

**EVALUATION OF OKRA GERMPLASM FOR RESISTANCE
TO JASSID, *Amrasca biguttula biguttula* (Ishida)**

Thesis

**Submitted to the Punjab Agricultural University
in partial fulfillment of the requirements
for the degree of**

**MASTER OF SCIENCE
in
ENTOMOLOGY
(Minor Subject: Plant Pathology)**

By

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(L-2014-A-45-M)**

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CERTIFICATE I

This is to certify that the thesis entitled, “**Evaluation of okra germplasm for resistance against jassid, *Amrasca biguttula biguttula* (Ishida)**” submitted for the degree of **Master of Science** in the subject of **Entomology (Minor Subject: Plant Pathology)** of the Punjab Agricultural University, Ludhiana, is a bonafide research work carried out by **Ramandeep Kaur Sandhi (L-2014-A-45-M)** under my supervision and that no part of this thesis has been submitted for any other degree.

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

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CERTIFICATE II

This is to certify that the thesis entitled, “**Evaluation of okra germplasm for resistance against jassid, *Amrasca biguttula biguttula* (Ishida)**” submitted by **Ramandeep Kaur Sandhi (L-2014-A-45-M)** to the Punjab Agricultural University, Ludhiana, in partial fulfillment of the requirements for the degree of **Master of Science** in the subject of **Entomology (Minor Subject: Plant Pathology)** has been approved by the student’s Advisory committee after an oral examination on the same in collaboration with an External Examiner.

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ABSTRACT

Studies on “Evaluation of okra germplasm for resistance to jassid, *Amrasca biguttula biguttula* (Ishida)” were carried out during *Kharif* 2015 at Vegetable Research Farm, Department of Vegetable Science, PAU, Ludhiana. Fifteen germplasm entries *viz.* accessions: IC0506027, IC0506118 and EC0306728; *Abelmoschus* spp.: *A. tuberculatus*, *A. moschatus*, *A. angulosus*, *A. tetraphyllus*, *A. manihot* and *A. caillei*; genotypes: POL-6 and POL-7; and four cultivated varieties: Punjab 8, Punjab Padmini, Punjab 7 and Pusa Sawani were screened against jassid in field and various morphological and biochemical parameters of leaves were studied. The correlation between jassid nymphal population and mid vein hair density, angle of insertion of hair, total phenols and tannins was negative and significant ($r = -0.67, -0.55, -0.83, -0.75$, respectively); negative and non-significant for hair length, total sugars and silica ($r = -0.48, -0.63$ and -0.59 , respectively) and positive and significant for lacination index, reducing sugars and lignins ($r = 0.77, 0.95$ and 0.90 , respectively). *Abelmoschus* spp. *A. tetraphyllus*, *A. angulosus* and *A. moschatus* were found to be field resistant on the basis of significantly lower nymphal jassid population (1.56-1.99), jassid injury index (1.16-1.27) and susceptibility index (2.70-2.92). High degree of resistance in these entries was found to be associated with high hair density (4.75-7.05), longer hair (1285.00-1513.20 μm), more erect hair (83.40-95.20°), broad leaves, high total sugars (15.21-18.36 mg/g), total phenols (1.52-1.58 mg/g), tannins (26.12-31.48 mg/g) and silica (32.66-33.17 mg/g) and low levels of reducing sugars (2.50-3.39 mg/g). While, *A. manihot*, *A. tuberculatus*, IC0506027 and EC0306728 were found moderately field resistant with variable levels of morphological and biochemical parameters. High hair density, broad leaves, moderate levels of total sugars, reducing sugars, total phenols, tannins and silica seems to be associated with moderate levels of resistance in these entries. The variable levels of above mentioned parameters in moderately resistant entries also indicated that a single factor is not responsible for resistance but combination of different factors may be conferring resistance to jassid.

Keywords: *Amrasca biguttula biguttula*, biochemical parameters, morphological parameters, okra and Scanning Electron Microscopy (SEM)

Signature of Major Advisor

Signature of Student

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ਸਾਰ-ਅੰਸ਼

ਪੀ.ਏ.ਯੂ., ਲੁਧਿਆਣਾ ਦੇ ਸਬਜ਼ੀ ਵਿਗਿਆਨ ਵਿਭਾਗ ਵਿੱਚ ਸਬਜ਼ੀ ਖੋਜ ਫਾਰਮ ਤੇ ਸਾਲ 2015 ਦੇ ਸਾਉਣੀ ਦੌਰਾਨ “ਭਿੰਡੀ ਦੇ ਜਰਮਪਲਾਜ਼ਮ ਦਾ ਹਰੇ ਤੇਲੇ, *ਅਮਰਾਸਕਾ ਬਿਗੂਟਲਾ ਬਿਗੂਟਲਾ* (ਇਸ਼ੀਡਾ) ਵਿਰੁੱਧ ਮੁਲਾਂਕਣ” ਸੰਬੰਧੀ ਖੋਜ ਤਜਰਬਾ ਕੀਤਾ ਗਿਆ। ਪੰਦਰਾਂ ਜਰਮਪਲਾਜ਼ਮ ਕਿਸਮਾਂ ਜੋ ਕਿ ਅਕਸੈਸ਼ਨਜ਼: IC0506027, IC0506118 ਅਤੇ EC0306728; ਅਬੈਲਮੋਸਕਸ ਕਿਸਮਾਂ: ਅਬੈਲਮੋਸਕਸ ਟਿਊਬਰਕਿਊਲੇਟਸ, ਅਬੈਲਮੋਸਕਸ ਮੌਸਚੈਟਸ, ਅਬੈਲਮੋਸਕਸ ਐਂਗੁਲੋਸਿਸ, ਅਬੈਲਮੋਸਕਸ ਟੈਟਰਾਫਾਇਲਸ, ਅਬੈਲਮੋਸਕਸ ਮੈਨੀਹਾਟ ਅਤੇ ਅਬੈਲਮੋਸਕਸ ਕੈਲੀ; ਜੀਨੋਟਾਈਪਸ: POL-6 ਅਤੇ POL-7; ਅਤੇ ਚਾਰ ਖੇਤੀ ਯੋਗ ਕਿਸਮਾਂ: ਪੰਜਾਬ-8, ਪੰਜਾਬ ਪਦਮਨੀ, ਪੰਜਾਬ-7 ਅਤੇ ਪੂਜਾ ਸਾਵਨੀ ਦਾ ਖੇਤ ਵਿੱਚ ਮੁਲਾਂਕਣ ਕੀਤਾ ਗਿਆ ਅਤੇ ਪੱਤਿਆਂ ਦੇ ਵੱਖ-ਵੱਖ ਮਾਰਫੋਲੋਜੀਕਲ ਅਤੇ ਬਾਇਓਕੈਮੀਕਲ ਮਾਪਦੰਡਾਂ ਬਾਰੇ ਵੀ ਖੋਜ ਕੀਤੀ ਗਈ। ਹਰੇ ਤੇਲੇ ਦੇ ਨਿੰਫ ਦੀ ਸੰਖਿਆ ਦਾ ਸਬੰਧ ਪੱਤੇ ਦੀ ਵਿਚਕਾਰਲੀ ਨਾੜੂ ਉੱਤੇ ਵਾਲਾਂ ਦੀ ਘਣਤਾ, ਵਾਲਾਂ ਦੇ ਕੋਣ, ਕੁੱਲ ਫੀਨੋਲ ਅਤੇ ਟੈਨਿਨਜ਼ ਨਾਲ ਨਾਕਾਰਾਤਮਕ ਅਤੇ ਅਰਥਪੂਰਨ ($r = -0.67, -0.55, -0.83, -0.75$, ਕ੍ਰਮਵਾਰ); ਵਾਲਾਂ ਦੀ ਲੰਬਾਈ, ਕੁੱਲ ਸੂਗਰਜ਼ ਅਤੇ ਸਿਲੀਕਾ ਨਾਲ ਨਾਕਾਰਾਤਮਕ ਅਤੇ ਅਰਥ ਹੀਣ ($r = -0.48, -0.63$ ਅਤੇ -0.59 , ਕ੍ਰਮਵਾਰ ਅਤੇ ਲੈਸੀਨੇਸ਼ਨ ਇੰਡੈਕਸ, ਰਿਡਯੂਸਿੰਗ ਸੂਗਰਜ਼ ਅਤੇ ਲਿਗਨਿਨਜ਼ ਨਾਲ ਸਾਕਾਰਾਤਮਕ ਅਤੇ ਅਰਥਪੂਰਨ ($r = 0.77, 0.95$ ਅਤੇ 0.90 , ਕ੍ਰਮਵਾਰ) ਪਾਇਆ ਗਿਆ। ਹਰੇ ਤੇਲੇ ਦੀ ਨਿੰਫ ਦੀ ਘੱਟ ਸੰਖਿਆ (1.56-1.99), ਹਰੇ ਤੇਲੇ ਦੇ ਘੱਟ ਨੁਕਸਾਨ ਇੰਡੈਕਸ (1.16-1.27) ਅਤੇ ਸੰਵੇਦਨਸ਼ੀਲਤਾ ਇੰਡੈਕਸ (2.70-2.92) ਦੇ ਆਧਾਰ ਤੇ ਅਬੈਲਮੋਸਕਸ ਕਿਸਮਾਂ: ਅਬੈਲਮੋਸਕਸ ਟੈਟਰਾਫਾਇਲਸ, ਅਬੈਲਮੋਸਕਸ ਐਂਗੁਲੋਸਿਸ ਅਤੇ ਅਬੈਲਮੋਸਕਸ ਮੌਸਚੈਟਸ ਵਿੱਚ ਖੇਤ ਪੱਧਰ ਦੀ ਪ੍ਰਤੀਰੋਧਕਤਾ ਪਾਈ ਗਈ। ਇਹਨਾਂ ਕਿਸਮਾਂ ਵਿੱਚ ਉੱਚ ਪੱਧਰ ਦੀ ਪ੍ਰਤੀਰੋਧਕਤਾ ਦਾ ਸਬੰਧ ਵਾਲਾਂ ਦੀ ਜ਼ਿਆਦਾ ਘਣਤਾ (4.75-7.05) ਲੰਬੇ ਵਾਲ (1285.00-1513.20 μ m), ਜ਼ਿਆਦਾ ਖੜੇ ਵਾਲ (83.40-95.20 $^\circ$), ਚੌੜੇ ਪੱਤੇ, ਵਧੇਰੇ ਕੁੱਲ ਸੂਗਰ (15.21-18.36 ਮਿ.ਗ੍ਰਾ. ਪ੍ਰਤੀ ਗ੍ਰਾ.), ਕੁੱਲ ਫੀਨੋਲ (1.52-1.58 ਮਿ.ਗ੍ਰਾ. ਪ੍ਰਤੀ ਗ੍ਰਾ.), ਟੈਨਿਨਜ਼ (26.12-31.48 ਮਿ.ਗ੍ਰਾ. ਪ੍ਰਤੀ ਗ੍ਰਾ.) ਅਤੇ ਸਿਲੀਕਾ (32.66-33.17 ਮਿ.ਗ੍ਰਾ. ਪ੍ਰਤੀ ਗ੍ਰਾ.); ਅਤੇ ਘੱਟ ਰਿਡਯੂਸਿੰਗ ਸੂਗਰਜ਼ (2.50-3.39 ਮਿ.ਗ੍ਰਾ. ਪ੍ਰਤੀ ਗ੍ਰਾ.) ਨਾਲ ਪਾਇਆ ਗਿਆ। ਜਦੋਂਕਿ, ਅਬੈਲਮੋਸਕਸ ਮੈਨੀਹਾਟ, ਅਬੈਲਮੋਸਕਸ ਟਿਊਬਰਕਿਊਲੇਟਸ, IC0506027 ਅਤੇ EC0306728 ਵਿੱਚ ਵੱਖ-ਵੱਖ ਦਰਜੇ ਦੇ ਮਾਰਫੋਲੋਜੀਕਲ ਅਤੇ ਬਾਇਓਕੈਮੀਕਲ ਮਾਪਦੰਡਾਂ ਕਰਕੇ ਖੇਤ ਪੱਧਰ ਤੇ ਦਰਮਿਆਨੇ ਦਰਜੇ ਦੀ ਪ੍ਰਤੀਰੋਧਕਤਾ ਪਾਈ ਗਈ। ਇਹਨਾਂ ਕਿਸਮਾਂ ਵਿੱਚ ਵਾਲਾਂ ਦੀ ਜ਼ਿਆਦਾ ਘਣਤਾ, ਚੌੜੇ ਪੱਤੇ, ਦਰਮਿਆਨੇ ਪੱਧਰ ਦੀਆਂ ਕੁੱਲ ਸੂਗਰਜ਼ ਰਿਡਯੂਸਿੰਗ ਸੂਗਰ, ਕੁੱਲ ਫੀਨੋਲਜ਼, ਟੈਨਿਨਜ਼ ਅਤੇ ਸਿਲੀਕਾ ਦਾ ਦਰਮਿਆਨੇ ਪੱਧਰ ਦੀ ਪ੍ਰਤੀਰੋਧਕਤਾ ਨਾਲ ਸੰਬੰਧ ਹੋ ਸਕਦਾ ਹੈ। ਦਰਮਿਆਨੇ ਪੱਧਰ ਦੀਆਂ ਵੱਖੇ ਵੱਖ ਪ੍ਰਤੀਰੋਧਕ ਕਿਸਮਾਂ ਵਿੱਚ ਉੱਪਰ ਦਿੱਤੇ ਹੋਏ ਮਾਪਦੰਡਾਂ ਦੇ ਦਰਜੇ ਇਹ ਦਰਸਾਉਂਦੇ ਹਨ ਕਿ ਪ੍ਰਤੀਰੋਧਕਤਾ ਲਈ ਕੋਈ ਇੱਕ ਕਾਰਨ ਜਿੰਮੇਵਾਰ ਨਹੀਂ ਹੋ ਸਕਦਾ ਜਦਕਿ ਵੱਖੇ-ਵੱਖਰੇ ਕਾਰਨਾਂ ਦਾ ਸੁਮੇਲ ਹਰੇ ਤੇਲੇ ਵਿਰੁੱਧ ਪ੍ਰਤੀਰੋਧਕਤਾ ਪ੍ਰਦਾਨ ਕਰਦਾ ਹੈ।

ਮੁੱਖ ਸ਼ਬਦ: ਅਮਰਾਸਕਾ ਬਿਗੂਟਲਾ ਬਿਗੂਟਲਾ, ਬਾਇਓਕੈਮੀਕਲ ਮਾਪਦੰਡ, ਭਿੰਡੀ, ਮਾਰਫੋਲੋਜੀਕਲ ਮਾਪਦੰਡ ਅਤੇ ਸਕੈਨਿੰਗ ਇਲੈਕਟਰੋਨ ਮਾਈਕ੍ਰੋਸਕੋਪੀ (SEM)

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CHAPTER I

INTRODUCTION

Okra, *Abelmoschus esculentus* (L.) Moench (Family, Malvaceae) is one of the popular and commercially cultivated vegetables of the tropical countries and is popularly known as 'Bhendi' or 'Ladies finger' (Singh *et al* 2014). It is grown as a summer and fall crop and is widely cultivated from tropics to sub tropics (Kochar 1986). It is cultivated to produce edible seed pods that are differentially used in particular regions of the world. The leaves are rich in crude protein, fibre, ash, fats and total nitrogen. The basal portions of fruits are rich in carbohydrates and fibers (Adelusi *et al* 2006). Due to its high iodine contents, the okra fruit is considered to be useful for the control of goiter. The fiber obtained from okra stem is used in paper industry (Martin 1982). The ripe seed of okra are sometimes roasted and ground as a coffee substitute, while the seed-powder has been used as substitute for the aluminum salts for water purification (Vaidya and Nanoti 1989). It has a long term potential for oil and meal production (Mays *et al* 1990). It is also used in curing ulcers, hemorrhoids, genito-urinary disorders and chronic dysentery (Singh *et al* 2014).

The total world area under cultivation of okra was 1.10 million ha with production of 8.69 million tonne and productivity of 7.90 tonne per ha. It is mainly grown in India, Nigeria, Sudan, Pakistan, Ghana, Egypt, Benin, Saudi Arabia, Mexico and Cameroon. India is the largest producer of okra followed by Nigeria. The total area under okra in India was 507 thousand ha with production of 5853 thousand tonne and productivity of 11.5 tonne per ha. In India, West Bengal is the leading okra producing state which has production of around 882.39 thousand tonne under 75.45 thousand ha with productivity of 11.70 tonne per ha followed by Andhra Pradesh (Anonymous 2015a). In Punjab, okra was grown under 3.20 thousand ha area with average yield of 10409 kg/ha and production of 33.35 thousand tonne (Anonymous 2015b)

The production of okra is hampered due to the attack of several insect pests but jassid, *Amrasca biguttula biguttula* (Ishida) (Homoptera: Cicadellidae) is one of the major insect pests on this crop which limits its cultivation significantly (Kakar and Dobra 1988, Singh *et al* 1993, Dubey *et al* 1999, Dhandapani *et al* 2003, Singh and Joshi 2004). This pest is more serious in the tropics and subtropics because of the favorable environmental conditions for its growth and development the year round.

Okra is the most suitable host for the survival and feeding of jassid nymphs (Hussain *et al* 1979, Bernardo and Taylo 1990, Singh and Singh 2005). Both jassid nymphs and adults are injurious and suck plant sap specially the older nymphs. At the early stages of cotton, okra and brinjal, 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 jassid attack

is severe, yellowish patches develop in the leaves which gradually turn brown and dry up. 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, withering and necrosis of leaves occur and ultimately, the leaves shed prematurely (Hussain and Lal 1940, Mahal 1973, Bindra and Mahal 1979, Bindra and Mahal 1981). Jassid attacks mainly the rainy season crop (Kumawat *et al* 2000).

The reduction in height of okra plants and number of leaves per plant due to the attack of jassid was observed up to 49.8 and 45.1 per cent, respectively by Rawat and Sahu (1973). Jassid is reported to cause yield loss ranging from 32.06-66.00 per cent (Bindra and Mahal 1981, Patel 1985, Singh and Brar 1994, and Singh *et al* 2013 in okra) and (Balasubramaniam *et al* 1977 in cotton). Mahal *et al* (1994) reported that the seed yield decreases by 0.396 g with every unit increase in cicadellid population.

Various insecticides namely Malathion for the vegetable crop and phorate granules /dimethoate/acetamiprid for the seed crop have been recommended by Punjab Agricultural University (Anonymous 2015b). At present, the most suitable method available for the control of jassid on okra is through the use of insecticides. The farmers are spraying insecticides indiscriminately for the control of this pest. There are reports from other workers regarding indiscriminate use of systemic insecticides from other places resulting in development of resistance in the pests to these insecticides (Ahmad *et al* 1999, Villegas *et al* 2006).

