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Host Plant Resistance Against Leafhopper (*Amrasca biguttula biguttula*) and Shoot and Fruit Borer (*Earias spp.*) in Okra: A Review

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ABSTRACT: Host plant resistance against leafhopper (*Amrasca biguttula biguttula)* and shoot and fruit borer (*Earias spp*.) in Okra reveals that the insect pests especially leafhopper and shoot and fruit borer caused significant losses in Okra yield. Collection, conservation and evaluation of Okra germplasms showed that resistant, moderately resistant and tolerant genotypes identified and some of them were released as varieties and practiced by the farmers to get higher yields with low incidence of major pests. Trichomes with high density, long and perpendicular to leaf surface showed negative correlation to leaf hopper incidence. Okra genotypes resistant to leafhopper contain more total chlorophyll, xanthophylls, carotene, tannins and silica. High reducing sugar, non reducing sugars, proteins, free amino acids mixture and pH have positive correlation with hopper incidence. High oxalic acid acts as feeding deterrent. Accumulation of total carbohydrates and wider sugar nitrogen ratio were responsible for non-preference to leafhopper. High and long trichomes on the fruit, hinder the ovipositiion on fruits but high density of hair on leaves facilitate more egg lying. Red coloured, thin and hard fruits with short calyx, less calyx diameter and thin shoot were found tolerant to borer attack. High tannin, total phenol, anthocyanin and silica contents were negatively correlated whereas high moisture, total sugars, reducing and non reducing sugars, proteins and free amino acids were positively correlated with borer infestation in okra genotypes .High Fibre and ash content in fruits were significantly negatively correlated with the infestation of *E. vittella*.
Keywords: Host Plant Resistance, *Amrasca biguttula biguttula* , *Earias spp*, Okra.

Introduction:

Okra[*Abelmoschus esculentus*(L.)Moench.]also known as bhindi orladies finger is a highly nutritive Kharif vegetable crop of the tropical and subtropical countries and most popular in India, Nigeria, Pakistan, Cameroon, Iraq and Ghana. India ranked first in world and grown in an area of 4.98 lakh ha with production of 57.84lakh MT and productivity of 11.60 MT/ha(Anonymous,2011).This crop is attacked by over 37 species of insect pests but leafhopper (*Amrasca biguttula biguttula)* and shoot and fruit borer (*Earias spp*.) are the major limiting factors in its gainful production. The avoidable losses in yield due to leafhopper worked out to be 63 to 88 per cent (Sharma *et al.*, 2001) and due to shoot and fruit borer it has been estimated up to 90 per cent. Shibalingaswamy *et al.*,(2002) reported that fruit borer (*Earias spp*.) alone caused 40 to 50 per cent yield losses in okra.

The insect pests in okra are generally managed by synthetic chemical insecticides and its continuous use led to the problems of environmental hazards and Cropping up of resistance in insects. Considering the consequences of chemical insecticides, now a day, focus is on to manage the pest by maximizing non chemical methods and to minimize the use of insecticides. In present context, with the environmental friendly pest management approach, Host Plant Resistance (HPR) is one of the most cost-effective and safe methods. Plants contain a large number of substances, which have their primary use as a means of defense against insect pests. A resistance variety can provide a base on which to construct an integrated control system (Maxwell *et al*., 1972, Gallun *et al*., 1975) and may be most fruitful when used in connection with other methods of control. HPR is seen to be a sustainable approach to pest management and evaluation of germplasm/genotypes of okra to insect pests is essential. So, increased emphasis is being given to develop the insect resistant varieties. Some sources of resistance in Okra against these pests have been identified yet enough are still to be explored. The general review on host plant resistance against insect pests in Okra is dealt with following sub heads:

(i) Steps for the studies of host plant resistance against insects.
(ii) Screening techniques.
(iii) Bases of resistance in okra against Leafhopper (*A. biguttula biguttula).*
(iv) Bases of resistance in okra against shoot and fruit borer (*Earias vittella).*

The work on relevant aspects of resistance on vegetable crops have been done by Kashyap and Verma (1983) and Sharma and Brar (1993).

(i) Steps for the studies of host plant resistance against insects

a) Collection and screening of germplasm against major insect-pests.
b) Identification of promising source of resistance.
c) Studies of mechanism of resistance.
d) Studies on inheritance of resistance.
e) Breeding for resistance and its suitability in IPM.
f) Studies of resistance in released varieties.

(ii) Screening techniques against leafhopper (*A. biguttula biguttula)* and shoot and fruit borer (Earias vittella) in Okra.

