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Biochemical basis of resistance in sesame against leaf webber and capsule borer, *Antigastra catalaunalis* Dupounchel (Pyraustidae: Lepidoptera)

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Abstract
During *kharif* 2016, sixty sesame genotypes were field screened against *Antigastra catalaunalis* Dup. at Zonal Agricultural Research Station, V. C. Farm, Mandya. Based on per cent leaf, flower and pod damage, the genotypes were categorised as HR (Highly resistant), R (Resistant), MR (Moderately Resistant), S (Susceptible) and HS (Highly Susceptible). The biochemical constituents *viz.*, total sugars, reducing sugars, total phenols, crude protein and total free amino acids was estimated in leaves and pods of selected genotypes and data was correlated with per cent damage. The studies revealed that, higher amount of total phenols in leaves and pods showed a significant negative correlation with per cent leaf (r = -0.94) and pod damage (r = -0.94) caused by *A. catalaunalis*. While, total sugars (r = 0.89, 0.96), reducing sugars (r = 0.92, 0.90), amino acids (r = 0.88, 0.89) and crude proteins (r = 0.95, 0.91) showed a significant positive relationship with per cent leaf and pod damage.

Keywords: *Antigastra catalaunalis*, genotypes, phenols, sugars, crude proteins

Introduction
Number of insects belonging to different orders and family have been recorded on sesame in various parts of the world and most important pests in India are leaf webber, *Antigastra catalaunalis* Duponchel (Pyraustidae: Lepidoptera), sphinx caterpillar, *Acherontia styx* Westw (Sphingidae: Lepidoptera); gall fly, *Asphondylia sesami* Felt (Cecidomyiidae: Diptera); cotton aphid, *Aphis gossypii* Glover (Aphididae: Homoptera); leaf hopper, *Orosius albicinctus* Distant (Cicadellidae: Homoptera) [5]. These pests occur in almost regular intervals on sesame at different stages of the crop and causes heavy damage. Among these insect pests, sesame leaf webber and capsule borer, *A. catalaunalis* is one of the most important and threatening pest of sesame and gained major pest status by causing 90 per cent yield losses [1].

The sesame leaf webber and capsule borer is reported to attack all growth stage. Its incidence can be seen two weeks after germination and damage will be more severe during flower initiation and capsule formation. *A. catalaunalis* feeds on tender foliage by webbing the top leaves, bores into the shoots, capsules and locules [13]. It completes its lifecycle in 21.26 ± 0.64 days with 12-14 generations/year [11].The newly hatched larvae initially feed on young leaves and shoots and during later stage, they roll the leaves and feed inside. Further the larvae feed on flowers, pods and seeds. The leaves, flowers and capsules were infested to the extent of 10 to 70 per cent, 34 to 62 per cent and 10 to 44 per cent respectively with a yield loss up to 72 per cent [14].

Plants posses various biochemical characteristics which acts as defensive barriers against insect pests. These biochemical characteristics play an important role in host plant resistance. For example a plant secondary metabolite, phenols which acts as prime biochemical factor for resistance against insect pests due to their anti-feedant as well as antibiosis property on growth and reproduction. Singh *et al.*, [16] reported significant negative correlation between total phenols and per cent pod damage by *A. catalaunalis*. So identification of these chemical traits could be used as markers in developing resistant varieties against the targeted pest. Since, our farmers primarily relay on chemicals to keep the pest population below economic injury level this has led to several problems like toxic residues, elimination of natural enemies, environmental disharmony. Hence development of resistant varieties would be an environmentally sound management tool for control of this pest. Hence the present study was undertaken to know the biochemical basis of resistance and susceptibility in sesame against *A. catalaunalis.*

Materials and Methods

A field study was conducted to evaluate 60 sesame genotypes under IVT and AVT including 7 local varieties under high pest pressure in replicated trial against *A. catalaunalis* at Zonal agricultural research station, V. C. Farm, Mandya during *kharif* 2016. Based on per cent leaf, flower and pod damage, the genotypes were categorised as HR (Highly resistant), R (Resistant), MR (Moderately Resistant), S (Susceptible) and HS (Highly Susceptible) by using 0-9 score chart as suggested by Sridhar and Gopalan [18]. Out of 60 screened genotypes, 21 genotypes representing each resistant category were selected for biochemical studies. The biochemical constituents *viz.*, total sugars, reducing sugars, total phenols, crude protein and total free amino acids was estimated in leaves and pods of selected genotypes. The leaves and pods were sampled at 30 and 60 days after sowing, respectively.