The repeated application of insecticides not only increases the pesticide resistance in the insects and the cost of production of crop, but also poses serious hazards to the operators, consumers and natural enemies. Therefore, it is required to look for an alternative method of pest control. The varietal resistance is a vital tool of integrated pest management in okra. In okra, the fruits are picked at short intervals, hence, the insecticidal application not only increases insecticidal load on crop but becomes hazardous too (Sardana and Dutta 1989). A resistant variety suppresses pest population with least disturbance to crop ecosystem and also reduces the need for harmful pesticides that pollute the environment. It is highly effective based on cost-benefit analysis and plays an important role in sustaining productivity (Dhaliwal and Arora 2003). Therefore, a resistant variety is a safe, economical and long lasting alternative method of pest control. Keeping the above facts in view, the present study was planned with the following objectives:

- Identification of okra germplasm resistant to jassid.
- Determination of bases of resistance (in terms of morphological and biochemical parameters) in okra germplasm.

CHAPTER II

REVIEW OF LITERATURE

Out of half a dozen species of leafhoppers infesting okra, jassid, *Amrasca biguttula biguttula* (Ishida) is one of the most economically important species attacking okra in India (Hussain and Lal 1940, Mahal 1975). Lot of research work on its incidence, crop losses, biology, and host plant resistance in okra has been carried out by various research workers. It is reviewed under different headings and sections as follows:

2.1 Seasonal incidence

The peak activity of jassid was observed from August to September in Punjab, Haryana and Rajasthan (Atwal *et al* 1969, Pareek *et al* 1986, Sharma and Sharma 1997a, Singh and Singh 2005).

Uthamasamy *et al* (1973) found that the incidence of jassids was more during monsoon season (August-October) than in the cold season (November-January) in Tamilnadu. Its infestation was reported highest in July and lowest in March on the okra crop (Uthamasamy 1980), whereas Dhamdhare *et al* (1984) observed that jassid remains active throughout the crop season on both *Kharif* and summer okra at Gwalior. The pest population was maximum when the crop was 69-77 days old. Mani *et al* (1986) reported more abundance of jassids in the *Kharif* than in *Rabi* season, which might be attributed to cold weather conditions. Uthamasamy (1988) reported that the incidence of leafhopper, *A. biguttula biguttula* on okra crop was highest on 25th and lowest on 35th day after sowing at Coimbatore (Tamil Nadu).

Devasthali and Saran (1997) reported that *A. biguttula biguttula* appears on okra crop in 1st week of July in Madhya Pradesh. Patel *et al* (1997) reported the significant relationship between leafhopper, *A. biguttula biguttula* level and maximum temperature as well as bright sunshine hours. The population of leafhopper increased in monsoon in Gujarat when temperature remained around 37°C along with at least 10 hour bright sunshine. Rai and Satpathy (1999) found gradual increase in the jassid population with the advancement of sowing dates up to mid-June. Ghosh *et al* (1999) also reported that jassid, *A. biguttula biguttula* showed its peak population in middle of June. However, Gogoi and Dutta (2000) revealed that jassid incidence was maximum in the last week of May during 1998 (37.53 nymphs per leaf) and middle of April during 1999 (30 nymphs per leaf).

Kumawat *et al* (2000) reported that the jassid infestation started in the fourth week of July at Jobner, Rajasthan and reached at its peak in the second and fourth week of September. Arif *et al* (2006) observed the 1st, 2nd and 3rd peak of jassid population during 3rd, 2nd and 2nd week of July, August and September, respectively. Ullah *et al* (2012) found that the *A. biguttula biguttula* population continuously increased from 3rd week of June to 2nd week of July at Rawalpindi, Pakistan.

2.2 Crop losses

The reduction in height of okra plants and number of leaves per plant and weight of healthy fruits due to the attack of jassid was observed up to 49.8, 45.1 and 69.9 per cent, respectively by Rawat and Sahu (1973). Krishnaiah (1980) reported about 40-56 per cent losses in okra due to leafhopper. Bindra and Mahal (1981) reported that jassid caused damage right from the early seedling stage to the fruit setting stage resulting in loss of 50 per cent yield. Similarly, jassid can cause 60 per cent yield loss in okra in Gujarat (Patel 1985). Singh and Brar (1994) reported that jassid alone can cause 32.06 to 40.84 per cent damage in okra yield. Jassid caused up to 63.41 % yield loss on okra (Sharma and Sharma 2001). Mahal *et al* (1994) reported that the seed yield decreases by 0.396 g with every unit increase in cicadellid population. The vegetative growth and yield reduction due to jassid attack to the extent of 54-66 per cent under unprotected conditions has been reported by Singh *et al* (2013).

2.3 Biology

The females of cotton jassid laid maximum of 29 eggs with an average of 15 eggs singly in the parenchymatous tissue of the leaf vein in okra, between vascular bundles and epidermis. The eggs hatched after 4-15 days in different seasons in cotton (Hussain and Lal 1940). The egg stage lasted for 3.3 and 2.4 days at 25 and 30°C, respectively (Atwal *et al* 1969). Jayasimha *et al* (2012) in okra observed that the incubation period of egg varied from 6 to 7 days. The 5 nymphal instars were completed in 7 days in summer and 21 days during winter. The nymphal duration at a constant temperature of 25 and 30°C was 10.8 and 8.7 days, respectively. The total nymphal period was 6-8 days. The pre oviposition period, oviposition period and post oviposition period were found to be 3-4, 16-17 and 3.5-4 days, respectively. The fecundity ranged between 14-20 days. Male and female longevity ranged between 21-26 days and 26-30 days, respectively. Total life cycle completed in 28-34 days. Hussain and Lal (1940) and Atwal *et al* (1969) also reported that the adults mated 2-16 days after emergence in cotton. The longevity of unmated females was up to 3 months, while the mated ones lived for 36 days in summer and 49 days in winter.

2.4 Host Plant Resistance

Host Plant Resistance (HPR) is one of the most important cost-effective and safe components of Integrated Pest Management (IPM). Many scientists have advocated the use of resistant varieties as one of the most potential methods of controlling insect pests (Beck 1965, Maxwell *et al* 1972, Van Dinther 1972, Gallun *et al* 1975, and Bhatti *et al* 1976). Considerable native diversity in cultivated and wild types occur in Indian sub-continent. The available variability including both indigenous and exotic germplasm has been utilized to a

considerable extent in the improvement of okra. Different workers have screened different okra germplasm for resistance to jassid on okra which is reviewed as under:

2.4.1 Screening of varieties

The counting of nymphs from underside of a few leaves selected from different portions of the plant was considered as a better index of jassid 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 jassid 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).

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 jassid with low nymphal population as well as extent of damage and Pusa Sawani and All Season as susceptible to jassid. Uthamasamy *et al* (1973) observed Pusa Sawani, A.E. 15 and A.E. 30 to be resistant to jassid at Coimbatore, Tamil Nadu. Sandhu *et al* (1974) screened 94 lines of okra against jassid at Ludhiana and reported Crimson Smooth Long as highly resistant to the jassid. 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 jassid 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 Kishor *et al* (1983).

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 jassid 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 jassid 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.

The criteria of susceptibility index for testing level of resistance under field conditions should be given priority over either jassid nymphal population or jassid 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 jassid 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 cotton jassid, *Amrasca biguttula biguttula* on different plant ages of two varieties of okra was studied by Mahal *et al* (1993) and it was found that fewer nymphs were 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.

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: 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 jassids 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 the poor survival, longer developmental period and smaller size of the *A. biguttula biguttula* nymphs on resistant variety IC 7194 throughout 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 season which indicated its 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 and 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 jassid in okra and reported all varieties as susceptible to jassid.

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 jassid. Arka Anamika and Parbhani Kranti were found to be moderately resistant against jassids (Ghosh *et al* 1999). Bhat (1999) also observed Varsha Uphar and Arka Anamika to be less preferred by jassids as compared to Shagun and Parbhani Kranti. Sharma *et al* (2001) 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 jassid. Kumar and Singh (2002) reported that the jassid 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 and Singh (2005) found lower nymphal population and lower visual injuries by jassid on resistant genotypes: HRB 128-1-1, HRB 118-2-1 and HRB 105-2-2 than on the susceptible genotypes: HRB 107-4-1 and HRB 121-1-1 during the peak period of infestation (4th week of August to 2nd week of September), while the variety Varsha Uphar showed an intermediate response.

Singh (2007) reported that the varieties viz. Pusa Makhmali, P-8, Harbhajan and Parbhani Kranti harbored more jassid 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 jassid and *A. caillei* showed symptomless carrier to jassid. 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 jassid. Prabu *et al* (2009) screened 85 accessions including cultivars, related species and their inter specific hybrids under field conditions against jassid and reported *A. moschatus*-1 and *A. ficulneus*-1 to be resistant and two biotypes of *A. tetraphyllus*, *A. manihot* spp. *manihot*, *A. manihot* spp. *tetraphyllus*, *A. manihot* (Linnaeus) Medikus, *A. tuberculatus* and *A. angulosus* as tolerant to jassid and *A. caillei*-1, *A. caillei*-2 and cultivars of *A. esculentus* as susceptible to jassid.

Jondhale (2007) recorded low population of leafhopper, *A. biguttula biguttula* in VRO-6 genotype. 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 jassid/leaf) and Kashi Pragati (1.78 jassid/leaf) as resistant against jassids. The varieties Pusa Sawani (4.18 jassid/leaf) and KS 410 (3.82 jassid/leaf) were found to be susceptible to jassid. Punjab-8 was reported to be tolerant to jassid (Anonymous 2015b). Halder *et al* (2016) reported okra genotypes SB-6 and SB-10 as susceptible and VROB-181 as tolerant under Varanasi conditions. Gangopadhyay *et al* (2016) studied the resistance sources in four wild species: *A. caillei*, *A. moschatus*, *A. manihot* and *A. tuberculatus* against jassid and reported the accessions of all these wild species as resistant to jassid.

2.4.2 Morphological basis of resistance

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 jassid. Other workers also reported that hairiness interfered with the feeding and oviposition by jassid (Husain and Lal 1940).

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 jassid resistance in cotton. Leaf area and its succulency play a part in jassid 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 jassid 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 jassid population or the extent of injury inflicted by it.

Uthamasamy (1980) reported that the okra variety AE 22 was less preferred for oviposition by *Amrasca 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 leaf hoppers (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 jassid population was negatively correlated with leaf hairiness (Sharma and Agarwal 1983). In brinjal, thickness of lamina and midrib were found positively correlated with jassid infestation, while the

thickness of lateral veins, density of midrib hair and length of midrib hair did not have significant correlation with jassid infestation (Subbaratnam *et al* 1983).

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 1985). 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 jassid 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). 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 jassid 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 jassid, but length of hair on the leaf-lamina was not so important for the jassid 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 hardness 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.

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 jassid population harbored by these varieties (Mahal *et al* 1993, 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 jassid-injury indices was negative and significant especially in case of three principal veins in okra (Dhillon 1997). 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. Ragumoorthi and Kumar (1999) observed thin midrib as a major factor for resistance in the varieties to leafhopper. Lines with thick veins favoured congregation of more hoppers and

early stage nymphs. Singh and Singh (2005) observed less number of eggs laid per leaf in the resistant genotypes than in susceptible ones, thereby indicating ovipositional antixenosis and found a negative and significant correlation between leafhopper oviposition and trichome density and trichome length on main vein and lateral veins.

Ahmad *et al* (2005) evaluated different varieties of cotton for resistance to jassid 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 jassid 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 jassid nymph population, while all the other morphological traits showed non-significant correlation to jassid population. 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. 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 jassid 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 jassid 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 jassid. The results showed that the physio-morphic characters of the brinjal plant play vital role in the population fluctuation of jassid (Muhammad *et al* 2012).

Antixenosis and antibiosis were the mechanism of resistance involving various plant parameters, *viz.* plant height, internodal length, trichome density on the ventral surface of the leaves, hair length, and hair density on mid-vein which had the negative association with leafhopper damage and oviposition by leafhopper. Leaf area, leaf thickness and protein content had no significant association (Murugesan and Kavitha 2010). Correlation coefficients 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 jassid population at Varanasi.

2.4.3 Morphological studies under Scanning Electron Microscope (SEM)

Many workers used SEM technology to study the morphology of different plants to study structure, shape, composition of trichomes and stomata on leaf surface etc. (Dahlin *et al* 1992, Tahir *et al* 1994, Valkama *et al* 2003, Favi *et al* 2008, Singhal *et al* 2010, Turley *et al* 2012). Kesavacharyulu *et al* (2004) conducted SEM studies on the mulberry genotypes for checking its influence on the rearing performance of silkworm, *Bombyx mori* L. and reported that higher density of trichomes on the mulberry leaves reduces the acceptability of leaf by the silkworm. Singhal *et al* (2010) conducted SEM studies on different mulberry genotypes for their leaf surface characteristics for checking their feeding value in silkworm rearing and found that Mandalaya was the most promising mulberry genotype with higher leaf yield and shorter trichome and idioblast lengths for silkworm rearing.

2.4.4 Biochemical basis of resistance

Certain genotypes, in spite of being less hairy are resistant to jassids (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). 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 *Amrasca devastans*. The varieties poor in nutritive values are less preferred for feeding by jassids.

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 jassid, *Amrasca 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 jassid 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 jassids.

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. Uthamasamy (1980) observed that the okra variety AE 22 was less preferred for feeding by *Amrasca devastans* due to its poor nutritive value. Similarly, the biochemical parameters associated with resistance to jassid 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* 1981).

Balasubramanian and Gopalan (1981) studied the mechanism of resistance of upland cotton, *Gossypium hirsutum* Linn. to leafhopper, *Amrasca biguttula biguttula* (Ishida) and found that cotton varieties resistant to jassid contained higher contents of total carbohydrates and reducing sugars, total phenols, calcium and phosphorus. The free amino acid content was high in the susceptible and tolerant varieties. Raju and Reddy (1982) reported a negative and significant correlation of nymphal population of jassid in cotton with total phenols and orthodihydroxy phenols and a positive and significant correlation with reducing sugars and tannins. Sharma and Agarwal (1983) found that the mean jassid population on cotton was negatively correlated with gossypol, sugar and free amino acids and positively correlated with free phenols and tannins.

Singh (1988) evaluated the jassid 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 jassid incidence. The effects of reducing sugars, protein and free amino acids were less significant. Singh and Agarwal (1988) studied the role of chemical components of resistant and susceptible genotypes of cotton and okra in ovipositional preference of cotton leafhopper and found that the total sugars, non-reducing sugars, tannins, silica and free gossypol in the leaves showed significant and negative correlation with the number of leafhopper eggs. They revealed that highly susceptible genotype of okra; AC-302 contained significantly higher amounts of proteins and lower amount of non-reducing and total sugars, tannins and silica as compared to the resistant genotypes. Highly susceptible genotype, Acala-4-42 of cotton, had a higher amount of proteins and higher amount of reducing sugars as compared to the highly resistant, BJR-741. A positive correlation between the protein contents and survival as well as oviposition of the jassid was reported by Singh and Taneja (1989). Ali *et al* (1995a) did not observe any role of proteins against the jassid attack and reported that reducing sugars had positive and significant correlation with the jassid 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). Barroga and Bernardo (1993) reported that the cause of death of jassids 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. 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. Extrafloral 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*.

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 jassid. 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 antiherbivore defence by increasing the abrasiveness and reducing the digestibility of grass leaves. 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.

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. 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 jassid on okra. When computed together, all the chemical components showed 99.7 per cent role on jassid population fluctuation. On the basis of this study, total sugars had negative and a significant correlation with jassid population and the resistant varieties (Makhmali, Punjab selection, and Green wonder) had lower sugars. 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 jassids.

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). Halder *et al* (2016) reported a significant and negative correlation between total phenol content and jassid incidence on okra.

CHAPTER III

MATERIAL AND METHODS

Studies on “Evaluation of okra germplasm for resistance to jassid, *Amrasca biguttula biguttula* (Ishida)” were carried out at Vegetable Research Farm, Punjab Agricultural University, Ludhiana. Morphological and biochemical parameters were studied in the Entomology Laboratory and Biochemistry Laboratory, respectively of the Department of Vegetable Science, whereas, Scanning Electron Microscopy (SEM) studies were conducted in Electron Microscopy and Nanoscience (EMN) Laboratory, PAU, Ludhiana during 2015-16.

3.1 Field evaluation of okra germplasm against jassid, *A. biguttula biguttula* (Ishida)

3.1.1 Sowing of the crop

The sowing of the crop was done at Vegetable Research Farm, Department of Vegetable Science, Punjab Agricultural University, Ludhiana. The seeds of 15 genotypes of okra were sown on 26th May 2015 in plot of 10 m² size. The experiment was laid out in the Randomized Block Design with three replications and the row to row and plant to plant spacing as 60 and 30 cm, respectively. An infestor row of susceptible variety Pusa Sawani was sown around each plot. Various agronomic practices were followed as per the Package of Practices for Cultivation of Vegetable Crops, Punjab Agricultural University, Ludhiana (Anonymous 2015b), except that the crop was kept unsprayed.

Fifteen germplasm entries of okra obtained from different sources in the country are listed in Table 1.

Table 1: Sources of okra germplasm evaluated during 2015 under field conditions

S. No.	Germplasm Entries	Source
	Accessions	
1.	IC0506027	NBPGR, New Delhi
2.	IC0506118	NBPGR, New Delhi
3.	EC0306728	NBPGR, New Delhi
	<i>Abelmoschus</i> spp.	
4.	<i>Abelmoschus tuberculatus</i>	IIVR, Varanasi
5.	<i>Abelmoschus moschatus</i>	IIVR, Varanasi
6.	<i>Abelmoschus angulosus</i>	IIVR, Varanasi
7.	<i>Abelmoschus tetraphyllus</i>	IIVR, Varanasi
8.	<i>Abelmoschus manihot</i>	IIVR, Varanasi
9.	<i>Abelmoschus caillei</i>	IIVR, Varanasi
	Genotypes	
10.	POL-6	PAU, Punjab
11.	POL-7	PAU, Punjab
	Cultivated varieties	
12.	Punjab-8	PAU, Punjab
13.	Punjab Padmini	PAU, Punjab
14.	Punjab -7	PAU, Punjab
15.	Pusa Sawani	IARI, New Delhi

The seeds of the above mentioned germplasm were also sown in the pots. The seeds of each entry were sown in 3 replications and the pots were covered with nylon net for protection against jassid.

3.1.2 Jassid population counts

The nymphal counts of jassid were made from underside of leaves. In each of the three replications, five plants of a variety were selected at random and tagged. From a plant, 3 leaves (one each from top, middle and bottom canopy) were selected at random. The observations were made once a week throughout the crop season at weekly intervals, commencing from 4th June when the crop was one week old.

3.1.3 Leaf injury

The plants in different varieties selected for population counts were simultaneously observed for hopper burn symptoms also. All the leaves of a plant were graded individually for the extent of jassid injury by following the five jassid injury grades (Plate 1) suggested by Mahal (1973).

Grade	Level of injury	Description
1	No damage	Entire leaf green
2	Low damage	About 1-25% leaf area showing hopperburn, yellowing at margins.
3	Medium damage	About 26-50% leaf area showing hopperburn, slight cupping at margins.
4	High damage	About 51-75% leaf area showing hopperburn, severe cupping and bronzing.
5	Severe damage	Entire leaf area showing hopperburn, petiole and leaf dry up.

The jassid injury index was determined as under:

$$\text{Jassid injury index} = \frac{G1L1 + G2L2 + G3L3 + G4L4 + G5L5}{L1 + L2 + L3 + L4 + L5}$$

Where, L1 to L5 are the number of leaves falling under injury grades G1 to G5, respectively.