(a) Screening techniques against Leafhopper (*A. biguttula biguttula*):

Sandhu *et al.* (1974) suggested following leafhopper injury grades based on the hopperburn symptoms.

Sl. No.	Symptoms	Category	Grade
1.	Healthy foliage without cupping	Highly Resistant	I
2.	Slight cupping or yellowing of leaves along margins	Resistant	II
3.	Pronounced cupping of leaves, yellowing at margins and bronze patches in leaf lamina	Moderately	III
4.	Extreme cupping and leaf necrosis	Susceptible	IV

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While Bindra and Mahal (1979) suggested the following leafhopper injury grades for the screening of okra germplasm.

Sl. No.	Level of injury	Nature of damage	Grade
1.	Entire leaf green	No damage	I
2.	About 25% leaf area showing hopper burn, yellowing at leaf margins	Low damage	II
3.	About 50% leaf area showing hopper burn, slight cupping at leaf margins	Medium damage	III
4.	About 75% leaf area showing hopper burn, severe cupping and bronzing	High damage	IV
5.	Entire leaf tissue showing hopper burn and becoming dead	Severe damage	V

The leafhopper injury index for each variety can be worked by the following formula :

$$\text{Leafhopper injury index} = \frac{G_1 L_a + G_2 L_b + G_3 L_e + G_4 L_d + G_5 L_e}{L_a + L_b + L_e + L_d + L_e}$$

Where, La to Le are leaves falling under the leafhopper injury and G1 to G5 are leafhopper injuri grades.

(b) Screening techniques against shoot and fruit borer (*Earias vittella*) based on fruit damage:

METHOD-I

Grade	Fruit Infestation(%)	Category
1	0	Immune
2	1-10	Highly Resistance
3	11-20	Fairly Resistance
4	21-30	Tolerant
5	31-40	Susceptible
6	41 and above	Highly susceptible

METHOD- II

Grade	Fruit Infestation(%)	Category
1	0	Immune
2	1-5	Resistance
3	6-15	Moderately Resistance
4	16-30	Moderately Susceptible
5	31-50	Susceptible

METHOD-III Grading technique by Gupta and Yadav, 1978

Grade	Fruit Infestation(%)	Category
1	1-5	Resistance
2	6-15	Moderately Resistance
3	16-30	Moderately Susceptible
4	31-50	Susceptible

(iii) Bases of resistance in okra against leafhopper (*A. biguttula biguttula*):

Okra is susceptible to a number of pests which effects its yield. Leafhopper,*Amrasca biguttula biguttula* (Ishida) (Homoptera: Cicadellidae) is categorized as notorious pest in the tropics and subtropics because environmental conditions are conducive year round for the growth and development of host and pest. This pest is amongst the most important sucking pests of okra crop (Singh *et al*. 1993; Kakar and Dobra, 1988; Dhandapani *et al*., 2003).They also reported that Okra crop is most suitable for oviposition(maximum reproduction), survival and feeding (Bernardo and Taylo, 1990 & Sharma and Singh, 2002). So, the evaluation of germ plasms/genotypes for developing suitable resistance/ tolerant cultivars/varieties is more fruitful in reducing insecticides load on Okra crop.

(A)Biophysical bases.

The morphological characters play important role in governing the resistance or susceptibility of a cultivar. The variety or germplasm may be preferred or non-preferred for egg laying or feeding because of its physical appearances like colour, hairiness, hardness etc. The morphological characters may be suitable for one insect but may be unsuitable for another insect.

a) **Density of trichomes (hair) on leave:** Dense population trichomes provide hindrance in feeding of early instar leafhopper and dense hair on veins are negatively correlated with oviposition (Bindra and Mahal, 1979).
b) **Angle of trichomes:** Trichomes perpendicular to leaf surface show resistance to leafhopper as they interfere in egg laying.
c) **Length of trichomes on mid rib and leaf lamina:** The longer the trichomes on leaf more it will be resistant leafhopper as long hair hinder in oviposition (Uthamasamy, 1985).
d) **Thickness of palisade cells:** The leafhopper incidence in okra remains positively correlated with plant height and stem thickness (Uthamasamy *et al., 1971*). Thickness of cortex in mid rib is also positively correlated with this insect.
e) **Effect of leaf veins:** main veins of leaf harbor higher number of ovipositional punctures for egg laying. Individually highest numbers of eggs are laid on main vein. Sub veins have the higher share of eggs than main and lateral veins. The resistant varieties have though and compact veins. Thickness of all categories of veins has positive correlation with egg deposition (Singh and Aggarwal, 1988; Sharma and Singh, 2002).
f) **Stature of plant:** Short statured varieties are less susceptible than long plants. They are very sensitive to microclimate, prefer low temperature and hence settle on tall plants.