Extraction of plant tissue in alcohol

Un-infested fresh leaves and pod samples from 30 and 60 days old plants of test entries was collected and thoroughly washed with distilled water and dried under shade. One gram of plant sample pieces of all the genotypes were taken in separate conical flask and 15 ml of 80 per cent ethanol was added. It was refluxed for 30 minutes on hot water bath. After boiling, the extract was cooled and the pieces of tissues were ground thoroughly in a mortar with pestle in slight ethanol. The supernatant was decanted in to another flask and residue was again re-extracted with small quantity of hot ethanol and again decanted. The extract was filtered using Whatman No. 1 filter paper and made up to a known volume with 80 per cent ethanol. The alcoholic extract was stored in refrigerator at 4º C and used for the estimation of biochemical constituents.

Total and reducing sugars were estimated as the method suggested by Somogyi [17], total phenols in leaves and pods of the plant tissue were estimated by following Folin-Ciocalteau method suggested by Bray and Thorpe [4], total free amino acid was estimated by following Ninhydrin method developed by Moore and Stein [12] and estimation of crude protein was done by following Micro-Kjeldahl method by Sadasivam and Manickam [15].

Statistical Analysis

The data obtained was subjected to ANOVA [6, 7] and means were separated by Tukey's HSD [19] for interpretation. Further the data was subjected to correlation to establish the relationship between biochemical constituents and per cent damage caused by *A. catalaunalis.*

Results and Discussion

Field evaluation of sesame genotypes against sesame leaf webber and capsule borer

Out of sixty screened genotypes five genotypes reacted as highly resistance (HR) to leaf webber and capsule borer. While, four genotypes of 60 collected and screened genotypes acted as resistant (R), four moderately resistant (MR) and seven genotypes as susceptible (S). While, 43 genotypes out of 60 genotypes were rated as highly susceptible (HS). To know the biochemical constituents associated with resistance and susceptibility 21 genotypes representing each resistant category was selected for further studies.

Total sugars

Total sugar content of different sesame genotypes varied between 7.75 to 22.09 mg/g and 6.97 to 19.20mg/g in leaves and pods, respectively. The highest quantity of total sugars was found in susceptible genotype AVT-14 and lowest was found in resistant genotype Kanakapura local (Table 1 and 2). Further, the correlation studies revealed a significant positive correlation with per cent leaf (r = 0.89) and pod (r = 0.96) damage caused by *A. catalaunalis* (Table 3). The present findings are in conformity with Bhavani *et al.*, [3] who reported that sugarcane genotypes susceptible to *Chilo infuscatellus* contained higher percentage of total sugars than the resistant ones. Similarly, Kandakoor *et al.*, [8] reported a significant positive correlative with thrips incidence and total sugars in groundnut. Kumar *et al.*, [10] also indicated that total sugars had a significant positive correlation with damage by pod fly in pigeon pea. This might be due to the role of sugars as a vital nutrient in plants Bhavani *et al.*, [3] Further, the difference in relative amount of sugars between different genotypes with difference in susceptibility indicated that these compounds might act as phagostimulant to the insect.

Table 1: Biochemical constituents in leaves of sesame genotypes against *A. catalaunalis*