3.1.4 Host plant susceptibility index

The susceptibility index for each replication of each entry was worked out on individual plant basis by multiplying the nymphal population with the respective jassid injury index.

3.1.5 Statistical analysis:

The data pertaining to sub sections 3.1.2, 3.1.3 and 3.1.4 were analyzed in Randomized Block Design (RBD) and subjected to ANOVA by using CPCS-1 software. Means were compared by LSD (p=0.05). Correlations were also worked out using MS-Excel.

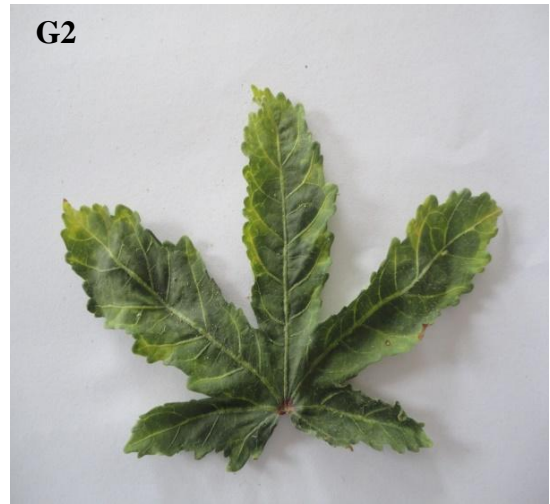


Plate 1: Injury index grades (G1 to G5)

3.2 Determination of basis of resistance in okra germplasm against jassid.

3.2.1 Morphological studies

Hairiness traits were studied in all varieties of okra from the first experiment sown in the field on 26th May at the Vegetable Research Farm, Department of Vegetable Science, Punjab Agricultural University, Ludhiana.

3.2.1.1 Hair density and Hair length

For hair density and hair length studies under SEM, single leaf from middle canopy of each entry of okra was plucked during the peak activity period of jassid (56 DAS). Small bits from near the base of the mid vein of the leaves were taken. These samples were processed as per the procedure of Russel and Bozzola (1999). Samples were fixed in 2.5% glutaraldehyde and then three washings were performed with 0.1 M Caco buffer. 1% Osmium tetroxide was added for 1 to 2 hours. After that, the samples were again washed thrice. After successive incubations with different concentrations of ethanol, the samples were placed in vacuum desiccator overnight. Samples were then placed on aluminium stub using double sided carbon tape and sputter coater model E-1010 for 30s. The samples were then viewed under SEM (Hitachi S-3400N) at different magnifications, i.e. 200, 300, 500 and 1000 μm depending upon the density and length of the hair in different germplasm entries and micrographs were clicked. The values of data regarding hair density at different magnifications were converted to average values at 500 μm magnification for the uniformity.

3.2.1.2 Angle of insertion

Single leaf each from middle canopy of selected five plants per replication was taken during the peak activity period of jassid (56 DAS) and observed for the angle of insertion of hair from near the base of the mid vein of the leaf under Axio Ai Zeiss Microscope using software Axiovision Release 4.7.2. From mid vein of each leaf, the angle of 5 hairs was measured. Average angle of insertion on the basis of these 5 observations was worked out for each replication.

3.2.1.3 Leaf shape

Single leaf each from middle canopy of randomly selected 5 plants from each entry was taken and their lobe length and leaf length was measured using measuring scale. Lacination index was worked out for all five leaves per replication based on the ratio of lobe length to leaf length. Leaf shape of each germplasm entries was determined by using lacination index and the entries were classified into different categories: broad, intermediate, narrow and lacinated leaves (Arumugam and Muthukrishnan 1977).

Sr 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

3.2.1.4 Statistical analysis: Correlations between the morphological parameters of different okra germplasm leaves and jassid nymphal counts, jassid injury index and jassid susceptibility index were worked out using MS-Excel. Standard deviation was worked out in case of hair density, hair length and angle of insertion of hair.

3.2.2 Biochemical Studies

On the basis of jassid susceptibility index, five promising germplasm entries with low to moderate field resistance were selected and evaluated for the different biochemical characteristics of okra leaves. The leaves of the selected entries from jassid infested plants (middle canopy) in the field crop as well as from the uninfested plants (middle canopy) grown in pots under protected environment were collected and washed properly to remove extraneous materials sticking to the surface of the leaves. The samples were dried in an oven and powdered to pass through 40 mesh sieve. The dried samples thus prepared were analyzed for different parameters by using standard methods.

3.2.2.1 Total Soluble Sugars, (Dubios *et al* 1956)

Principle

In hot acidic medium glucose is dehydrated to hydroxymethyl furfural. This forms an orange - yellow colored product with phenol and has absorption maximum at 490 nm.

(A) Extraction procedure:

a) Reagents

- i) Ethanol (80% and 70%)
- ii) Lead acetate (saturated)
- iii) Sodium oxalate

500 mg dried leaf sample was weighed and refluxed with 80% ethanol in conical flask fitted with water condenser for two hours. Then supernatant was collected and again refluxed the content with 70% ethanol and pooled the supernatants. The extraction was repeated thrice. Ethanol from pooled extract was removed at 50°C in a flash evaporator under vacuum. Then 1.0 ml of saturated lead acetate was added. This was kept for four hours or till all the proteins in the extract get precipitated. To this, a pinch of sodium oxalate was added to remove the excess lead ions from the extract. It was again kept for two hours. Thereafter, the extract was filtered through Whatmann no. 1 filter paper. The clear extract thus obtained was made upto 100 ml with distilled water and centrifuged before sugar estimation.

(B) Estimation

a) Reagents

- i) 5% phenol (w/v) redistilled
- ii) Conc. Sulphuric acid (H_2SO_4)

(b) Procedure

To 0.2 ml of sugar extract, 0.8 ml of distilled water and 1.0 ml of 5% phenol was added followed by the addition of 5.0 ml of conc. H_2SO_4 . The H_2SO_4 was poured directly in the center of the test tube to ensure proper mixing. After 10 min, tubes were cooled to room temperature under running water. After 20 min, the absorbance was read at 490 nm against reagent blank. The concentration of total sugars was read from standard curve prepared by using glucose in range of 10-100 $\mu\text{g/ml}$.

3.2.2.2 Reducing sugars, (Somogyi 1952)

Principle

The reducing sugars, when heated with alkaline copper tartrate, reduce the copper from cupric to cuprous state and thus cuprous oxide is formed. When cuprous oxide is treated with arsenomolybdic acid, the reduction of molybdic acid to molybdenum blue takes place. The blue colour developed is compared with the set of standards in colorimeter at 620 nm.

(A) Reagents

(1) Alkaline Copper tartrate:

- (a) 2.5 g anhydrous sodium carbonate, 2 g of sodium bicarbonate, 2.5 g potassium sodium tartrate and 20 g of anhydrous sodium sulphate were dissolved in 80 ml of water and final volume was made upto 100 ml.
- (b) 15 g copper sulphate was dissolved in small amount of distilled water. Then one drop of H_2SO_4 was added and volume was made upto 100 ml.

Then, 4ml of (b) and 96 ml of solution (a) were mixed before use.

(2) Arsenomolybdate reagent:

2.5 g ammonium molybdate was dissolved in 45 ml of water, and then 2.5 ml H_2SO_4 were added and mixed well. Then 0.3 g disodium hydrogen arsenate was dissolved in 25 ml H_2O , both were mixed and incubated at 37°C for 24-48 hours.

(3) Standard stock glucose solution:

100 mg in 100 ml distilled water.

(4) Working standard - Dilute 10 ml of stock solution to 100 ml with distilled water (100 $\mu\text{g/ml}$).

Procedure

In a test tube, 1 ml of sugar extract and 1.0 ml alkaline copper tartrate was added. The solution was heated for 10 minutes. Then the tubes were cooled at room temperature and 1.0 ml of arsenomolybdic reagent was added. In the solution, 7.0 ml of water was added to make

the final volume of 10 ml. After 10 minutes, the absorbance was read at 620 nm. The concentration of total sugars was read from standard curve prepared by using glucose in range of 10-100 µg/ml.

3.2.2.3 Total Phenols, (Bray and Thorpe 1954)

Principle

Phenols react with an oxidizing agent (phosphomolybdate) in Folin-Ciocalteu reagent under alkaline conditions and result in the formation of blue coloured complex, which is read at 760 nm colorimetrically.

Reagents

1. 80% Methanol
2. Folin-Ciocalteu's reagent (FCR)
3. 20% Na₂CO₃ (20 g dissolved in 100 ml water)
4. Standard (100 mg catechol was dissolved in 100 ml water). This was diluted 10 times for a working standard.

Procedure

0.5 g of oven dried sample was taken in a conical flask with 80% methanol and was refluxed for 2 hours. The extraction was repeated thrice. The pooled extracts were filtered in 25 ml volumetric flask and volume was made up to 25 ml. From this filtrate, 5 ml aliquot was taken in a beaker and the contents were evaporated to dryness. In the same beaker, 0.5 ml Folin-Ciocalteu's reagent and 6.5 ml distilled water was added. After 3 min, 20% Na₂CO₃ was added and total volume was made up to 25 ml. After 1 hour, the contents were centrifuged and the absorbance was read at 760 nm against reagent blank. The concentration of phenols in the test sample was calculated from the standard curve using catechol (10-100 µg/ml).

3.2.2.4 Tannins, (Schanderl 1970)

Principle

Tannin-like compounds reduce phosphotungstomolybdic acid in alkaline solution to produce a blue coloured solution, the intensity of which is proportional to the amount of tannins. The intensity is measured in a spectrophotometer at 700 nm.

Reagents

1. Folin-Denis Reagent: 100 g sodium tungstate and 20 g phosphomolybdic acid were dissolved in 750 ml distilled water in a conical flask and then 50 ml phosphoric acid was added. The mixture was refluxed for 2 hours and total volume was made up to 1 litre with distilled water. The reagent was protected from exposure to sunlight by storing in amber coloured bottle in the dark.
2. Sodium carbonate solution: 350 g sodium carbonate was dissolved in 1 litre of water at 70-80°C. After allowing it to stand for one night, the solution was filtered.

3. Standard tannic acid solution: 100 mg tannic acid was dissolved in 100 ml of distilled water.
4. Working Standard solution: 10 ml of the stock solution was diluted to 100 ml with distilled water.

Procedure

0.5 g of oven dried material was taken in a conical flask and 75 ml distilled water were added. The flask was heated gently and then boiled for 30 min. After that, it was centrifuged at 2000 rpm for 20 min and the supernatant was collected. From this, 1 ml aliquot was taken in a test tube and, 0.5 ml Folin-Denis reagent followed by 1 ml sodium carbonate solution was added. The total volume was made up to 10 ml with distilled water. After 30 min, the absorbance was read at 700 nm. The concentration of tannin was determined from standard curve of tannic acid (10-100 $\mu\text{g/ml}$).

3.2.2.5 Lignins, (Stafford 1960)

Principle

The sample is extracted in NaOH solution and the aliquot samples are adjusted to pH 7.0 and 12.3. The amount of lignin is calculated by a difference between A_{245} (pH 7.0) and A_{350} (pH 12.3).

Reagents

1. Diethyl ether
2. 0.1 M Sodium phosphate buffer, pH 7.0
3. 0.1 N NaOH (4 g dissolved in 1000 ml) and 0.5 N NaOH (20 g dissolved in 1000 ml)
4. 2 N HCl (17.456 ml of conc. HCl diluted to 100 ml with distilled water)

Procedure

100 mg of oven dried material was ground with diethyl ether in a mortar. Washings were discarded and extraction was repeated until it was free from chlorophyll pigment. The contents were centrifuged at 2000 rpm for 5 min and the supernatant was decanted off. The sediment was washed with water and re-centrifuged and the supernatant was again discarded. These washings were repeated thrice. After washings, 2 ml 0.5 N NaOH was added to the residue and was extracted at 70-80° C for 12-16 hours. After cooling, 0.45 ml of 2 N HCl was added and the pH was adjusted to 7.0 with NaOH. The total volume was made up to 3 ml with water and the contents were again centrifuged at 2000 rpm for 5 min. The supernatant was collected and termed as crude extract. In two sets of test tubes, 0.8 ml of extract was added to each test tube. In one set, 0.8 ml of 0.1 M sodium phosphate buffer, pH 7.0 was added to each test tube. In the other set, 0.8 ml 0.1 N NaOH was added to each test tube. The absorbance was read at 245 and 350 nm. The lignin concentration was derived from the difference between A_{245} and A_{350} (E_{350}) on pH 7.0 and 12.3 samples diluted with buffer and NaOH, respectively. The lignin concentration was expressed as $\Delta E_{350}/\text{sample}$.

3.2.2.6 Silica, (Piper 1950)

Principle

The plant material was ground and ashed at 600° C. The ash was extracted with dilute HCl and the weight of insoluble residue remaining after ashing was determined.

Reagents

1. Dilute HCl: Dilute conc. HCl (1:1 v/v)
2. Dilute HCl: Dilute conc. HCl with water (1:20)
3. Conc. HNO₃

Procedure

2-5 g oven dried and powdered plant material was taken in a crucible and was heated over a gas burner at low heat. After that, it was transferred to a muffle furnace maintained at 300° C. The ashing was done slowly and carefully until the ash became greyish white/grey. After cooling, the ash was moistened with little water in a flask and covered with a funnel. With the help of funnel, 40 ml dilute HCl (1:1) was added to avoid any loss by effervescence. The flasks were placed on water bath and were digested for 20-30 min. One ml of conc. HNO₃ was added to each flask to oxidize any ferrous salts and the contents were evaporated to dryness in an oven at 110°C for complete dehydration. Then, the dried contents were moistened with 10 ml dilute HCl (1:1) followed by 50 ml distilled water and heated on water bath until all soluble salts were in solution. After that, the mixture was filtered through a pre-weighed Whatmann no. 1 filter paper. The ash adhering to the sides of the flasks was washed with hot dilute HCl (1:20) and filtered. Then the amount of insoluble residue on the filter paper was determined. The amount of silica was determined by subtracting the weight of filter paper from the weight of filter paper containing ash.

Silica content = (Weight of filter paper + ash) – (Weight of filter paper)

3.2.2.7 Statistical Analysis

The data pertaining to biochemical parameters were subjected to ANOVA using CPCS-1 software. The means were compared by LSD (p=0.05). The correlations between these parameters and the field parameters were also worked out.

CHAPTER IV

RESULTS AND DISCUSSION

Studies on “Evaluation of okra germplasm for resistance to jassid, *Amrasca biguttula biguttula* (Ishida)” were conducted at the Vegetable Research Farm, Department of Vegetable Science, Punjab Agricultural University, Ludhiana during 2015-2016. Fifteen okra germplasm entries including three accessions: IC0506027, IC0506118 and EC0306728; six *Abelmoschus* spp.: *A. tuberculatus*, *A. moschatus*, *A. angulosus*, *A. tetraphyllus*, *A. manihot* and *A. caillei*; two genotypes: POL-6 and POL-7 and four cultivated varieties: Pusa Sawani, Punjab 7, Punjab Padmini and Punjab 8 were screened under field conditions for resistance to jassid. The morphological and biochemical bases of resistance in these entries were also studied. The results are presented under the following sub-sections.

4.1 Field evaluation of okra germplasm against jassid, *A. biguttula biguttula* (Ishida)

Jassid nymphal population and jassid injury index were observed for different okra germplasm entries at weekly intervals under field conditions during crop season in 2015. Based on the jassid nymphal counts and jassid injury index, susceptibility index for each entry at weekly intervals was worked out. These parameters are discussed in detail as follows:

4.1.1 Jassid nymphal population

Jassid nymphal population per leaf on various entries of okra (Table 2) was nil at 7 and 14 days after sowing (DAS). Afterwards, the nymphal population appeared on the crop when the crop was 21 days old (0.00-0.42) and continued to increase till 77 DAS (2.89-22.88) and then declined but remained there till the end of the crop season i.e. up to 98 DAS.

In the beginning of the crop season, there was no jassid nymph population till 14 DAS, may be due to rainfall (4.8 mm) on 4th June, 2015 i.e. after one week after sowing and the poor establishment of the plants during this period. The population started appearing from 21 DAS at very low level. After 28 DAS, the population in some of the entries sharply increased with the advancement of the crop age and the peak infestation of jassid was observed from 42 to 77 DAS. It declined in the end of the crop season. This might be due to moderate to heavy rainfall occurred on 18th August (54.0 mm) and on 21st August (26.8 mm) and otherwise also the crop was exhausted by the time.

The differences in the jassid nymphal population among different germplasm entries were non-significant up to 14 DAS. Afterwards, the population recorded at different day intervals varied significantly among different entries. On 21 DAS, all *Abelmoschus* spp.: *A. tuberculatus*, *A. moschatus*, *A. angulosus*, *A. tetraphyllus*, *A. manihot*, and *A. caillei* did not harbour any nymph population, while significantly lower nymphal population was recorded in accession IC0506027 (0.20 nymphs per leaf) as compared to other accessions,

genotypes and all the cultivated varieties (0.26-0.42 nymphs per leaf). On 28 DAS, no jassid nymphs were recorded in *A. tetraphyllus* followed by *A. moschatus*, *A. manihot*, *A. angulosus*, and accessions, IC0506027, IC0506118, and EC0306728 in which significantly lower nymph population (0.22-0.53 nymphs) was recorded. At 35 DAS, significantly lower nymphal population (0.31) was registered in *A. tetraphyllus* followed by IC0506027, *A. angulosus*, *A. manihot*, IC0506118, and *A. tuberculatus* (0.73-1.15). The other entries harbored significantly higher jassid nymphal population (2.13-12.09). At 42 DAS, lowest jassid nymphs were observed in the *Abemoschus* spp.: *A. tetraphyllus*, *A. manihot*, *A. moschatus*, *A. angulosus*, and *A. tuberculatus* (0.98-1.62) and accession IC0506027 followed by accessions: IC0506118, EC0306728, and *A. caillei* (2.62-3.62). Significantly higher population was observed in two genotypes and all the cultivated varieties viz. Pusa Sawani followed by POL-7, Punjab 8, POL-6, Punjab 7 and Punjab Padmini (8.00-26.37) in the descending order. The same trend of nymphal population was observed at age of 49 DAS in case of *A. tetraphyllus*, *A. moschatus*, *A. manihot*, *A. angulosus* and IC0506027.

From 56 to 70 DAS, *A. moschatus*, *A. angulosus*, and *A. tetraphyllus* had significantly lower jassid nymphal population per leaf (1.27-2.56, 1.27-1.53 and 1.80-2.27 at 56, 63 and 70 DAS, respectively). At 56 to 63 DAS, *A. manihot* also registered significantly lower jassid nymphal population (3.06 and 3.80, respectively). However, the nymphal population increased at 70 DAS with 9.07 nymphs per leaf. Moderate jassid population was observed in all accessions: IC0506027, IC0506118, EC0306728 and *Abelmoschus* spp.: *A. tuberculatus* (7.47-11.04, 5.42-8.33 and 4.84-9.53 nymphs per leaf at 56, 63 and 70 DAS, respectively). The other entries viz. Pusa Sawani followed by POL-7, Punjab 7, Punjab Padmini, Punjab 8, POL-6 and *A. caillei* harbored significantly higher jassid nymphal population (11.0-24.11, 11.31-21.17 and 17.22-29.09 nymphs per leaf at 56, 63 and 70 DAS, respectively) in the descending order. The highest population was registered in Pusa Sawani i.e. 24.11-29.09 nymphs per leaf during 56-70 DAS. At 77 DAS, *A. tetraphyllus* and *A. manihot* had significantly lower jassid nymphal population, i.e. 2.89 and 4.07 nymphs per leaf, respectively followed by *A. angulosus* and *A. moschatus* (5.89-7.75) as compared to other genotypes (8.13-22.88 nymphs per leaf).

