and bottom level canopy (2.77/ plant). These finding though do not agree with those of Jayaramaiah and Jagadish (1996) probably due to differences in the host and pest species involved. Nevertheless, it indicates that middle level canopy is the most preferred site in sunflower for colonization by leafhopper, implying that any sort of leafhopper management operation either, biological or chemical, should be focused towards middle and top level canopy of sunflower crop.

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Table 2. Reaction of sunflower germplasm entries to leafhopper infestation

Leafhopper no per plant	Hopper burn injury per plant	Genotypic reaction to leafhopper	Germplasm entries
0-1	0-1	Resistant	RH-95-C-1, AHT 12, OPV 2,CMS 103 B, KBSH 53, KBSH 72, OPV3, NCP 198, KBSH 1, AHT 13 (10)
1-2	2	Moderately resistant	KBSH 71, GKVK-2, GKVK- 1 RHA 630, RHA 378, RHA 265, UASB 929, UASB934, UASB788, UASB 771, NCP 32, RHA 589, RHA 275, REC 443, RHA 272, RHA 272, RHA 265, LTRR-83-273, OPV-6, OPV-4, EC734877, KBSH 75, RSFH130, KBSH 74, RHA- M-17R, KBSH1, AHT 1,AHT 4, AHT 6, AHT8, AHT9, AHT 11, NCP 198, IHT 239, IHT 241, IHT 242, IHT 244, IHT 245, IHT 246, IHT 248, GMU 611, GMU 612, GMU 613, GMU 615, GMU 616, GMU 609, GMU 612, GMU 613, GMU 614, GMU 619, GMU 620
2-3	3	Susceptible	KBSH 44, RHA 275, EC734873, EC734874, RHA 589, RHA 857, UASB 933, UASB 932, UASB 790, RHA 857, REC 447, GPR 135, OPV 5, KBSH 73, KBSH 76, RHA 469, AHT 2, AHT 3, AHT 5, AHT 7, AHT 10, EC73846, IHT 238, IHT 240, IHT 243, IHT 247, IHT 249, GMU604,GMU 606, GMU610, GMU 614, GMU 617, GMU 618
Above 3	4-5	Highly susceptible	DRSF 108,RHA 284, EC 734840, EC 734844, NCP 22, NCP28, KBSH 41, Morden, UASB 560 (9)

Table 3. Spatial distribution pattern of leafhopper in sunflower canopy

Crop canopy			
	Top	**Middle**	**Bottom**
Mean leafhopper no per plant	5.16	6.37	2.77
± SD	1.82	2.22	1.46