Genotypes		Leaf damage (%)		Total sugars (mg/g)	Reducing sugars (mg/g)	Total phenols (mg/g)	TFA (mg/g)	Crude proteins (%)
HR	IVT 15	5.94	(13.90)^{a}	8.93^{abc}	5.00^{a}	14.24^{a}	2.00^{a}	15.70^{a}
	IVT 5-1	4.04	(11.60)^{a}	8.51^{ab}	5.20^{ab}	14.68^{a}	2.14^{a}	15.20^{a}
	AVT 8	3.77	(10.90)^{a}	8.43^{ab}	5.25^{ab}	14.13^{a}	2.15^{a}	15.40^{a}
	Kanakapura	3.53	(10.80)^{a}	7.75^{a}	4.85^{a}	15.08^{a}	2.01^{a}	15.10^{a}
	IVT 9	7.29	(15.60)^{ab}	8.85^{abc}	5.15^{ab}	14.53^{a}	2.23^{ab}	15.50^{a}
R	IVT 23	9.40	(17.70)^{abc}	9.23^{abc}	7.65^{cd}	12.11^{abc}	2.31^{ab}	16.30^{abc}
	IVT 27	8.92	(17.20)^{abc}	8.89^{abc}	6.25^{abc}	13.53^{ab}	2.37^{ab}	16.00^{ab}
	AVT 1	9.70	(18.10)^{abc}	9.01^{abc}	7.35^{bcd}	12.52^{abc}	2.42^{ab}	16.00^{ab}
MR	IVT 19	15.62	(23.20)^{cd}	11.89^{abcde}	7.95^{cd}	11.33^{abc}	2.37^{abcd}	17.30^{abcde}
	Mangala	19.25	(26.00)^{de}	11.57^{abcde}	7.90^{cd}	11.28^{abc}	2.91^{abcd}	16.90^{abcde}
	Madla	15.20	(23.00)^{bcd}	11.14^{abcd}	7.40^{bcd}	11.62^{abc}	2.72^{abc}	16.70^{abcd}
S	IVT 5	28.11	(32.00)^{fg}	13.05^{bcde}	10.30^{ef}	9.43^{bcd}	3.44^{abcd}	19.40^{defg}
	IVT 11	19.25	(26.00)^{de}	13.43^{cde}	8.95^{de}	8.23^{cd}	4.52^{cde}	19.10^{cdefg}
	IVT 21	25.65	(30.40)^{ef}	13.09^{bcde}	9.00^{de}	6.82^{d}	4.57^{cde}	18.90^{cdefg}
	Shivalli	17.75	(22.40)^{de}	15.67^{def}	9.55^{def}	8.24^{cd}	4.49^{cde}	18.80^{bcdef}
	AVT 4-2	25.10	(30.10)^{ef}	15.72^{def}	10.30^{ef}	6.97^{d}	4.16^{bcde}	19.40^{defg}
HS	IVT 14	34.64	(36.10)^{ghi}	20.73^{g}	12.60^{gh}	5.60^{d}	5.86^{e}	19.70^{efg}
	AVT 13	35.63	(36.60)^{ghi}	19.29^{fg}	13.00^{ghi}	6.82^{d}	5.92^{e}	20.70^{g}
	AVT 14	29.21	(31.70)^{fgh}	22.09^{g}	15.00^{i}	6.73^{d}	6.00^{e}	20.90^{g}
	AVT DS 5	40.57	(39.60)^{i}	16.40^{ef}	11.50^{fg}	5.55^{d}	4.68^{de}	20.30^{fg}
	GT 1	36.44	(37.10)^{hi}	19.54^{fg}	13.80^{hi}	6.57^{d}	4.80^{de}	19.80^{fg}
SE m±		1.30		0.90	0.30	0.90	0.40	0.50
CD @ p= 0.05		3.80		2.70	0.70	2.50	1.10	1.50

TFA- Total free amino acids; Figures in the parentheses indicate arc sin transformed values; Values in the column followed by common letters are non significant at p = 0.05 as per Tukey's HSD (Tukey, 1965) [19].

Table 2: Biochemical constituents in pods of sesame genotypes against *A. catalaunalis*