At the end of crop season from 84-98 DAS, overall nymphal population declined and varied levels of population were observed among different entries. The reason could be the exhaustion of the crop in some entries due to severe hopper burn symptoms and shifting of the population from these exhausted entries to the entries with least hopper burns and comparatively better foliage.

Table 2. Mean population of jassid nymphs at weekly intervals in different germplasm of okra during 2015

Entry	Nymphal population per leaf (days after sowing)														
	7	14	21	28	35	42	49	56	63	70	77	84	91	98	Pooled mean
IC0506027	0.00	0.00	0.20 (1.09)	0.53 (1.23)	0.73 (1.30)	1.44 (1.55)	2.93 (1.97)	7.47 (2.89)	5.76 (2.59)	6.38 (2.72)	11.57 (3.54)	4.36 (2.31)	2.72 (1.92)	1.62 (1.62)	3.26 (1.91)
IC0506118	0.00	0.00	0.38 (1.17)	0.40 (1.18)	1.11 (1.44)	2.62 (1.90)	3.20 (2.05)	9.93 (3.29)	6.09 (2.64)	9.53 (3.23)	22.00 (4.79)	1.53 (1.58)	1.22 (1.49)	1.40 (1.54)	4.24 (2.02)
EC0306728	0.00	0.00	0.35 (1.16)	0.49 (1.22)	2.13 (1.76)	3.26 (2.06)	3.95 (2.22)	11.04 (3.41)	8.33 (3.05)	8.66 (3.09)	8.13 (3.02)	3.73 (2.17)	1.82 (1.68)	1.44 (1.56)	3.81 (2.03)
<i>Abelmoschus tuberculatus</i>	0.00	0.00	0.00 (1.00)	0.93 (1.38)	1.15 (1.44)	1.62 (1.61)	2.66 (1.89)	8.51 (3.03)	5.42 (2.53)	4.84 (2.42)	10.07 (3.32)	9.76 (3.27)	1.87 (1.69)	2.47 (1.86)	3.52 (1.96)
<i>Abelmoschus moschatus</i>	0.00	0.00	0.00 (1.00)	0.22 (1.10)	2.41 (1.84)	1.27 (1.50)	1.55 (1.59)	1.27 (1.50)	1.27 (1.50)	2.27 (1.81)	7.75 (2.96)	5.73 (2.59)	2.09 (1.75)	1.98 (1.72)	1.99 (1.63)
<i>Abelmoschus angulosus</i>	0.00	0.00	0.00 (1.00)	0.38 (1.16)	0.98 (1.40)	1.33 (1.52)	2.29 (1.80)	2.22 (1.79)	1.46 (1.56)	1.80 (1.67)	5.89 (2.62)	5.64 (2.56)	1.25 (1.49)	0.84 (1.35)	1.72 (1.57)
<i>Abelmoschus tetraphyllus</i>	0.00	0.00	0.00 (1.00)	0.00 (1.00)	0.31 (1.14)	0.98 (1.40)	1.44 (1.55)	2.56 (1.87)	1.53 (1.59)	2.07 (1.75)	2.89 (1.96)	5.60 (2.57)	2.88 (1.94)	1.56 (1.59)	1.56 (1.53)
<i>Abelmoschus manihot</i>	0.00	0.00	0.00 (1.00)	0.22 (1.09)	1.07 (1.39)	1.22 (1.49)	1.98 (1.72)	3.06 (2.01)	3.80 (2.19)	9.07 (3.17)	4.07 (2.24)	2.19 (1.78)	1.00 (1.41)	1.02 (1.42)	2.05 (1.64)
<i>Abelmoschus caillei</i>	0.00	0.00	0.00 (1.00)	1.45 (1.53)	2.74 (1.88)	3.62 (2.14)	11.42 (3.52)	15.42 (4.04)	13.69 (3.83)	17.23 (4.27)	20.62 (4.65)	8.13 (3.02)	3.80 (2.19)	2.48 (1.85)	7.19 (2.57)
POL-6	0.00	0.00	0.42 (1.19)	4.66 (2.29)	6.95 (2.82)	12.39 (3.67)	16.27 (4.14)	15.69 (4.08)	11.75 (3.57)	17.22 (4.27)	18.33 (4.39)	8.40 (3.06)	1.49 (1.57)	1.09 (1.44)	8.19 (2.75)
POL-7	0.00	0.00	0.29 (1.13)	3.31 (2.07)	8.24 (3.03)	18.18 (4.37)	18.86 (4.45)	20.73 (4.66)	14.42 (3.92)	26.82 (5.27)	17.95 (4.35)	4.69 (2.37)	2.51 (1.87)	2.04 (1.74)	9.86 (2.95)
Punjab 8	0.00	0.00	0.33 (1.15)	2.22 (1.76)	10.14 (3.32)	13.13 (3.76)	15.93 (4.11)	15.55 (4.07)	17.71 (4.32)	22.42 (4.83)	17.55 (4.30)	11.33 (3.51)	3.62 (2.14)	1.49 (1.58)	9.39 (2.92)
Punjab Padmini	0.00	0.00	0.26 (1.12)	2.55 (1.88)	8.17 (3.02)	8.00 (2.99)	10.31 (3.36)	18.85 (4.45)	11.31 (3.50)	17.62 (4.31)	22.88 (4.88)	10.78 (3.43)	3.29 (2.06)	1.76 (1.65)	8.27 (2.76)
Punjab 7	0.00	0.00	0.29 (1.13)	3.24 (2.05)	9.11 (3.12)	12.20 (3.62)	19.66 (4.54)	11.04 (3.46)	11.73 (3.57)	25.93 (5.17)	19.02 (4.47)	13.31 (3.78)	4.44 (2.33)	2.04 (1.74)	9.43 (2.93)
Pusa Sawani	0.00	0.00	0.40 (1.18)	5.37 (2.50)	12.09 (3.62)	26.37 (5.23)	30.35 (5.59)	24.11 (5.01)	21.17 (4.71)	29.09 (5.48)	22.29 (4.82)	16.82 (4.22)	5.13 (2.47)	2.44 (1.85)	13.97 (3.48)
SE	0.000	0.000	0.004	0.071	0.107	0.023	0.371	0.097	0.025	0.546	0.033	0.026	0.029	0.009	0.037
CD (p=0.05)	NS	NS	(0.11)	(0.45)	(0.55)	(0.25)	(0.32)	(0.52)	(0.26)	(0.39)	(0.30)	(0.27)	(0.28)	(0.17)	0.08
CV%	0.00	0.00	6.01	17.06	15.08	5.80	6.48	9.41	5.23	6.56	4.86	5.73	9.09	6.07	8.32

Figures in parentheses are $\sqrt{n + 1}$ transformed

The pooled data indicated that all the germplasm entries differed significantly with respect to the mean jassid nymphal population. Out of six *Abelmoschus* spp., *A. tetraphyllus* followed by *A. angulosus*, *A. moschatus* and *A. manihot* registered significantly lower jassid population (1.56-2.05 nymphs per leaf). Moderate jassid population was observed in accessions: IC0506027, EC0306728 and IC0506118, and *A. tuberculatus* (3.26-4.24 nymphs). The other genotypes and cultivated varieties were observed with significantly higher jassid nymphal population (7.19-13.97 nymphs per leaf). However, Pusa Sawani was recorded with the maximum jassid population (13.97 nymphs per leaf).

4.1.2 Jassid injury index

The data regarding jassid injury index of various entries of okra at weekly intervals during crop season is given in Table 3. No jassid injury was observed in all the okra entries till 21 DAS. Afterwards, the jassid infestation increased till the end of the crop season. From 28 to 42 DAS, consistently and significantly lower jassid injury index (1.00-1.05, 1.00-1.09 and 1.00-1.28 at 28, 35 and 42 DAS respectively) was observed in all the *Abelmoschus* spp.: *A. tetraphyllus*, *A. moschatus*, *A. angulosus*, *A. manihot*, *A. tuberculatus* and *A. caillei*, and in accessions: IC0506118 and IC0506027 as compared to accession EC0306728; other two genotypes and cultivated varieties (1.19-1.34, 1.26-1.51, and 1.29-2.76 jassid injury index) at 28, 35 and 42 DAS, respectively. Pusa Sawani exhibited significantly higher jassid injury index (1.34-2.76) during this period.

Out of six *Abelmoschus* spp., significantly and consistently lowest injury was registered in *A. moschatus*, *A. tetraphyllus* and *A. angulosus* from 49-98 DAS with injury grade ranging from 1.07-1.59, 1.00-1.84 and 1.07-1.93, respectively. Consistently significant and higher jassid injury index was recorded in two genotypes: POL-6 (2.32-2.84) and POL-7 (2.87-3.20) and cultivated varieties: Pusa Sawani (2.77-3.30), Punjab 7 (2.36-2.84), Punjab Padmini (2.49-2.74) and Punjab 8 (2.54-3.03) from 49 to 98 DAS. Highest jassid injury was recorded in Pusa Sawani (1.34-3.30) followed by POL-7 (1.32-3.20) throughout the season. The injury index in different entries during peak activity period of jassid (63 DAS) is given in Plates 2(a), 2(b) and 2(c). Other *Abelmoschus* spp.: *A. manihot* and *A. tuberculatus* and accession IC0506027 exhibited moderate jassid injury index ranging from 1.18-1.27, 1.23-1.46 and 1.22-1.46, respectively from 49 to 63 DAS. Afterwards, jassid injury index increased in *A. tuberculatus*, *A. manihot* and IC0506027 also and continued to increase throughout the season. The remaining entries, *A. caillei*, IC0506118 and EC0306728 also showed significantly higher jassid injury ranging from 1.50-3.15, 1.32-2.81 and 1.30-2.42, respectively throughout the season (49-98 DAS), but it was lower than in other genotypes and cultivated varieties.

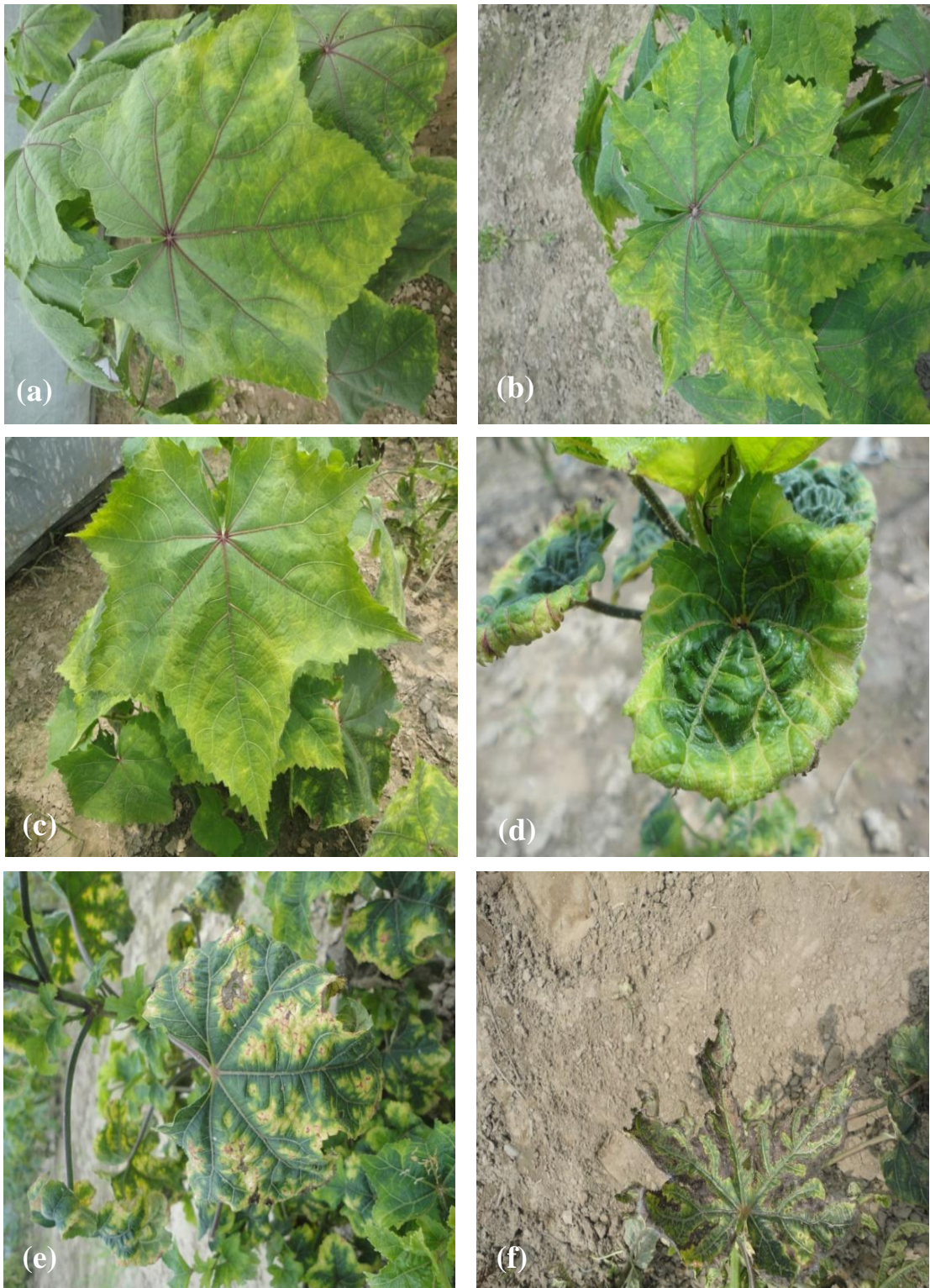


Plate 2(a): Reaction of *Abelmoschus* spp. i.e. (a) *A. moschatus*, (b) *A. angulosus*, (c) *A. tetraphyllus*, (d) *A. manihot*, (e) *A. tuberculatus*, (f) *A. caillei* to the jassid injury during the peak activity period of jassid (63 DAS)

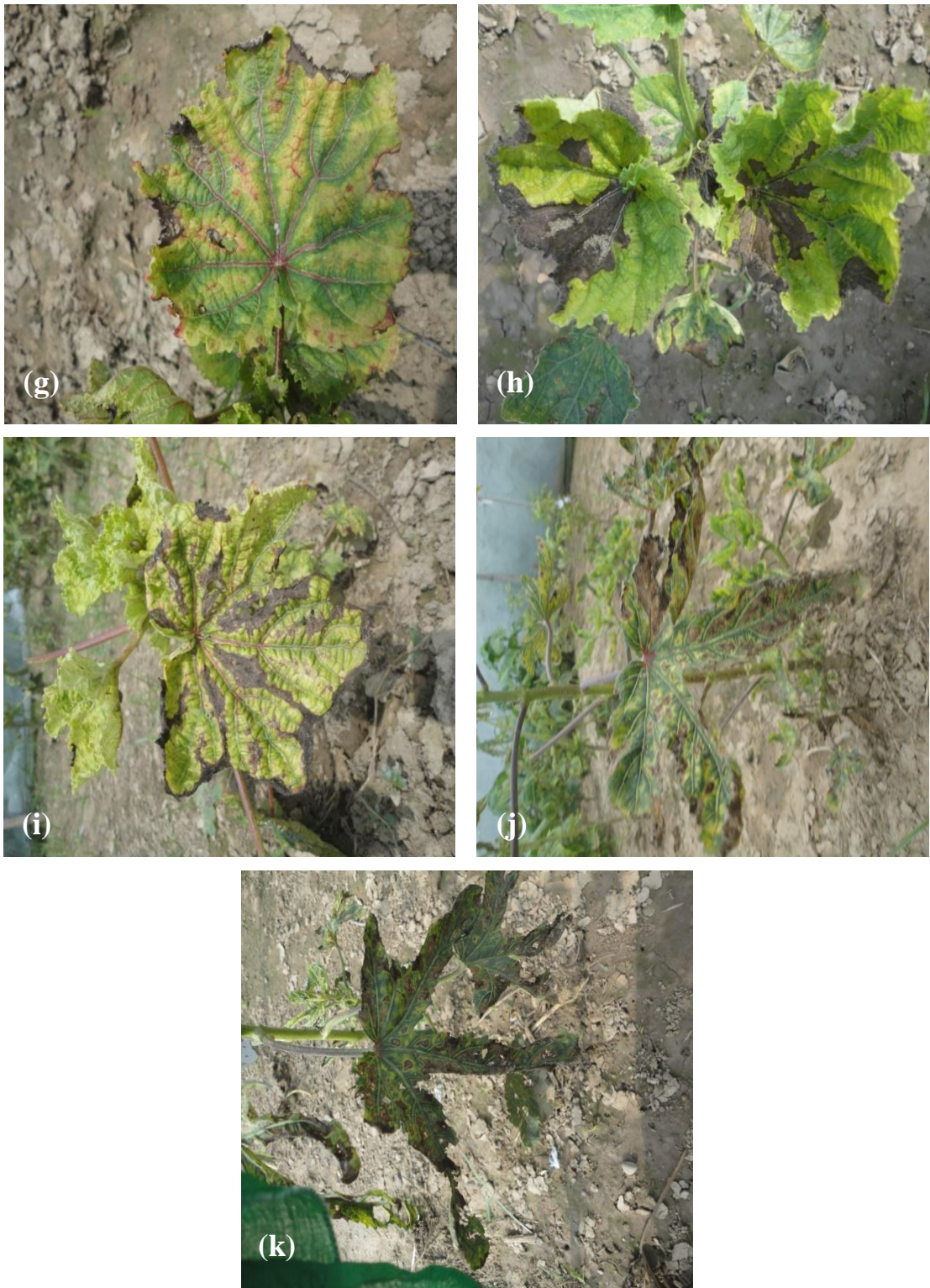


Plate 2(b): Reaction of accessions and genotypes i.e. (g) IC0506027, (h) EC0306728, (i) IC0506118, (j) POL-6, (k) POL-7 to the jassid injury during peak activity period of jassid (63 DAS)