(B) Resistance varieties of okra against leafhopper

Sr. No.	Variety	Bases of resistance
a)	White velvet	More hair density on leaf lamina
b)	Clemson spines	-do-
c)	Early long green	-do-
d)	AE-27	-do-
e)	Siswal Local-2	More and long hair of leaf
f)	Varsha Uphar	Tolerant

Many other source of resistance against this pest are *Abelmoschus manihot, A. moschatus, A aungens,* Crimson smooth long, IC-7194, IC 8899, IC-7194, New selection, Sel 2-2, Sel-6-2, A6-27, IC-75, BL-1, BL-3, IC-12930, Pusa Rashmi, AE-15, AE-30, HB45, BH 39, HB 43.

Different workers also reported resistant/tolerant genotypes or verities of okra.Mahal (1973) screened 10 varieties of okra and found the varieties New Selection, Sel-2-2, Sel-1 and Sel-6-2 as resistant to leafhopper with low nymphal population as well as extent of damage and Pusa Sawani and All Season as susceptible to leafhopper. Uthamasamy *et al* (1973) observed Pusa Sawani, A.E. 15 and A.E. 30 to be resistant to leafhopper at Coimbatore, Tamil Nadu. Sandhu *et al* (1974) screened 94 lines of okra against leafhopper at Ludhiana and reported Crimson Smooth Long as highly resistant to the leafhopper. While, *Abelmoschus manihot*, *A. manihot* var. *Teba* (I.W. 552), *A. moschatus* (E.C. 1502), *A.* pungens (I.W. 129), *A. tuberculatus* (I.W. 495), Bhindi Sawani, I.C 7194, I.C. 8899 were observed to be moderately resistant with slight cupping and yellowing of leaves.

(C) Biochemical bases:

Okra genotypes resistant to leafhopper contain more total chlorophyll, xanthophylls andcarotene but less organic acids (Uthamasamy, 1988). High amount of total sugar, non reducing sugars, tannins and silica also lead to resistance, High reducing sugar, non reducing sugars, proteins, free amino acids mixture and pH have positive correlation with hopper incidence. High oxalic acid acts as feeding deterrent. Accumulation of total carbohydrates and low level of total nitrogen resulting in a wider sugar nitrogen ratio were responsible for non-preference to leafhopper.

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Table 1. Biochemical traits v/s resistance in okra

Variety	Total sugar	Tannin	Silica	Resistance category
A.moschatus	5.39	32.05	6.0	Highly Resistant
Sel-2	4.39	17.45	4.3	Highly Resistant
AC-302	2.19	13.33	2.1	Highly Susceptible

Singh (1988) evaluated the leafhopper on susceptible genotypes of okra i.e. Pusa Sawani, KS 305 and AC 302 and resistant genotypes: Line 14-78 and wild specie *Abelmoschus moschatus* and found higher amounts of total sugars, non-reducing sugars, tannins and silica in the leaves of resistant genotypes, because these factors had significant negative correlation with pest incidence. Moisture content and pH had positive correlation with leafhopper incidence. The effects of reducing sugars, protein and free amino acids were less significant. 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 leafhopper was reported by Singh and Taneja (1989). 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 leafhopper. 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.

When computed together, all the chemical components showed 99.7 per cent role on leafhopper population fluctuation. On the basis of this study, total sugars had negative and a

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significant correlation with leafhopper 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 leafhoppers. 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* (2015) reported a significant and negative correlation between total phenol content and leafhopper incidence on okra.

(iv)Bases of resistance in okra against shoot and fruit borer (*Earias spp.)*.

Shoot and fruit borer, *Earias vitella* (Fabricius) severely attacks the tender fruits causing nearly 52 to 71 per cent yield loss in the production of quality fruits (Pareek and Bhargava, 2003). Management of *E. vitella* through host-plant resistance has gained importance in recent past due to increased awareness among consumers regarding the adverse effects of pesticide residues. Several tolerant against shoot and fruit borer genotypes are available (Jalgaonkar *et al.*, 2002; Sharma *et al.*, 2007). However, there is a need for identifying the resistant germplasm for future progress in developing new promising varieties/ hybrids.

(A) Morphological characters

a) High and long trichomes (hair) on the fruits hinder the ovipositiion on fruits but high density of hair on leaves facilitate more egg lying.
b) AE-22 germplasm showed preference for oviposition.
c) Genotypes having thin and hard fruits with short calyx, less calyx diameter and thin shoot were found tolerant to borer attack.
d) Red coloured genotypes were observed tolerant to borer (Srinivasan and Naryanswamy, 1961).