Genotypes		Pod damage (%)		Total sugars (mg/g)	Reducing sugars (mg/g)	Total phenols (mg/g)	TFA (mg/g)	Crude proteins (%)
HR	IVT 15	1.84	(7.76)^{a}	8.43^{ab}	6.55^{bc}	11.33^{ab}	2.90^{abcd}	13.00^{abcd}
	IVT 5-1	1.86	(7.80)^{a}	8.51^{ab}	4.90^{ab}	11.53^{ab}	1.74^{a}	13.30^{abcd}
	AVT 8	1.38	(6.70)^{a}	7.83^{a}	4.85^{ab}	11.19^{ab}	1.38^{a}	12.90a^{bc}
	Kanakapura	1.26	(6.40)^{a}	6.97^{a}	4.25^{a}	11.90^{a}	1.45^{a}	12.10^{a}
	IVT 9	1.94	(8.00)^{a}	8.34^{ab}	4.40^{a}	11.24^{ab}	1.54^{a}	12.60^{ab}
R	IVT 23	1.65	(7.30)^{a}	9.53^{abc}	7.05^{cd}	10.67^{abc}	2.28^{abc}	14.00^{abcd}
	IVT 27	1.46	(6.90)^{a}	9.19^{abc}	6.55^{bc}	11.04^{ab}	2.98^{abcd}	13.80^{abcd}
	AVT 1	1.46	(6.90)^{a}	9.28^{abc}	6.60^{bc}	11.15^{ab}	2.11^{ab}	14.20^{abcd}
MR	IVT 19	3.98	(11.50)^{ab}	10.46^{abc}	8.60^{def}	9.92^{bcd}	4.62^{cde}	14.60^{abcd}
	Mangala	3.54	(10.80)^{ab}	10.80^{abc}	9.15^{ef}	9.81^{bcd}	4.24^{bcde}	14.90^{abcd}
	Madla	2.09	(8.30)^{a}	10.06^{abc}	8.35^{cde}	10.35^{abc}	3.37^{abc}	14.30^{abcd}
S	IVT 5	5.84	(13.90)^{bcd}	12.59^{bcd}	9.50^{ef}	8.60^{def}	5.13^{abcd}	15.40^{abcd}
	IVT 11	3.81	(11.30)^{ab}	13.69^{cde}	10.50^{fg}	8.13^{ef}	5.48^{e}	15.70^{abcd}
	IVT 21	4.83	(12.70)^{abc}	13.09^{cde}	11.65^{gh}	9.23^{cde}	5.17^{de}	15.70^{abcd}
	Shivalli	5.54	(13.60)^{bcd}	13.18^{cde}	10.30^{efg}	7.80^{efg}	5.22^{cde}	16.00^{bcd}
	AVT 4-2	5.71	(13.80)^{bcd}	13.43^{cde}	10.60^{fg}	7.33^{fg}	5.58^{e}	15.50^{abcd}
HS	IVT 14	8.56	(16.40)^{d}	17.42^{ef}	11.90^{gh}	6.98^{fg}	5.66^{e}	16.60^{cd}
	AVT 13	6.69	(15.00)^{bcd}	16.45^{def}	13.20^{hi}	6.99^{fg}	5.87^{e}	16.10^{bcd}
	AVT 14	8.56	(17.00)^{cd}	19.20^{f}	14.05^{i}	6.23^{g}	5.90^{e}	16.90^{d}
	AVT DS 5	6.25	(14.40)^{bcd}	15.55^{def}	13.50^{hi}	6.33^{def}	5.77^{de}	16.30^{bcd}
	GT 1	6.55	(14.70)^{bcd}	15.39^{def}	13.60^{hi}	6.29^{g}	4.74^{de}	16.60^{cd}
SEm±		0.80		0.90	0.20	0.40	0.50	0.70
CD @ 5%		2.30		2.50	0.50	1.00	1.40	1.90

TFA- Total free amino acids; TFA- Total free amino acids; Figures in the parentheses indicate arc sin transformed values; Values in the column followed by common letters are non significant at p = 0.05 as per Tukey's HSD (Tukey, 1965) [19].

Reducing sugars

The amount of reducing sugars was significantly higher in leaves and pods of susceptible genotypes compared to resistant genotypes. The highest quantity (15.00 mg/g) of reducing sugars was noticed in leaves of susceptible genotype AVT-14 and lowest (4.85 mg/g) was recorded in resistant genotype Kanakapura local (Table 1). Similarly in the pods, the amount of reducing reducing sugars were high (14.05 mg/g) in susceptible genotype, AVT 14. The reducing sugars both in leaves (r = 0.90) and pods (r = 0.90) showed a significant positive correlation with per cent damage by *A. catalaunalis* (Table 3). The results of present investigation are in accordance with Singh *et al.*, [16] who reported that the reducing sugars in leaves of sesame genotypes had a significant and positive impact on per cent leaf and pod damage by *A. catalaunalis.* These findings are in close agreement with Kumar *et al.*, [10] who reported a significant positive relationship with the susceptibility of pigeon pea to pod fly. Since, reducing sugars are considered to be an essential component in insect nutrition, it plays a vital role in host selection by phytophagous insects. Hence their concentration in plant is positively associated with feeding behavior of insects.