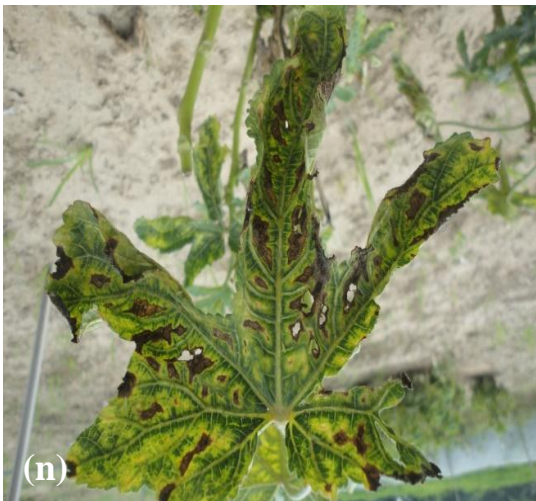
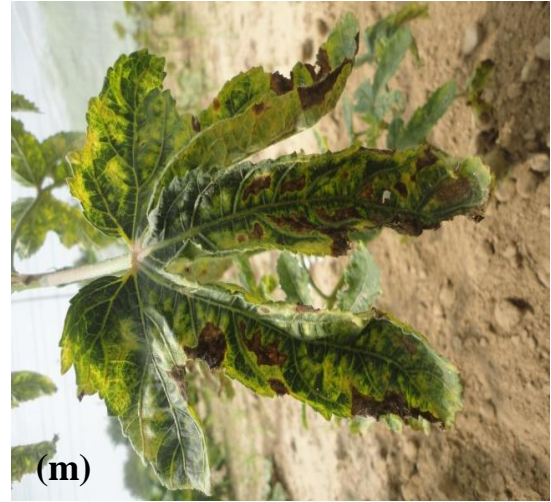


Plate 2(c): Reaction of cultivated okra varieties i.e. (l) Punjab 8, (m) Punjab Padmini, (n) Punjab 7, (o) Pusa Sawani to jassid injury during the peak activity period of jassid (63 DAS)

Table 3. Mean jassid injury index in different germplasm of okra during 2015

Entry	Jassid injury index (days after sowing)														Pooled mean
	7	14	21	28	35	42	49	56	63	70	77	84	91	98	
IC0506027	1.00	1.00	1.00	1.05	1.09	1.17	1.22	1.33	1.46	2.28	2.25	2.49	2.59	2.61	1.59
IC0506118	1.00	1.00	1.00	1.03	1.05	1.09	1.32	2.03	2.18	2.51	2.49	2.67	2.73	2.81	1.75
EC0306728	1.00	1.00	1.00	1.19	1.26	1.29	1.30	1.54	1.69	1.99	2.41	2.35	2.42	2.36	1.61
<i>Abelmoschus tuberculatus</i>	1.00	1.00	1.00	1.00	1.04	1.14	1.23	1.46	1.38	1.84	2.01	2.98	2.97	2.99	1.65
<i>Abelmoschus moschatus</i>	1.00	1.00	1.00	1.00	1.01	1.02	1.07	1.11	1.14	1.20	1.22	1.44	1.46	1.59	1.16
<i>Abelmoschus angulosus</i>	1.00	1.00	1.00	1.00	1.01	1.04	1.07	1.10	1.11	1.29	1.50	1.93	1.86	1.90	1.27
<i>Abelmoschus tetraphyllus</i>	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.07	1.13	1.54	1.53	1.67	1.80	1.84	1.25
<i>Abelmoschus manihot</i>	1.00	1.00	1.00	1.00	1.00	1.04	1.18	1.22	1.27	1.99	2.36	2.64	2.71	2.75	1.58
<i>Abelmoschus caillei</i>	1.00	1.00	1.00	1.00	1.07	1.28	1.50	1.97	2.23	2.57	2.74	2.99	3.11	3.15	1.90
POL-6	1.00	1.00	1.00	1.30	1.31	2.32	2.32	2.71	2.84	2.66	2.59	2.71	2.76	2.84	2.09
POL-7	1.00	1.00	1.00	1.32	1.29	1.85	3.09	3.12	3.20	2.93	2.87	2.89	2.91	2.95	2.24
Punjab 8	1.00	1.00	1.00	1.19	1.45	2.36	2.67	2.77	2.80	2.63	2.54	2.87	2.95	3.03	2.16
PunjabPadmini	1.00	1.00	1.00	1.23	1.27	1.91	2.49	2.63	2.74	2.63	2.62	2.61	2.69	2.70	2.04
Punjab 7	1.00	1.00	1.00	1.29	1.33	2.15	2.36	2.47	2.54	2.59	2.66	2.77	2.82	2.84	2.06
PusaSawani	1.00	1.00	1.00	1.34	1.51	2.76	3.24	3.30	3.03	2.77	2.82	2.95	2.87	2.90	2.32
SE	0.000	0.000	0.000	0.005	0.009	0.033	0.062	0.075	0.069	0.053	0.029	0.075	0.042	0.044	0.035
CD(p=0.05)	NS	NS	NS	0.11	0.12	0.30	0.41	0.46	0.44	0.39	0.29	0.46	0.34	0.35	0.30
CV%	0.00	0.00	0.00	5.99	6.18	11.57	13.53	13.79	12.87	10.36	7.49	10.80	7.99	7.97	10.59

The pooled data indicated the same trend of jassid injury in all the germplasm entries with significantly lower injury grade (1.16-1.27) in *A. moschatus*, *A. tetraphyllus*, *A. angulosus* followed by moderate injury index (1.58-1.75) in *A. manihot*, *A. tuberculatus*; and accessions, IC0506027, IC0506118 and EC0306728. While, cultivated variety Pusa Sawani and genotype POL-7 exhibited significantly highest jassid injury index (2.32 and 2.24, respectively).

4.1.3 Susceptibility index:

The susceptibility index in different entries (Table 4) was nil up to 14 DAS. Afterwards, significantly and consistently lowest susceptibility index was registered in *A. angulosus* (0.00-2.45) followed by *A. moschatus* (0.00-2.72) and *A. tetraphyllus* (0.00-3.18) and moderate susceptibility index in *A. tuberculatus* (0.00-13.07) and *A. manihot* (0.00-17.77) followed by accessions: IC0506027 (0.20-14.61), EC0306728 (0.35-17.20) and IC0506118 (0.38-25.01) during 21-70 DAS. The entries with moderate susceptibility index at 77 DAS also showed low susceptibility index later in the season.

When the crop was 77 days old, the susceptibility index increased in almost all the accessions (19.66-54.89) and *Abelmoschus* spp. (8.92-56.30) except *A. tetraphyllus* (4.46) and it remained low till the end of the crop season. Significantly highest susceptibility index was recorded in Pusa Sawani (0.40-98.05) followed by POL-7 (0.29-78.54), Punjab 7 (0.29-67.91), Punjab Padmini (0.26-60.02), Punjab 8 (0.33-58.86), and POL-6 (0.42-47.48) in the descending order during the crop season. The highest susceptibility index was observed for Pusa Sawani (98.05) at 49 DAS followed by POL-7 (78.54) at 70 DAS, Punjab 7 (67.91) at 70 DAS, Punjab Padmini (60.02) at 77 DAS, Punjab 8 (58.86) at 70 DAS, and POL-6 (47.48) at 77 DAS. The susceptibility index reduced in susceptible *Abelmoschus* spp. *A. caillei* and *A. tuberculatus*; the three accessions: IC0506027, IC0506118 and EC0306728; two genotypes and all the cultivars during the end of the crop season. The reason may be that the reduction of the pest population in these entries owing to severe hopper burn symptoms and such leaves might not be able to support the pest population further. The susceptibility index was also reduced in *A. moschatus* (9.47 to 3.05) from 77 to 98 DAS, *A. manihot* (17.77 to 2.68) from 70 to 98 DAS, *A. angulosus* (10.53 to 1.60) from 84 to 98 DAS and *A. tetraphyllus* (9.34 to 2.89) from 84 to 98 DAS. The reason for reduction in the susceptibility index of the resistant and moderately resistant *Abelmoschus* spp. was different from the susceptible entries. In the case of low to moderately resistant genotypes, the plants were comparatively in good condition indicating some sort of antibiosis mechanism operating behind this.

Table 4. Mean susceptibility index of jassid in different germplasm of okra during 2015

Entry	Susceptibility index* (days after sowing)														Pooled mean
	7	14	21	28	35	42	49	56	63	70	77	84	91	98	
IC0506027	0.00	0.00	0.20 (1.09)	0.56 (1.25)	0.88 (1.37)	1.68 (1.62)	3.58 (2.13)	10.09 (3.27)	8.14 (3.02)	14.61 (3.94)	26.25 (5.20)	10.96 (3.44)	7.06 (2.83)	4.21 (2.28)	7.35 (2.62)
IC0506118	0.00	0.00	0.38 (1.17)	0.41 (1.19)	1.17 (1.47)	2.87 (1.96)	4.23 (2.28)	19.69 (4.54)	13.27 (3.73)	25.01 (4.99)	54.89 (7.46)	4.11 (2.26)	3.34 (2.08)	3.96 (2.22)	11.11 (2.95)
EC0306728	0.00	0.00	0.35 (1.16)	0.58 (1.25)	2.69 (1.90)	4.14 (2.26)	5.15 (2.47)	17.20 (4.16)	13.83 (3.82)	16.75 (4.21)	19.66 (4.53)	8.79 (3.11)	4.37 (2.31)	3.27 (2.07)	8.06 (2.77)
<i>Abelmoschus tuberculatus</i>	0.00	0.00	0.00 (1.00)	0.93 (1.38)	1.16 (1.45)	1.81 (1.67)	3.24 (2.03)	13.07 (3.64)	7.46 (2.89)	8.83 (3.13)	20.26 (4.60)	29.26 (5.48)	5.54 (2.56)	7.38 (2.89)	8.25 (2.73)
<i>Abelmoschus moschatus</i>	0.00	0.00	0.00 (1.00)	0.22 (1.10)	2.44 (1.85)	1.28 (1.50)	1.66 (1.63)	1.39 (1.54)	1.44 (1.56)	2.72 (1.93)	9.47 (3.23)	8.26 (3.04)	3.05 (2.01)	3.12 (2.02)	2.92 (1.87)
<i>Abelmoschus angulosus</i>	0.00	0.00	0.00 (1.00)	0.38 (1.16)	0.98 (1.40)	1.40 (1.54)	2.44 (1.85)	2.45 (1.85)	1.62 (1.61)	2.28 (1.81)	8.92 (3.13)	10.53 (3.38)	2.32 (1.82)	1.60 (1.61)	2.91 (1.85)
<i>Abelmoschus tetraphyllus</i>	0.00	0.00	0.00 (1.00)	0.00 (1.00)	0.31 (1.14)	0.98 (1.40)	1.44 (1.55)	2.73 (1.92)	1.73 (1.65)	3.18 (2.04)	4.46 (2.32)	9.34 (3.21)	5.37 (2.46)	2.89 (1.96)	2.70 (1.81)
<i>Abelmoschus manihot</i>	0.00	0.00	0.00 (1.00)	0.22 (1.09)	1.07 (1.39)	1.26 (1.50)	2.34 (1.82)	3.73 (2.17)	4.79 (2.40)	17.77 (4.32)	9.60 (3.23)	5.81 (2.60)	2.68 (1.91)	2.78 (1.94)	4.34 (2.12)
<i>Abelmoschus caillei</i>	0.00	0.00	0.00 (1.00)	1.45 (1.53)	2.99 (1.94)	4.75 (2.38)	17.30 (4.25)	30.03 (5.55)	30.76 (5.61)	44.32 (6.72)	56.30 (7.57)	24.25 (5.02)	11.84 (3.58)	7.80 (2.96)	19.32 (4.01)
POL-6	0.00	0.00	0.42 (1.19)	6.13 (2.57)	9.16 (3.18)	28.49 (5.43)	38.72 (6.22)	42.57 (6.60)	33.40 (5.86)	45.79 (6.84)	47.48 (6.96)	22.90 (4.88)	4.10 (2.25)	3.10 (2.02)	23.52 (4.50)
POL-7	0.00	0.00	0.29 (1.13)	4.36 (2.31)	10.54 (3.39)	33.55 (5.87)	58.49 (7.69)	64.60 (8.09)	46.29 (6.86)	78.54 (8.91)	51.56 (7.25)	13.58 (3.79)	7.35 (2.87)	6.04 (2.65)	31.26 (5.07)
Punjab 8	0.00	0.00	0.33 (1.15)	2.77 (1.88)	14.75 (3.95)	30.85 (5.63)	42.48 (6.59)	43.04 (6.63)	49.46 (7.10)	58.86 (7.72)	44.61 (6.75)	32.62 (5.79)	10.62 (3.40)	4.51 (2.34)	27.91 (4.91)
Punjab Padmini	0.00	0.00	0.26 (1.12)	3.18 (2.03)	10.32 (3.36)	15.26 (4.03)	25.72 (5.16)	49.31 (7.09)	30.75 (5.61)	46.40 (6.88)	60.02 (7.81)	28.02 (5.38)	8.71 (3.11)	4.67 (2.37)	23.55 (4.50)
Punjab 7	0.00	0.00	0.29 (1.13)	4.29 (2.27)	12.08 (3.55)	26.15 (5.19)	46.50 (6.88)	27.39 (5.31)	29.80 (5.55)	67.91 (8.25)	50.49 (7.17)	36.96 (6.15)	12.60 (3.67)	5.79 (2.60)	26.69 (4.81)
Pusa Sawani	0.00	0.00	0.40 (1.18)	7.36 (2.85)	18.27 (4.39)	72.76 (8.58)	98.05 (9.94)	79.34 (8.96)	64.40 (8.08)	80.42 (9.02)	62.73 (7.98)	49.65 (7.11)	14.77 (3.96)	7.05 (2.84)	46.27 (6.24)
SE	0.000	0.000	0.004	0.108	0.139	0.063	0.229	0.266	0.132	0.264	0.122	0.120	0.094	0.023	0.130
CD(p=0.05)	NS	NS	(0.11)	(0.55)	(0.62)	(0.42)	(0.80)	(0.86)	(0.61)	(0.86)	(0.58)	(0.58)	(0.51)	(0.25)	(0.17)
CV%	0.00	0.00	6.01	19.79	15.68	7.44	11.51	10.85	8.32	9.54	6.15	8.05	11.26	6.55	10.27

* Susceptibility index = Product of jassid nymphal population and jassid injury index

Figures in parentheses are $\sqrt{n + 1}$ transformed

The pooled data indicated that a significantly lower susceptibility index in *A. tetraphyllus* (2.70), *A. angulosus* (2.91) and *A. moschatus* (2.92). Moderate susceptibility index was registered in *A. manihot* (4.34), IC0506027 (7.35), EC0306728 (8.06) and *A. tuberculatus* (8.25). Significantly highest susceptibility index was recorded in Pusa Sawani (46.27) followed by POL-7 (31.26), Punjab 8 (27.91), Punjab 7 (26.69), Punjab Padmini (23.55), POL-6 (23.52), *A. caillei* (19.32) and IC0506118 (11.11) in the descending order.

4.1.4 Correlation among jassid nymphal population, jassid injury index and susceptibility index

No correlation among jassid nymphal population, jassid injury index and susceptibility index was there till 14 DAS. The mean jassid nymphal population had a positive and highly significant correlation with jassid injury index (0.77-0.94) from 28 to 77 DAS (Table 5). The coefficient of determination was also very high in the range of 59-88 per cent during this period. However, after 77 DAS, the correlation values were non-significant (0.33-0.35) which may be due to low jassid population in the crop. The overall correlation among these parameters was positive and significant (0.64) with 41 per cent coefficient of determination.

Similarly, the nymphal population exhibited a very strong positive correlation with the susceptibility index at weekly intervals (0.94-1.00) with coefficient of determination from 88 to 100 per cent during 21-98 DAS, except for the first two weeks where no nymphal population was observed owing to the rainfall. The overall correlation between nymphal population and susceptibility index was positive and highly significant (0.98) with 96 per cent coefficient of determination.

A positive and highly significant correlation between jassid injury index and susceptibility index was obtained with correlation values ranging from 0.84 to 0.96 with the coefficient of determination from 71 to 92 per cent from 28 to 77 DAS. In the last phase of the crop (84-98 DAS), correlation was found positive and significant with correlation values from 0.56 to 0.70 with comparatively lower coefficient of determination (31 to 49 per cent) may be due of low level of population in different entries during that period. Overall correlation between jassid injury index and susceptibility index was 0.69 with 48 per cent of coefficient of determination.

The above data revealed that there was a direct relationship among mean jassid nymphal population, jassid injury index and susceptibility index of all the germplasm entries. Present findings are supported by Lal (1989) and Dhillon (1997) who also reported the positive and significant correlation among jassid nymphal population, jassid injury index and susceptibility index. Out of the 15 entries, *A. tetraphyllus* registered the lowest jassid

Table 5. Correlation among jassid nymphal population, jassid injury index and susceptibility index

Parameter	Correlation values (days after sowing)														Overall correlation	
	7	14	21	28	35	42	49	56	63	70	77	84	91	98		
Nymphal population	r:	0.00	0.00	0.00	0.89*	0.93*	0.92*	0.93*	0.94*	0.90*	0.86*	0.77*	0.34	0.33	0.35	0.64*
vs																
Injury index	R:	0.00	0.00	0.00	0.79	0.86	0.85	0.86	0.88	0.81	0.74	0.59	0.12	0.11	0.12	0.41
Nymphal population	r:	0.00	0.00	1.00	0.99*	0.99*	0.98*	0.98*	0.97*	0.98*	0.99*	0.99*	0.98*	0.96*	0.94*	0.98*
vs																
Susceptibility index	R:	0.00	0.00	1.00	0.98	0.98	0.96	0.96	0.94	0.96	0.98	0.98	0.96	0.92	0.88	0.96
Injury index	r:	0.00	0.00	0.00	0.89*	0.94*	0.92*	0.94*	0.96*	0.93*	0.88*	0.84*	0.57*	0.56*	0.70*	0.69*
vs																
Susceptibility index	R:	0.00	0.00	0.00	0.79	0.88	0.85	0.88	0.92	0.86	0.77	0.71	0.32	0.31	0.49	0.48

r - Correlation coefficient, R - Coefficient of Determination

*Significant, $n_{df, \alpha}$ (13, $p = 0.05$), $r_{0.05 | tab|} = 0.51$

population followed by *A. angulosus*, *A. moschatus* and *A. manihot*. The *Abelmoschus* spp.: *A. tuberculatus* and accessions: IC0506027, EC0306728, and IC0506118 harbored the moderate jassid population. The significantly lower jassid injury index and susceptibility index were observed in *A. moschatus*, *A. tetraphyllus* and *A. angulosus* followed by moderate injury index and susceptibility index in *A. manihot*, *A. tuberculatus*; and accessions, IC0506027 and EC0306728 except IC0506118 in which significantly higher susceptibility index was observed. The *Abelmoschus* spp.: *A. caillei* had significantly higher jassid nymphal population, injury index and susceptibility index. The present findings are in conformity with the other workers viz. Singh *et al* (2007) who reported *A. angulosus* and *A. moschatus* as tolerant to jassid and Prabhu *et al* (2009) who also reported *A. moschatus* as resistant, *A. manihot* and *A. tetraphyllus* as tolerant and *A. caillei* as susceptible to jassid. However, Gangopadhyay *et al* (2016) reported *A. caillei*, *A. moschatus*, *A. manihot* and *A. tuberculatus* as resistant to jassid. Although, the jassid nymphal population was significantly lower in case of *A. manihot* but its susceptibility index was observed to be moderate. These results are in agreement with the findings of Sandhu *et al* (1974) who also reported the moderate degree of resistance in *A. manihot* and *A. tuberculatus*. One accession IC0506118, genotypes POL-6 and POL-7 and all the cultivated varieties showed higher susceptibility index under field conditions. However, these findings are contradictory to the findings of other workers who reported Punjab Padmini as moderately resistant (Lal 1989, Gonde *et al* 2013) and Punjab 8 as tolerant (Anonymous 2015b). In the present studies, Pusa Sawani harbored the highest jassid nymphal population, injury index and susceptibility index which is in conformity with the findings of Mahal (1973), Uthamasamy (1986), Singh (1988), Mahal *et al* (1993), Hooda *et al* (1997), Sharma and Sharma (1997a), Sharma *et al* (2001), Kumar and Singh (2002), Iqbal *et al* (2008) and Gonde *et al* (2013) who also reported it as highly susceptible.