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Table 2. Nymphal survival v/s resistance in okra

Genotype	Leafhopper nymphs/leaf	Nymphal duration (days)	Nymphal survival	Resistance category
A.moschatus	0.6	11.84	29.69	Highly Resistant
Line 14-78	4.0	9.99	55.90	Moderately Resistant
Sel-2	5.3	7.66	85.91	-do-
KS 305	8.9	6.61	95.35	Highly Susceptible
Pusa Sawani	9.7	6.94	96.92	-do-
AC 302	10.7	6.15	97.42	-do-

Several worker screened and reported resistant/tolerant genotypes for their use in developing improved cultivars/varieties. Gupta and Yadav (1978) reported moderately resistant genotypes, IC117216, IC140935,IC433695, IIVR-10 on no. basis and IC117216, IC433695, IIVR-10 on weight basis. Banger et. al.(2012) observed that Out of ten genotypes/cultivars, AOL 05 -1 found highly resistant which recorded significantly lower number of larvae per plant, per cent shoot as well as fruit damage. Genotype AOL 08-5 recorded higher number of larvae per plant,per cent shoot as well as fruit damage and was found most susceptible. Ahmad and Rizwi(1992) reported resistant genotypes,Ae57,PMS8,Parkins long green,PKX,9275 and Karnaul special, out of which parkins long green and karnaul special were released for general cultivation in India.Sharma and Singh (2010) showed that shoot of varieties less susceptible to okra shoot and fruit borer Earias spp. had more lignified tissues with compact vascular bundles and narrow shoot pith. Significant negative correlation was found between silica content and degree of shoot damage. The fruit borer preferred the dark green coloured fruits less. The varieties having medium long, less smooth, more trichomes and minimum seeded fruits were less infested. Gautam *et al.* (2014) observed that 16 germplasms were moderately resistance, 22 moderately susceptible and 62 susceptible. Minimum fruit damage was observed in germplasm 472 whereas maximum observed in Thin No. 3.Halder et. al.(2015) observed that highly susceptible genotype SB 8 had relatively lower number of trichomes (24) as compared to tolerant genotype SB 6 which had 51.8 trichomes/cm2. Fruit length, width and fruit weight showed a positive correlation (r value = 0.376, 0.034, 0.026, respectively) with borer incidence. Susceptible genotype SB 8 possessed lower fruit angle (23.4°) and stem thickness (1.17 cm) as compared to tolerant genotype SB 6 (26.4° and 1.28 cm, respectively). Similarly, higher number of total leaves (38.8), fruits (15.75) and branches (3.6) per plant were also recorded from SB 8 as compared to other tolerant lines (SB 6, VROR 160, SB10).

(B) Biochemical characters

High tannin and silica contents were negatively correlated whereas high moisture, total sugars, reducing and non reducing sugars, proteins and free amino acids were positively correlated with borer infestation in okra genotypes (Singh, 1987; Singh and Taneja, 1991).Banger et. al.(2012) found that Fibre and ash content in fruits were significantly negatively correlated with the infestation of *E. vittella*. Negligible role of chlorophyll content in the fruits on infestation of. *E vitella* was observed.Sharma and Singh (2010) showed that the biochemical characters such as total sugar and crude protein were positively correlated with fruit borer infestation, whereas, total phenols had negative correlation in Okra.Halder et. al.(2015) observed that the biochemical parameters, total phenol and anthocyanin showed negative correlation with the borer incidence. Free-choice arena and ovipostional tests also confirmed that highest larval orientation and egg laying were in susceptible genotype SB 8 (53.3 and 19.7%, respectively) than the tolerant genotype,SB 6.

(C) Ecological resistance

Dwarf and early flower bearing varieties escaped the shoot and fruit borer infestation.

(D) Sources of resistance against shoot and fruit borer

The following genotypes of okra have been identified as resistant/tolerant to shoot and fruit borer. Bhindi Red-1; Bhindi Red-II; Red Wonder 1 & II; AE-3; AE-22; AE-57; AE-67; Wonder Pink; Sel.1-1 x AE-79; Narnaul special; Perkin's Long Green; Clemson spineless; White snow (Kashyap and Verma, 1983) Sel. Round; Indo-American hybrid; Rashmi; EMS 8-1, Ludhiana Secection 2-2, Siswal Local-2, Pb-57; MR-8; MR12-1; Pradhani Kranti; AE-17 and Panjab Padmani.

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