Total phenols

In general the total phenols were higher in resistant genotypes compared to susceptible**.** In the leaf tissue of resistant genotype the total phenols varied from 14.13 to 15.08 mg/g, while in susceptible genotypes it varied between 5.52 to 6.82 mg/g. Among the resistant genotypes, Kanakapura local recorded maximum amount of total phenols (15.08 mg/g) in leaf tissue (Table 1). The data showed a significant negative (r = -0.94) relation with total phenols and incidence of *A. catalaunalis* (Table 3). In pod tissues the amount of total phenols ranged from 11.19 to 11.90 mg/g in resistant genotype and 6.23 to 6.99 mg/g in susceptible genotypes (Table 2). The amount of total phenols was high (11.90 mg/g) in the pods of resistant genotype Kanakapura local and was low (6.23 mg/g) in the pods of susceptible genotype AVT 14. The correlation study revealed that the phenol content in the pods of sesame was found to be negatively (r = -0.94) associated with leaf webber and shoot borer infestation (Table 3).

Table 3: Relationship between biochemical constituents and *A. catalaunalis*

Biochemical parameters	Correlation coefficient (r)	
	Leaves	Pods
Total sugars (mg/g)	0.89**	0.96**
Reducing sugars (mg/g)	0.92**	0.90**
Total phenols (mg/g)	- 0.94**	- 0.94**
Total free amino acids (mg/g)	0.88**	0.89**
Crude protein (%)	0.95**	0.91**

**Significant at p = 0.01

The results of the present investigations are in close agreement with Karuppaiah *et al.*, [9] who reported that the total phenols in the leaves, flowers and pods were negatively correlated with damage of *A. catalaunalis*.The present results are confirmed with the findings of Singh *et al.*, [16] who reported significant negative correlation between total phenols and per cent pod damage by *A. catalaunalis* in sesame. The present findings are also in close agreement with Vijaykumar *et al*., [21, 20] who reported higher amount of total phenols in gall midge resistant rice genotypes compared to susceptible genotypes. Similar results were reported by Anantharaju and Muthiah [2] who reported negative association with spotted pod borer incidence in pigeon pea. In majority of plants, phenols acts as prime biochemical factor for resistance due to their anti-feedant as well as antibiosis property on growth and reproduction.

Total free amino acids

The susceptible genotype AVT-14 recorded significantly higher total free amino acids (6.00 mg/g and 5.90 mg/g) in leaves and pods, respectively (Table 1 and 2). While in resistant genotypes the total free amino acid content was ranging between 2.00 to 2.30 mg/g and 1.38 to 2.90 mg/g in leaves and pods, respectively. Further the correlation studies revealed a significant positive (r = 0.88 and 0.89) association with total free amino acids and per cent leaf and pod damage, respectively (Table 3). The results are in conformity with Anantharaju and Muthiah [2] who reported a significant positive association with spotted pod borer and total amino acids. These findings are also in close agreements with the reports of Kumar *et al.,* [10] and Kandakoor *et al.,* [8].

Crude proteins

Crude protein content varied between 15.10 to 20.90 % and 12.10 to 16.90% in leaves and pods, respectively. Lower crude protein content was recorded in resistant genotypes, while susceptible genotypes had higher quantities of crude proteins both in leaves and pods. The correlation studies revealed that there was a significant positive association between crude protein and per cent leaf and pod damage r = 0.95 and r = 0.91 respectively (Table 3). Singh *et al.,* [16] reported that the crude proteins in sesame had a significant and positive impact on per cent pod damage by *A. catalaunalis.* These findings are in close agreement with Anantharaju and Muthiah [2] who reported a significant positive relationship with the susceptibility of pigeon pea to spotted pod borer. In majority of plants, proteins are considered to be an essential component in insect nutrition, and it plays a vital role in insect growth, development, survival and reproduction.

Conclusion

The genotypes with more phenols and less total sugars, reducing sugars, total free amino acid and crude in leaves and pods suffered less leaf and pod damage by leaf webber. Hence these bio chemical traits can be used as markers in identifying resistant sources against the targeted pest.