4.2 Determination of basis of resistance in okra germplasm against jassid

4.2.1 Morphological studies

The different morphological parameters such as hair density, hair length, angle of insertion of hair and lacination index of leaves of different okra entries were observed. The hair density and hair length on the mid vein of leaves of different entries were observed under SEM during the peak activity period of jassid (56 DAS). The angle of insertion of hair was measured with the help of Axio Ai Zeiss Microscope using software Axiovision Release 4.7.2. The results are discussed as follows:

4.2.1.1 Hair density

High hair density was recorded in *A. angulosus* (7.50) followed by *A. tuberculatus* (5.08), *A. moschatus* (5.00) and *A. tetraphyllus* (4.75) which imparted moderate to high field resistance to jassid. Moderate hair density (2.56-3.31) was recorded in POL-7, IC0506027, IC0506118, Punjab

8, POL-6, and *A. manihot*. However, lower hair density (1.17-1.89) was found in EC0306728, *A. caillei*, Punjab 7, Punjab Padmini, and Pusa Sawani (Table 6) and Plate 3(a), 3(b) and 3(c).

The jassid nymphal population, injury index and susceptibility index all had a negative and significant correlation with hair density (-0.67, -0.59 and -0.56, respectively) with coefficient of determination 45, 35 and 31 per cent, respectively (Table 7). Similarly, the negative correlation between mean jassid population and leaf hair density was reported by many workers (Singh and Singh 2005, Anitha and Nandihalli 2009, Iqbal *et al* 2011b, Ullah *et al* 2012, Halder *et al* 2016 in okra; Khan and Agarwal 1984, Ali *et al* 1995b, Bashir *et al* 2001 in cotton; and Cassi-Lit and Bernardo 1990, Taylo and Bernardo 1995, Muhammad *et al* 2012 in brinjal). Dhillon (1997) also reported a negative and significant correlation between hair density on mid-vein and jassid injury indices in okra.

The *Abelmoschus* spp., *A. angulosus*, *A. tuberculatus*, *A. moschatus* and *A. tetraphyllus* which showed moderate to high field resistance had the high hair density. Out of other entries: IC0506027, EC0306728 and *A. manihot* which showed moderate degree of resistance in the field, IC0506027 and *A. manihot* also had moderate hair density except EC0306728 which exhibited lower hair density. The susceptible genotypes, *A. caillei*, POL-6, POL-7, Punjab Padmini, Punjab 7 and Pusa Sawani had comparatively lower hair density except Punjab 8 which had comparatively moderate hair density. From the data, it is clear that higher hair density plays an important role in imparting field resistance to jassid by hindering the oviposition and feeding behavior of the pest. In the present study, Pusa Sawani was found to be highly susceptible to jassid and had the lower hair density which is in line with the work of many workers who reported low hair density on mid veins of Pusa Sawani leaves (Mahal 1993, Hooda *et al* 1997, Dhankhar and Mishra 2001, Thakur *et al* 2003). Lal (1989) also reported that hair were more dense on the resistant varieties IC-7194 and New selection than those on the susceptible Pusa Sawani, Punjab Padmini, P-7 and Sel-2-2.

4.2.1.2 Hair length

The data regarding hair length (μm) in different okra entries is given in Table 6 and Plate 3(a), 3(b) and 3(c). The longest hair ($>1000 \mu\text{m}$ hair length) were registered in *A. moschatus* (1513.20 μm) followed by *A. angulosus* (1418.00 μm), and *A. tetraphyllus* (1285 μm). Moderate hair length (between 500-1000 μm hair length) was observed in Pusa Sawani (757.60 μm), Punjab 7 (711.20 μm), POL-7 (704.80 μm), EC0306728 (626.40 μm), Punjab 8 (617.60 μm), IC0506027 (544.40 μm), *A. caillei* (537.40 μm), and POL-6 (508.20 μm). However, the short hair ($< 500 \mu\text{m}$ hair length) were recorded in *A. tuberculatus* (328.20 μm), *A. manihot* (404 μm), IC0506118 (427 μm) and Punjab Padmini (437 μm).

The jassid nymphal population, jassid injury index and susceptibility index all had a negative but non-significant correlation with hair length (- 0.48, - 0.38 and - 0.33, respectively) with coefficient of determination of 23, 14 and 11 per cent, respectively (Table 7). The present findings are supported by many workers (Hooda *et al* 1997, Singh and Singh 2005, Iqbal *et al* 2011b in okra; Ali *et al* 1995b, Dhillon 1997 in cotton, and Cassi-Lit and Bernardo 1990, Taylo and Bernardo 1995, Muhammad *et al* 2012 in brinjal).

The *Abelmoschus* spp.: *A. moschatus*, *A. angulosus* and *A. tetraphyllus* showing high field resistance also had longer hair than the other germplasm entries. These results are in agreement with Lal (1989) who reported that resistant varieties: IC-7194 and New Selection had longer hair than susceptible variety Pusa Sawani. On the other hand, IC0506027, *A. manihot*, EC0306728, and *A. tuberculatus* which showed moderate degree of resistance in the field had comparatively short to moderate hairs as compared to susceptible entries. This indicates that the other morphological and biochemical factors rather than the hair length may be responsible for the field resistance in these entries.

4.2.1.3 Angle of insertion of hair

The angle of insertion of hair on mid-vein of okra leaves showed significant differences among different entries (Table 6). Comparatively wider angle of insertion of hair was observed in *A. angulosus* (95.20°) followed by *A. tetraphyllus* (86.73°) and *A. moschatus* (83.40°). In these *Abelmoschus* spp., hairs were almost erect in nature (angle > 60°). Whereas, less erect hair (angle between 30 to 60°) were observed in two *Abelmoschus* spp.: *A. caillei* and *A. manihot*; accessions: IC0506027, IC0506118 and EC0306728; other genotypes: POL-6 and POL-7 and all cultivated varieties: Pusa Sawani, Punjab 7, Punjab 8, and Punjab Padmini (37.94°-52.66°). Least erect hair (angle < 30°) were recorded in *A. tuberculatus* (27.99°).

The jassid nymphal population, jassid injury index and susceptibility index all had a negative correlation with angle of insertion of hair (- 0.55, - 0.47 and - 0.42, respectively) with coefficient of determination 30, 22 and 18 per cent, respectively which was significant only in case of jassid nymphal population (Table 7). The present results are in tune with the results of Dhillon (1997) also reported a negative and significant correlation between angle of insertion of hair on mid vein and mean jassid injury indices.

Table 6. Morphological characteristics of okra germplasm during peak activity of jassid (56 DAS)

Entry	Hair density*	Hair length (μm)**	Angle of insertion ($^{\circ}$)***	Lacination index	Shape
IC0506027	2.79 \pm 0.97	544.40 \pm 35.60	48.20 \pm 0.83	0.39	Broad
IC0506118	2.83 \pm 2.02	427.00 \pm 25.17	49.02 \pm 0.17	0.38	Broad
EC0306728	1.17 \pm 0.34	626.40 \pm 21.33	52.66 \pm 2.08	0.44	Broad
<i>Abelmoschus tuberculatus</i>	5.08 \pm 1.76	328.20 \pm 54.21	27.99 \pm 0.71	0.49	Broad
<i>Abelmoschus moschatus</i>	5.00 \pm 0.00	1513.20 \pm 511.31	83.40 \pm 2.14	0.47	Broad
<i>Abelmoschus angulosus</i>	7.50 \pm 0.71	1418.00 \pm 238.49	95.20 \pm 5.83	0.54	Broad
<i>Abelmoschus tetraphyllus</i>	4.75 \pm 1.06	1285.00 \pm 152.15	86.73 \pm 5.76	0.47	Broad
<i>Abelmoschus manihot</i>	3.31 \pm 1.08	404.00 \pm 47.23	38.98 \pm 1.65	0.33	Broad
<i>Abelmoschus caillei</i>	1.83 \pm 1.02	537.40 \pm 47.79	37.94 \pm 2.50	0.61	Intermediate
POL-6	3.22 \pm 1.68	508.20 \pm 82.71	42.86 \pm 7.60	0.70	Intermediate
POL-7	2.56 \pm 1.26	704.80 \pm 146.37	48.67 \pm 1.13	0.76	Narrow
Punjab 8	3.06 \pm 1.53	617.60 \pm 54.74	45.41 \pm 1.93	0.80	Narrow
Punjab Padmini	1.89 \pm 1.02	437.80 \pm 62.17	48.38 \pm 6.46	0.74	Narrow
Punjab 7	1.42 \pm 0.52	711.20 \pm 101.93	45.46 \pm 2.05	0.77	Narrow
Pusa Sawani	1.67 \pm 0.58	757.60 \pm 112.77	47.32 \pm 9.70	0.78	Narrow

Figures representing mean \pm standard deviation

*Hair density at magnification of 500 μm were observed under SEM

**Hair length were observed under SEM

***Angle of insertion of hair were observed under Axio Ai Zeiss Microscope

The *Abelmoschus* spp. viz. *A. moschatus*, *A. angulosus*, and *A. tetraphyllus* which showed high field resistance had erect hair and genotypes with moderate field resistance such as IC0506027, EC0306728 and *A. manihot* had less erect hair. Mahal (1978) and Dhillon (1997) also reported that resistant germplasm entries had more erect hair than the susceptible entries. However, *A. tuberculatus* showed moderate field resistance had almost flat hair indicating that some other factors are responsible for resistance in it.

Table 7. Correlation of morphological characters with jassid population, jassid injury index and susceptibility index during the peak activity of jassid (56 DAS)

Parameter	Correlation values at peak activity of jassid				
		Hair density	Hair length	Angle of insertion	Lacination index
Nymphal population	r:	- 0.67*	- 0.48	- 0.55*	0.77*
	R:	0.45	0.23	0.30	0.59
Jassid injury index	r:	- 0.59*	- 0.38	- 0.47	0.85*
	R:	0.35	0.14	0.22	0.72
Susceptibility index	r:	- 0.56*	- 0.33	- 0.42	0.82*
	R:	0.31	0.11	0.18	0.67

r - Correlation coefficient, R - Coefficient of Determination

*Significant, $n_{df, \alpha}$ (13, $p = 0.05$), $r_{0.05|tab|} = 0.51$

4.2.1.4 Lacination index:

All the accessions: IC0506027, IC0506118 and EC0306728 and *Abelmoschus* spp.: *A. moschatus*, *A. angulosus*, *A. tetraphyllus*, *A. tuberculatus* and *A. manihot* had broad leaves with lacination index value ranging from 0.33-0.54 except in *A. caillei* which had intermediate type of leaves with 0.61 lacination index value. Narrow leaves with lacination index value ranging from 0.74 to 0.80 were observed in genotype POL-7 and all the cultivated varieties except genotype POL-6 which had intermediate type of leaves with 0.70 lacination index (Table 6).

The lacination index had a positive and highly significant correlation of 0.77, 0.85 and 0.82 with jassid nymphal population, jassid injury index and susceptibility index, respectively with 59, 72 and 67 per cent coefficient of determination, respectively.

It is evident from the above mentioned results that, *A. moschatus*, *A. angulosus* and *A. tetraphyllus* showing high field resistance had the broad leaves. Similarly, other entries, IC0506027, IC0506118, EC0306728, *A. manihot* and *A. tuberculatus* which showed moderate level of resistance in the field also had the broad leaves. The susceptible entries under field conditions i.e. *A. caillei* and POL-6 had intermediate leaves. The genotype POL-7 and all cultivated varieties: Punjab 8, Punjab 7, Punjab Padmini, Pusa Sawani had narrow leaves which showed susceptibility to jassid under field conditions. The data indicates that the entries with broader leaves were more resistant to jassid than the entries with narrow leaves.

The above data indicated that the correlation among all the morphological parameters (Table 7) and jassid nymphal population, jassid injury index and susceptibility

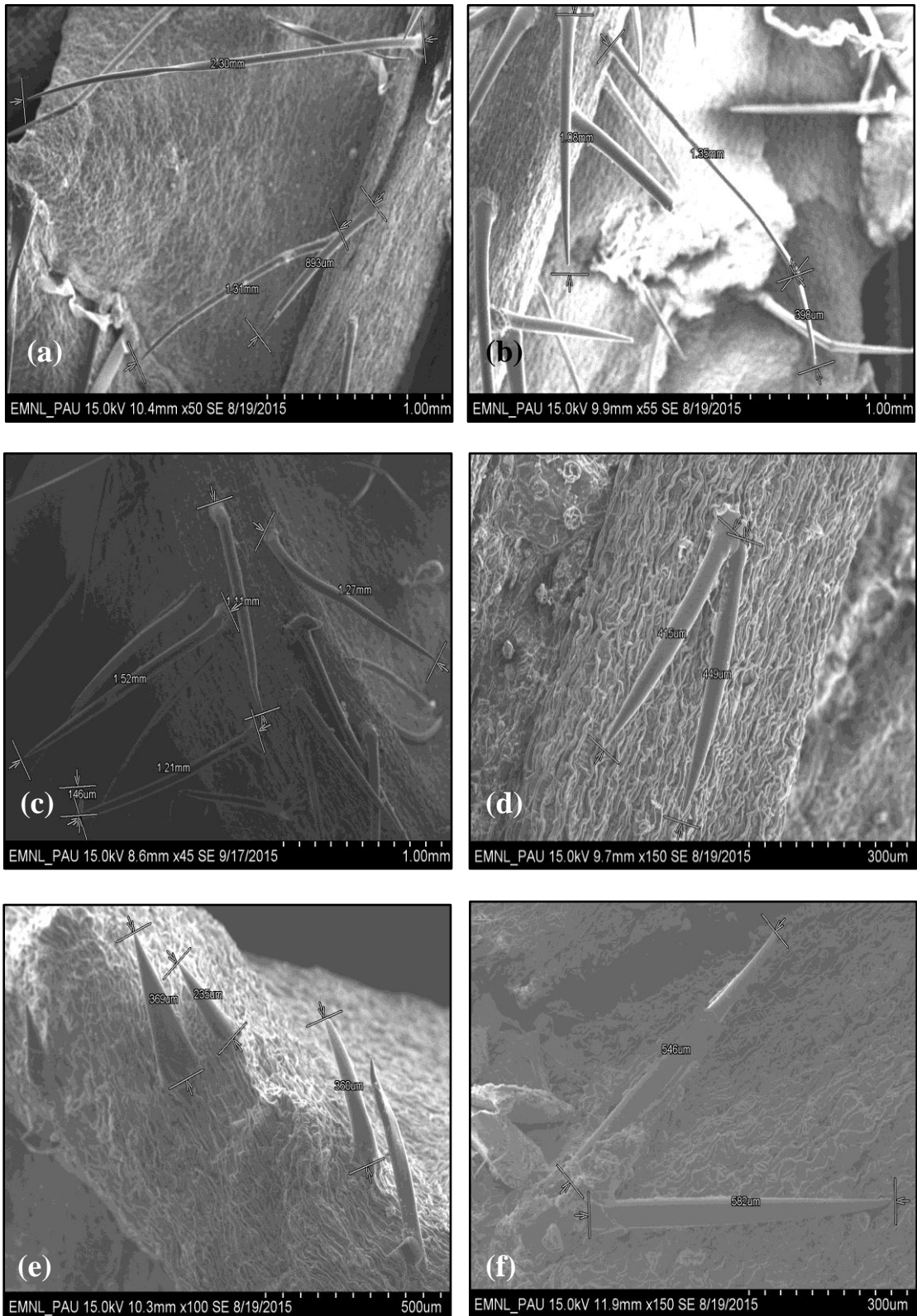


Plate 3(a): Scanning Electron Micrographs of mid vein hair density and hair length in *Abelmoschus* spp. i.e. (a) *A. moschatus*, (b) *A. angulosus*, (c) *A. tetraphyllus*, (d) *A. manihot*, (e) *A. tuberculatus*, (f) *A. caillei* during the peak activity period of jassid (56 DAS)

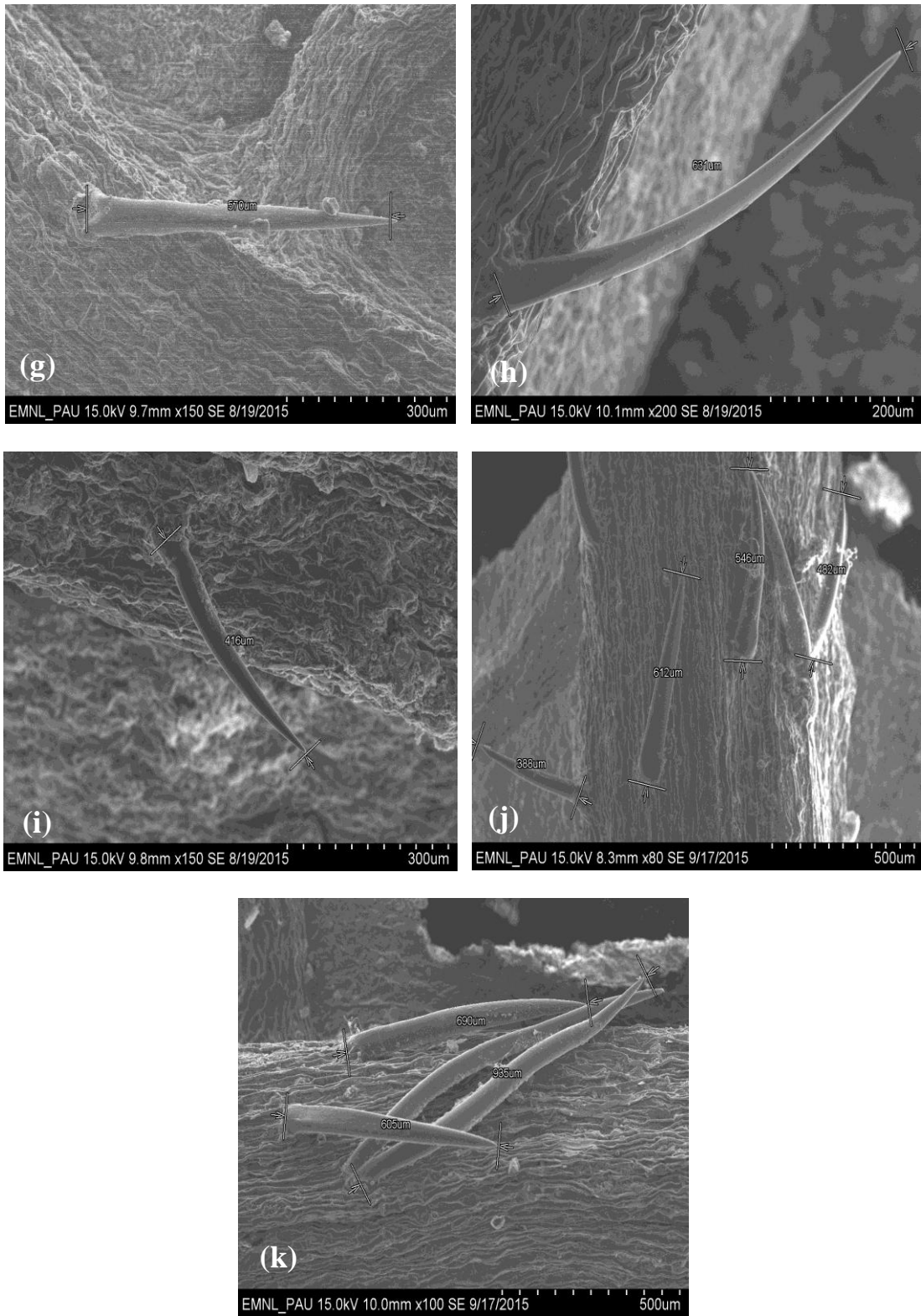


Plate 3(b): Scanning Electron Micrographs of mid vein hair density and hair length in accessions i.e. IC0506027, EC0306728 and IC0506118 and genotypes; POL-6 and POL-7 during the peak activity period of jassid (56 DAS)