References

1. Ahuja DB, Bhakhetia DRC. Bio-ecology and management of insect pests of sesame: A Review. Journal of Insect Science. 1995; 8:1-19.
2. Anantharaju P, Muthiah AR. Biochemical components in relation to pests incidence of pigeonpea spotted pod borer (*Maruca vitrata*) and blister beetle (*Mylabris* spp.). Legume Research. 2008; 31(2):87-93.
3. Bhavani B, Reddy KD, Rao NV, Lakshmi MB. Biochemical basis for antibiosis mechanism of resistance in sugarcane to early shoot borer, *Chilo infuscatellus* Snellen. Tropical Agricultural Research. 2012; 23(2):126-141.
4. Bray HG, Thorpe WV. Analysis of phenolic compounds of interest in metabolism. Methods of Biochemical Analysis. 1954; 52:1-27.
5. Chaudhary R, Rai S, Singh KM. Economic injury level of sesamum leaf webber, *Antigastra catalaunalis* (Dup.) in Delhi. Indian Journal of Plant Protection. 1987; 15:136-141.
6. Gomez KQ, Gomez AA. Statistical procedures for agricultural research with emphasis on rice. International Rice Research Institute, Los Banos, Philippines, 1984, 268.
7. Hosmand RA. Statistical Methods for Agricultural Sciences. Timber press, Portland, Oregon, USA, 1988, 405.
8. Kandakoor SB, Khan HK, Chakravarthy AK, Kumar ACT, Venkataravana P. Biochemical constituents influencing thrips resistance in groundnut germplasm. Journal of Environmental Biology. 2013; 35:675-681.
9. Karuppaiah V, Nadarajan L, Kumar K. Mechanism of resistance in sesame genotypes to *Antigastra catalaunalis* Dup., Annals of Plant Protection Sciences. 2009; 17(2):337-340.
10. Kumar GS, Krishna TM, Prasanthi L, Sudhakar P, Devaki K. Morphological and biochemical traits associated with resistance to pod fly, *Melanagromyza obtusa* (Malloch) in pigeonpea. International Journal of Applied Biology and Pharmaceutical Technology. 2015; 6(3):134-141.
11. Menon MGR, Rattan L, Bhattacherjee NS. Studies on *Antigastra catalaunalis* (Duponchel), the til leaf roller. Indian Journal of Entomology. 1960; 22:1-6.
12. Moore S, Stein WH. Photometric ninhydrin method for use in the chromatography of amino acids method. Journal of Biological Chemistry. 1948; 176:367-388.
13. Narayanan SU, Nadarajan L. Evidence for a male-produced sex pheromone in sesame leaf webber, *Antigastra catalaunalis* Duponchel (Pyraustidae: Lepidoptera). Current Science, 2005; 88(4):631-634.
14. Rai HS, Gupta MP, Verma ML. Insect pests of sesame and their integrated management. Indian Farming. 2001, 30-32.
15. Sadasivam S, Manickam A. Biochemical methods, Second edition, New Age International, New Delhi, 1996, 256.
16. Singh H, Jaglan RS, Kharub SS. Antibiosis in some sesame genotypes against shoot webber and capsule borer, *Antigastra catalaunalis* Dup., Journal of Insect Science. 1990; 3(2):174-176.
17. Somogyi M. Estimation of sugars by colorimetric method. Journal of Biological Chemistry. 1952; 200:245.
18. Sridhar PR, Gopalan M. Studies on screening and mechanism of resistance against the shoot webber, *Antigastra catalaunalis* (Duponchel). Entomon. 2002; 27(4):365-373.
19. Tukey JW. The technical tools of statistics. American Statistician. 1965; 19:23-28.
20. Vijaykumar L, Patil SU, Chakravarthy AK. Biochemical basis of resistance in rice against Asian rice gall midge, *Orseolia oryzae* (Wood-Mason) (Diptera: Cecidomyiidae). Current Biotica. 2012; 6(2):163-170.
21. Vijaykumar L, Chakravarthy AK, Patil SU, Rajanna D. Resistance mechanism in rice to the midge *Orseolia oryzae* (Diptera: Cecidomyiidae).Journal of Economic Enotomology. 2009; 102(4):1628-1639.