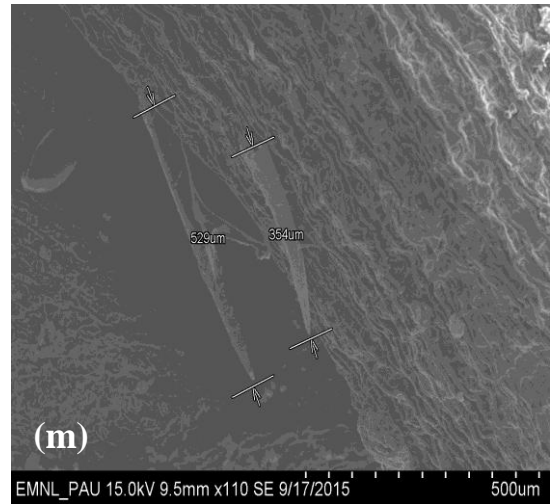
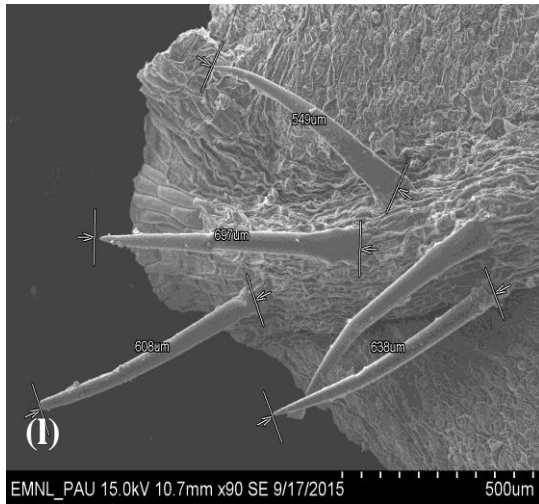


Plate 3(c): Scanning Electron Micrographs of mid vein hair density and hair length in cultivated okra varieties i.e. (l) Punjab 8, (m) Punjab Padmini, (n) Punjab 7, (o) Pusa Sawani during peak activity of jassid (56 DAS)

index was not of a very high magnitude as the coefficient of determination in all the cases was very low 0.11-0.45 except lacination index. These results are in conformity with the findings of Lal (1989) who also reported the less magnitude of coefficient of determination in case of these parameters in different okra varieties and concluded that the hair density and hair length on mid vein of okra leaves can be used only for selection of resistant varieties, but these cannot be relied upon solely for evaluation of resistance sources in the okra germplasm.

4.2.2 Biochemical studies

Promising entries based on their field performance were further evaluated for biochemical parameters: total sugars, reducing sugars, total phenols, tannins, lignins and silica (Table 8). These parameters were studied in both jassid infested and uninfested okra leaves during the peak activity period of jassid (56 DAS). The results depicted that all the biochemical parameters were lower in jassid infested leaves under field conditions as compared to uninfested leaves grown under protected environment in almost all the entries, but their trend in different okra entries was same under both conditions (Figure 1 and Figure 2). The results pertaining to biochemical parameters for jassid infested leaves are described as below:

4.2.2.1 Total sugars

The data pertaining to the total sugars in promising okra entries are given in Table 8. The results revealed significant differences among selected entries. Significantly higher total sugars were observed in some of the *Abelmoschus* spp. which showed high field resistance namely *A. moschatus* (18.36 mg/g) followed by *A. angulosus* (16.44 mg/g) and *A. tetraphyllus* (15.21 mg/g). The accessions, IC0506027 and EC0306728 which were moderately resistant under field conditions had significantly moderate, but higher sugar content (13.21 and 12.11 mg/g, respectively) as compared to POL-7 (10.09 mg/g), *A. manihot* (9.01 mg/g), Pusa Sawani (8.59 mg/g) and *A. tuberculatus* (8.14 mg/g).

In present studies, the sugar content in the different entries after infestation ranged between 0.81-1.84 per cent and *A. moschatus* had the highest sugar content (18.36 mg/g). This range was lower than that reported by Singh and Agarwal (1988) where total sugars ranged from 2.19-5.39 per cent in different okra varieties at the time of oviposition (pre-infestation period) with highest sugars in *A. moschatus* (5.39 per cent).

The total sugar content in jassid infested leaves showed negative but non-significant correlation i.e. - 0.63, - 0.57 and - 0.55 with coefficient of determination of 40, 32, and 30 per cent with nymphal population, jassid injury index, and jassid susceptibility index, respectively (Table 9). The results revealed that higher the sugar content in the genotype, lower the jassid

attack as high total sugars acts as phagodeterrents. Hu *et al* (2010) also reported that the insecticidal activity of the sugars is likely due to an antifeedant effect on the whitefly.

These results are partially supported by the findings of Sharma and Agarwal (1983), Singh and Agarwal (1988), Hooda *et al* (1997). Iqbal *et al* (2011a) reported that total sugars had a negative and significant correlation with jassid population and the resistant varieties (Makhmali, Punjab selection, Green wonder) had lower sugars. However, Taylo and Bernardo (1995) reported high total free sugar per cent in susceptible varieties of okra which are in non conformity with the present findings.

4.2.2.2 Reducing sugars

The data with respect to reducing sugars in promising okra entries are given in Table 8 and the differences among selected entries were found to be significant. Significantly lower reducing sugar contents were registered in *A. tetraphyllum* (2.76 mg/g) and *A. angulosus* (2.50 mg/g) followed by *A. moschatus* (3.39 mg/g) which behaved as resistant under field conditions. Significantly higher reducing sugar content was obtained in the susceptible genotypes, Pusa Sawani (8.42 mg/g) and POL-7 (7.64 mg/g). The *Abelmoschus* spp.: *A. manihot* and *A. tuberculatus* and accessions: IC0506027 and EC0306728 with moderate level of field resistance had significantly moderate level of reducing sugars (ranging from 4.38 to 5.78 mg/g).

Singh and Agarwal (1988) reported the range of reducing sugars from 0.22 to 0.45 per cent in different okra entries with 0.22 per cent in highly resistant genotype, *A. moschatus* at the time of oviposition of jassid which is slightly lower than that in the present findings, may be due to the observations were taken after jassid infestation stage and not at the time of oviposition.

The reducing sugar content in jassid infested leaves showed highly positive and significant correlation with r value 0.95, 0.89 and 0.88 and coefficient of determination of 90, 79 and 72 per cent for the jassid population, jassid injury index and susceptibility index, respectively (Table 9). It is evident from the data that with increase in reducing sugars, the jassid population increases. In present study, reducing sugars seem to be behaving as phagostimulants for the jassid.

Table 8. Biochemical constituents in jassid infested and uninfested leaves of promising okra germplasm during the peak activity of jassid (56 DAS)

Entry	Total sugars (mg/g)		Reducing sugars (mg/g)		Total phenols (mg/g)		Tannins (mg/g)		Lignins ($\Delta E_{350}/g$)		Silica (mg/g)	
	I	UI	I	UI	I	UI	I	UI	I	UI	I	UI
IC0506027	13.21 ± 0.50	14.54 ± 0.44	5.43 ± 0.18	6.82 ± 0.17	1.44 ± 0.04	1.46 ± 0.01	20.71 ± 0.58	18.64 ± 0.85	5.51 ± 0.10	6.60 ± 0.29	23.89 ± 0.56	36.68 ± 0.58
EC0306728	12.11 ± 0.58	15.42 ± 0.56	5.78 ± 0.15	7.39 ± 0.15	1.39 ± 0.05	1.41 ± 0.01	17.46 ± 0.82	23.72 ± 0.60	4.49 ± 0.09	5.73 ± 0.24	25.97 ± 0.47	35.33 ± 1.47
<i>Abelmoschus tuberculatus</i>	8.14 ± 0.15	12.92 ± 0.87	5.75 ± 0.38	7.56 ± 0.30	1.46 ± 0.02	1.51 ± 0.01	20.89 ± 0.45	21.61 ± 0.73	4.48 ± 0.15	7.13 ± 0.44	21.14 ± 0.02	28.46 ± 0.90
<i>Abelmoschus moschatus</i>	18.36 ± 0.67	18.85 ± 0.81	3.39 ± 0.20	4.91 ± 0.15	1.58 ± 0.02	1.70 ± 0.01	29.74 ± 0.26	30.92 ± 1.35	3.79 ± 0.04	5.11 ± 0.04	33.17 ± 0.56	44.14 ± 0.61
<i>Abelmoschus angulosus</i>	16.44 ± 0.65	16.87 ± 0.55	2.50 ± 0.09	4.99 ± 0.04	1.52 ± 0.01	1.64 ± 0.01	26.12 ± 0.91	30.35 ± 1.21	3.84 ± 0.17	6.13 ± 0.15	32.84 ± 0.50	41.74 ± 0.88
<i>Abelmoschus tetraphyllus</i>	15.21 ± 0.87	16.52 ± 0.36	2.76 ± 0.15	3.61 ± 0.16	1.56 ± 0.05	1.59 ± 0.01	31.48 ± 1.88	34.59 ± 1.15	4.30 ± 0.20	6.05 ± 0.19	32.66 ± 0.80	41.19 ± 0.55
<i>Abelmoschus manihot</i>	9.01 ± 0.20	9.63 ± 0.30	4.38 ± 0.33	5.77 ± 0.29	1.43 ± 0.04	1.47 ± 0.01	15.95 ± 0.94	20.19 ± 0.63	5.55 ± 0.17	8.98 ± 0.31	14.99 ± 0.39	24.15 ± 1.67
POL-7	10.09 ± 0.59	10.87 ± 0.46	7.64 ± 0.22	8.70 ± 0.24	1.41 ± 0.02	1.50 ± 0.02	14.68 ± 1.40	17.08 ± 1.71	8.13 ± 0.24	8.71 ± 0.34	22.06 ± 0.51	28.09 ± 0.58
Pusa Sawani	8.59 ± 0.66	10.98 ± 0.86	8.42 ± 0.02	8.09 ± 0.18	1.33 ± 0.06	1.38 ± 0.02	14.49 ± 1.19	14.96 ± 0.99	8.38 ± 0.08	7.97 ± 0.14	15.23 ± 0.40	23.71 ± 0.49
CD (p=0.05)	1.74	1.89	0.51	0.58	0.12	0.04	3.16	2.86	0.42	0.83	1.71	2.90
CV(%)	8.14	7.79	5.78	5.23	4.72	1.51	8.58	7.01	4.50	6.93	4.02	4.97

Figures representing Mean \pm SE (Standard Error)

I-Jassid infested leaves, UI-Healthy/Uninfested leaves

The present findings corroborate the results of Singh and Agarwal (1988) and Iqbal *et al* (2011a) in okra who also observed that the susceptible genotypes had higher reducing sugars than resistant genotypes and had significant positive correlation with jassid population. On the contrary, Balasubramanian and Gopalan (1981) observed that resistant varieties of cotton had higher contents of reducing sugars.

4.2.2.3 Total phenols

The data regarding total phenols in the promising okra entries are given in Table 8. The results showed significant differences among selected entries with respect to phenolic contents. Total phenols were found significantly higher in *A. moschatus* (1.58 mg/g) and *A. angulosus* (1.52 mg/g) followed by *A. tetraphyllus* (1.56 mg/g) which behaved comparatively resistant under field conditions. Some of moderately field resistant *Abelmoschus* spp.: *A. manihot* and *A. tuberculatus*; accession IC0506027 and the susceptible genotype POL-7 had moderate levels of phenol contents (1.41-1.46 mg/g). Significantly lower total phenol contents were observed in susceptible variety Pusa Sawani (1.33 mg/g) followed by moderately resistant accession EC0306728 (1.39 mg/g). Higher phenol content in POL-7 might be responsible for lesser susceptibility to jassid as compared to Pusa Sawani. In the accession EC0306728, the resistance may be imparted by other biochemical factors like total sugars, reducing sugars and silica content rather than total phenols.

The phenolic contents had a negative and highly significant correlation of - 0.83, - 0.74 and - 0.74 with jassid nymphal population, jassid injury index, and jassid susceptibility index (Table 9). High coefficient of determination (69, 55 and 55 per cent for jassid nymphal population, jassid injury index and jassid susceptibility index, respectively) was also observed. This means that higher the total phenols in the genotype, the lesser the jassid attack. This might be due to the fact that the phenols act as antifeedant to insect herbivores as reported by Simmonds (2003).

The results are in agreement with Hooda *et al* (1997), Vaishali *et al* (2012), and Halder *et al* (2016) who also reported a negative and significant correlation between total phenols and jassid incidence. However, Sharma and Agarwal (1983) observed a positive correlation between the phenolic content and jassid population. Taylo and Bernardo (1995) also reported that the susceptible and resistant genotypes did not have much significant difference with respect to sugars and phenolic contents in the extrafloral nectaries of the okra leaves.

Table 9. Correlation of jassid population, jassid injury index and susceptibility index with the biochemical constituents of leaves of promising okra germplasm

Parameter	Correlation values at the peak activity period of jassid (56 DAS)						
		Total sugars (mg/g)	Reducing sugars (mg/g)	Total phenols (mg/g)	Tannins (mg/g)	Lignins ($\Delta E_{350}/g$)	Silica (mg/g)
Nymphal population	r:	- 0.63	0.95*	- 0.83*	- 0.75*	0.90*	- 0.59
	R:	0.40	0.90	0.69	0.56	0.81	0.35
Jassid injury index	r:	- 0.57	0.89*	- 0.74*	- 0.74*	0.94*	- 0.56
	R:	0.32	0.79	0.55	0.55	0.88	0.31
Susceptibility index	r:	- 0.55	0.88*	- 0.74*	0.72*	0.93*	- 0.55
	R:	0.30	0.72	0.55	0.52	0.86	0.30

r - Correlation coefficient, R - Coefficient of determination

*Significant, $n_{df, \alpha}$ (7, $p = 0.05$), $r_{0.05|tab|=0.67}$

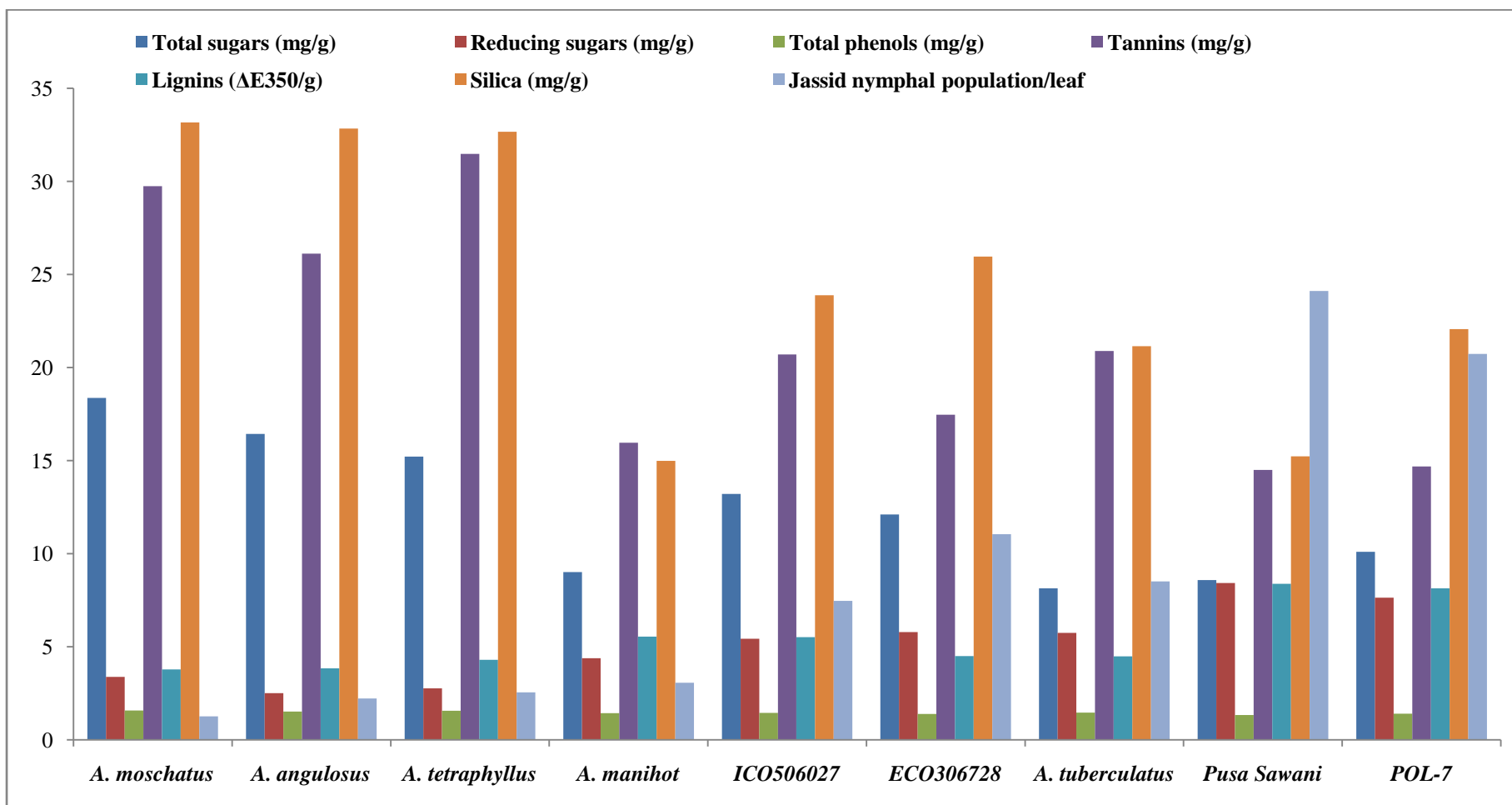


Figure 1. Biochemical characteristics of jassid infested leaves and jassid nymphal population per leaf at peak activity of jassid (56 DAS)

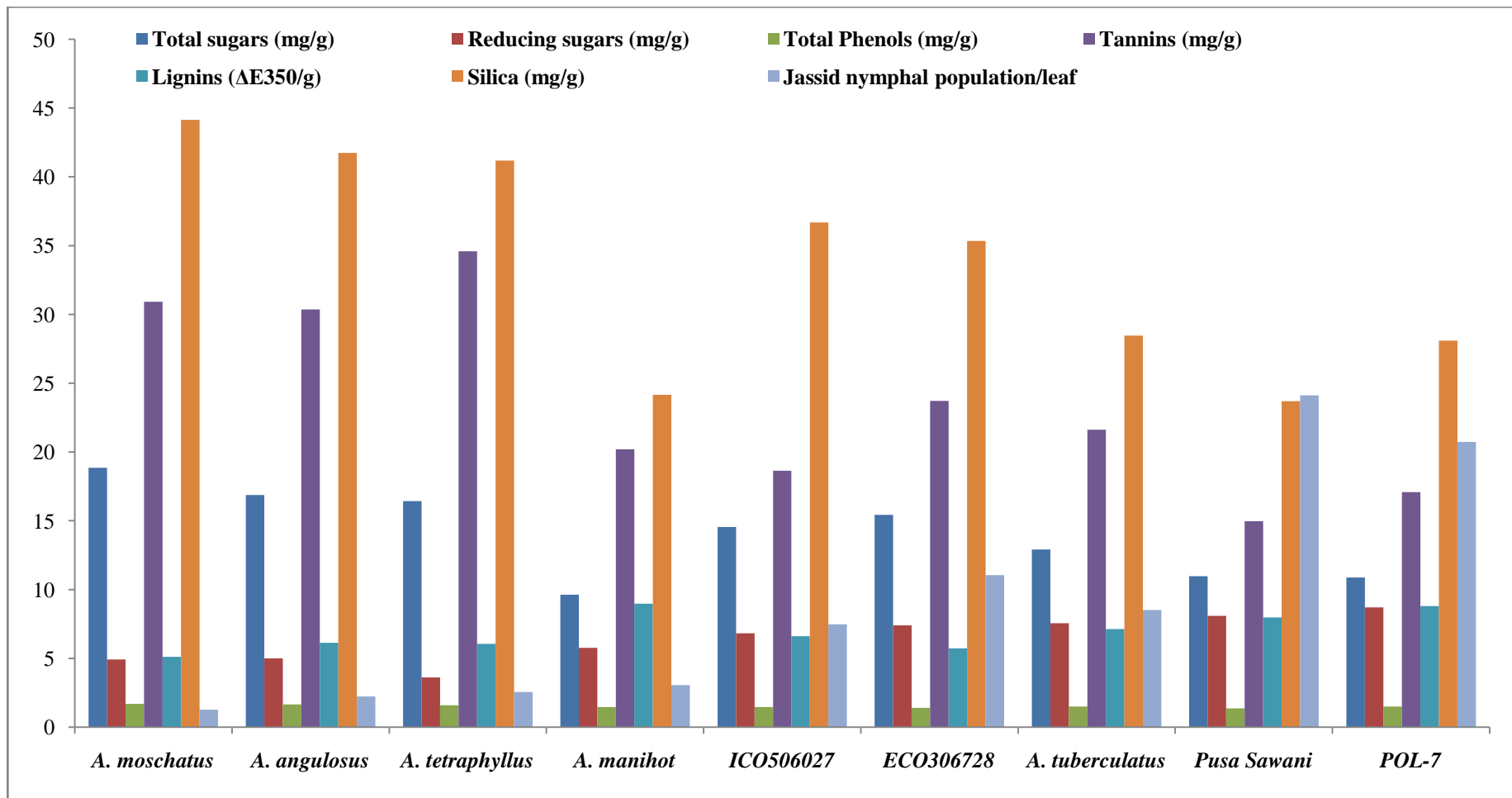


Figure 2. Biochemical characteristics of uninfested leaves and jassid nymphal population per leaf at peak activity of jassid (56 DAS)

4.2.2.4 Tannins

The results pertaining to tannins depicted significant differences among the selected entries (Table 8). Significantly higher tannin levels were found in *A. tetraphyllus* and *A. moschatus* (31.48 and 29.74 mg/g, respectively) followed by *A. angulosus* (26.12 mg/g) which exhibited higher field resistance. Significantly lower tannin contents were obtained in susceptible entries Pusa Sawani and POL-7 (14.49 and 14.68 mg/g, respectively) than the moderately field resistant accession EC0306728 and *A. manihot* (15.95 and 17.46 mg/g, respectively). The accession IC0506027 and *A. tuberculatus* which had moderate level of field resistance were observed with moderate level of tannin contents (20.71 and 20.89 mg/g, respectively). The present findings are in line with the findings of Singh and Agarwal (1988) who reported tannin content in the leaves of different okra entries in the range of 11.55-32.05 mg/g, the highest being in *A. moschatus* with 32.05 mg/g and quoted it as highly resistant.

The tannins showed a negative and highly significant correlation with jassid nymphal population, jassid injury index, and jassid susceptibility index with r value of - 0.75, - 0.74 and - 0.72 with coefficient of determination of 56, 55 and 52 per cent, respectively (Table 9). This indicated that with the increase in the tannin content in leaves of okra, jassid population and its injury decreases. From this, it can be concluded that high tannin content in resistant entries acts as feeding deterrent. Sharma *et al* (2009) and Barbehenn and Peter (2011) also reported 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.

The present findings are in conformity with the studies of Singh and Agarwal (1988) and Hooda *et al* (1997) in okra that the resistant varieties had significantly higher tannin content and had negative correlation with jassid population. The present results are in non conformity with Sharma and Agarwal (1983), Raju and Reddy (1982) and Shinde *et al* (2014) in cotton who reported significant positive correlation between tannin content and jassid population in cotton.

4.2.2.5 Lignins

The data with respect to lignin content in selected entries is given in Table 9. Some *Abelmoschus* spp.: *A. moschatus* and *A. angulosus* which showed field resistance also had significantly lower lignins (3.79 $\Delta E_{350}/g$ and 3.84 $\Delta E_{350}/g$, respectively) followed by *A. tetraphyllus*, *A. tuberculatus* and EC0306728 (4.30-4.49 $\Delta E_{350}/g$). Significantly higher lignin contents were observed in susceptible genotype POL-7 (8.13 $\Delta E_{350}/g$) and cultivated variety Pusa Sawani (8.38 $\Delta E_{350}/g$). The moderately field resistant entries *viz.* IC0506027 and *A. manihot* had moderate lignin contents (ranging between 5.51-5.55 $\Delta E_{350}/g$) which was significantly higher than *A. tetraphyllus* and significantly lower than Pusa Sawani and POL-7.

Lignins showed a positive and highly significant correlation (Table 9) with the jassid population, injury index, and susceptibility index (0.90, 0.94 and 0.93, respectively). The coefficient of determination for these parameters was also very high i.e. 81, 88 and 86 per cent, respectively.

These results are in agreement with Iqbal *et al* (2011a) who also reported that lignins had a significant and positive correlation with jassid population in okra. But the results are not in agreement with Johnson *et al* (2009) who reported that lignin; a phenolic heteropolymer by increasing the leaf toughness reduces the feeding of herbivores, and also decreases the nutritional content of the leaf. Lignin synthesis has been found to be induced by herbivory attack and their rapid depositions reduce further growth of the herbivore fecundity. In present studies, low levels of lignins might not be associated with resistance to jassid.

4.2.2.6 Silica

The data regarding silica contents in promising entries is given in Table 8. Significantly higher levels of silica content (32.66-33.17 mg/g) were found in field resistant *Abelmoschus* spp.: *A. moschatus*, *A. angulosus*, and *A. tetraphyllus*. Significantly lower levels of silica contents were recorded in moderately field resistant *Abelmoschus* spp. *A. manihot* (14.99 mg/g) and susceptible variety Pusa Sawani (15.23 mg/g); while moderate levels of silica were observed in moderately field resistant accessions *viz.* IC0506027 and EC0306728; *Abelmoschus* spp. *A. tuberculatus* and susceptible genotype POL-7 (21.14-25.97 mg/g). Singh and Agarwal (1988) reported the silica content in the range of 2.10 to 6.00 per cent in different genotypes of okra with 6.00 per cent in *A. moschatus* at the time of oviposition of jassid and quoted it as highly resistant. However, in present study, the range of silica contents in different entries was low which might be due to the fact that leaves were taken after the jassid infestation during the peak activity period for biochemical analysis.

Silica showed a negative and non-significant correlation, i.e. - 0.59, - 0.56 and - 0.55 with the jassid population, jassid injury index, and jassid susceptibility index, respectively (Table 9) and the coefficient of determination of 35, 31 and 30 per cent, respectively.

These observations are supported by Singh and Agarwal (1988), Hooda *et al* (1997), and Iqbal *et al* (2011a) who reported that the resistant varieties had significantly high silica content and had negative correlation with jassid population. It is evident from the data that higher silica contents lead to lesser jassid attack as it causes abrasiveness to the plant tissue. Singh *et al* (1972) reported 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 jassids. Massey *et al* (2006) also reported that silica may act as an antiherbivore defence by increasing the abrasiveness and reducing the digestibility of leaves.

On the basis of the above results, it was observed that the different biochemical constituents played a significant role in providing resistance to the *Abelmoschus* sp: *A.*

moschatus, *A. angulosus* and *A. tetraphyllus*. High total sugars, phenols, tannins, silica, and low reducing sugars confer resistance in these genotypes. Moreover, not a single factor is responsible for the resistance but the combination of different parameters together governs the exhibition of resistance in these genotypes.

The overall results indicated that higher degree of field resistance to jassid was observed in *Abelmoschus* spp.: *A. moschatus*, *A. angulosus* and *A. tetraphyllus*. The resistance in these entries might be associated with high mid vein hair density, longer hair, more erect hair, broader leaves, and higher level of total sugars, total phenols, tannins and silica, and lower levels of reducing sugars. The morphological and biochemical traits such as moderate hair density, broader leaves, moderate levels of reducing sugars and phenols in *A. manihot*; high hair density, broader leaves, moderate levels of reducing sugars, phenols, tannins and silica in *A. tuberculatus*; moderate hair density, broader leaves, moderate levels of total sugars, reducing sugars, phenols, tannins, and silica in IC0506027; and broader leaves, moderate levels of total sugars, reducing sugars and silica in EC0306728 seems to be associated with moderate level of field resistance against jassid in these entries. In this way, the results depicted that morphological (high hair density, length, angle of insertion and broad leaves) and biochemical constituents (high total sugars, phenols, tannins and silica, and low reducing sugars) play an important role in imparting resistance in field resistant *Abelmoschus* spp.: *A. moschatus*, *A. angulosus* and *A. tetraphyllus*. However, the variable levels of above mentioned parameters in moderately resistant and susceptible entries indicated that a single factor is not responsible for the resistance but the combination of different morphological and biochemical parameters together governed the exhibition of resistance in these entries against jassids.

CHAPTER V

SUMMARY

Studies on “Evaluation of okra germplasm for resistance to jassid, *Amrasca biguttula biguttula* (Ishida)” were conducted at the Vegetable Research Farm, Department of Vegetable Science, Punjab Agricultural University, Ludhiana during *Kharif* 2015. Fifteen okra germplasm entries including three accessions: IC0506027, IC0506118 and EC0306728; six *Abelmoschus* spp.: *A. tuberculatus*, *A. moschatus*, *A. angulosus*, *A. tetraphyllus*, *A. manihot* and *A. caillei*; two genotypes: POL-6 and POL-7 and four cultivated varieties: Pusa Sawani, Punjab 7, Punjab Padmini and Punjab 8 were screened under field conditions for resistance to jassid. Jassid nymphal population and jassid injury index was recorded for each entry at weekly intervals during the crop season. Later on, susceptibility index was also worked out on the basis of jassid nymphal population and jassid injury index for each week. Hair density and hair length on the mid vein under Scanning Electron Microscope (SEM); angle of insertion of hair on mid vein under Axio Ai Zeiss microscope using software Axiovision Release 4.7.2 and lacination index based on the ratio between lobe length and leaf length for each germplasm entry were observed during the peak activity period of jassid (56 DAS). Six biochemical parameters: total sugars, reducing sugars, total phenols, tannins, lignins and silica were also studied for the promising entries during peak infestation period of jassid (56 DAS) under laboratory conditions.

Out of six *Abelmoschus* spp., *A. tetraphyllus* followed by *A. angulosus*, *A. moschatus* and *A. manihot* registered significantly lower jassid population. Moderate jassid population was observed in accessions: IC0506027, EC0306728, and IC0506118, and *A. tuberculatus*. *Abelmoschus* spp. *A. caillei*, two genotypes: POL-6 and POL-7 and cultivated varieties: Punjab 8, Punjab Padmini, Punjab 7 and Pusa Sawani were observed with significantly higher jassid nymphal population. However, Pusa Sawani was recorded with the maximum jassid population.

Significantly lower injury index and susceptibility index were recorded in the *A. moschatus*, *A. tetraphyllus*, *A. angulosus* followed by moderate injury index and susceptibility index in *A. manihot*, *A. tuberculatus*; and accessions, IC0506027 and EC0306728. Significantly higher injury index and susceptibility index were observed in *A. caielli*, two genotypes POL-6 and POL-7, and all cultivated varieties: Punjab 8, Punjab Padmini, Punjab 7 and Pusa Sawani. The cultivated variety Pusa Sawani and genotype POL-7 exhibited significantly highest jassid injury index and susceptibility index. There was positive and significant correlation among jassid nymphal population, jassid injury index and susceptibility index.

Higher hair density was recorded in *A. angulosus*, *A. tuberculatus*, *A. moschatus*, and *A. tetraphyllum* (4.75-7.50). Moderate hair density was observed in *A. manihot*, genotypes POL-6 and POL-7; accessions: IC0506027, IC0506118 and cultivated variety Punjab 8 (2.56-3.31). Comparatively lower hair density (1.17-1.89) was registered in *Abelmoschus* spp. *A. caillei*, accessions EC0306728 and cultivated varieties: Punjab 7, Punjab Padmini and Pusa Sawani. The correlation of hair density studied with jassid nymphal population, jassid injury index and susceptibility index was negative and significant.

Longer hairs were registered in *A. moschatus*, *A. angulosus* and *A. tetraphyllum* (1285.00-1513.20 μm). However, moderately long hairs were observed in *Abelmoschus* spp. *A. caillei*, accessions: IC0506027, EC0306728, genotypes POL-6 and POL-7 and cultivated varieties: Punjab 8, Punjab 7 and Pusa Sawani (508.20-757.60 μm). *Abelmoschus* spp.: *A. tuberculatus*, *A. manihot*, accession IC0506118, and cultivated variety Punjab Padmini, were observed with the short hair (328.20-437.80 μm). Hair length showed a negative but non-significant correlation with nymphal population, jassid injury and susceptibility index.

Wider angle of insertion of mid vein hair was observed in *A. angulosus*, *A. tetraphyllum* and *A. moschatus* (83.40-95.20°). Comparatively less erect hair were observed in two *Abelmoschus* spp.: *A. caillei* and *A. manihot*; accessions: IC0506027, IC0506118 and EC0306728; two genotypes: POL-6 and POL-7 and all cultivated varieties: Pusa Sawani, Punjab 7, Punjab 8, and Punjab Padmini (37.94-52.66°). The least erect hairs were recorded in *A. tuberculatus* (27.99°). The angle of insertion of hair showed a negative correlation with the jassid nymphal population, jassid injury index and susceptibility index but it was significant in case of nymphal population only.

Broad leaves were found in the accessions: IC0506027, IC0506118 and EC0306728 and *Abelmoschus* spp.: *A. moschatus*, *A. angulosus*, *A. tetraphyllum*, *A. tuberculatus* and *A. manihot*. Intermediate types of leaves were observed in *A. caillei* and genotype POL-6. Narrow leaves were observed in genotype POL-7 and all the cultivated varieties: Punjab 8, Punjab Padmini, Punjab 7 and Pusa Sawani. The lacination index of the okra leaves had highly positive and significant correlation with jassid nymphal population, jassid injury index and susceptibility index.

Significantly higher total sugars were observed in some of the *Abelmoschus* spp. *A. moschatus* followed by *A. angulosus* and *A. tetraphyllum*. Moderate level of sugar contents were observed in accessions, IC0506027 and EC0306728. Significantly lower sugar contents were recorded in *A. manihot*, *A. tuberculatus*, POL-7 and Pusa Sawani. There was a negative and non-significant correlation between total sugars and jassid nymphal population, jassid injury index and susceptibility index.

Significantly lower reducing sugar contents were registered in *A. tetraphyllum* and *A. angulosus* followed by *A. moschatus*. Moderate levels of reducing sugars were observed in *A.*

manihot and *A. tuberculatus* and accessions: IC0506027 and EC0306728, while, significantly higher reducing sugars were obtained in Pusa Sawani and POL-7. The correlation of reducing sugars with jassid nymphal population, jassid injury index and susceptibility index was positive and highly significant.

Total phenols were found significantly higher in *A. moschatus* and *A. angulosus* followed by *A. tetraphyllus*. Moderate levels of total phenol contents were observed in *A. manihot* and *A. tuberculatus*; IC0506027 and POL-7. Significantly lower total phenol contents were observed in Pusa Sawani followed by EC0306728. The total phenols also showed highly negative and significant correlation with jassid nymphal population, jassid injury index and susceptibility index.

Significantly higher tannin levels were found in *A. tetraphyllus* and *A. moschatus* followed by *A. angulosus*. Moderate level of tannin contents were obtained in IC0506027 and *A. tuberculatus*. Significantly lower tannin contents were observed in *A. manihot*, EC0306728, POL-7 and Pusa Sawani. Tannins had negative and significant correlation with jassid nymphal population, jassid injury index and susceptibility index.

Significantly lower lignins were obtained in *A. moschatus* and *A. angulosus* followed by *A. tetraphyllus*, *A. tuberculatus* and EC0306728. IC0506027 and *A. manihot* had moderate levels of lignin contents. Significantly higher levels of lignins were observed in genotype POL-7 and cultivated variety Pusa Sawani. A positive and highly significant correlation was observed between lignins and jassid nymphal population, jassid injury index and susceptibility index.

Significantly higher levels of silica contents were found in *A. moschatus*, *A. angulosus*, and *A. tetraphyllus*. Moderate levels of silica contents were observed in accessions viz. IC0506027 and EC0306728; *A. tuberculatus* and genotype POL-7. However, *Abelmoschus* spp. *A. manihot* and cultivated variety Pusa Sawani were observed with significantly lower levels of silica. Silica showed a negative and non-significant correlation with the jassid nymphal counts, jassid injury index and susceptibility index.

From this, it can be concluded that higher degree of field resistance observed in *Abelmoschus* spp.: *A. moschatus*, *A. angulosus* and *A. tetraphyllus* might be associated with high mid vein hair density, longer hair, more erect hair, broader leaves, higher level of total sugars, total phenols, tannins and silica, and lower levels of reducing sugars. The variable levels of these parameters in moderately resistant entries: *A. tuberculatus*, *A. manihot*, IC0506027 and EC0306728 might be due to the fact that one single factor is not responsible for the resistance but different parameters altogether might contribute in imparting resistance in the germplasm. Pusa Sawani and POL-7 were found to be highly susceptible to jassid, *A. biguttula biguttula*.

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