Available online at www.ijpab.com

DOI: http://dx.doi.org/10.18782/2582-2845.7912

ISSN: 2582 – 2845

Ind. J. Pure App. Biosci. (2020) *8*(1), 74-85

Research Article

Indian Journal of Pure & Applied Biosciences

Peer-Reviewed, Refereed, Open Access Journal

Mechanisms of Resistance in Groundnut Genotypes against Groundnut Leaf Miner, *Aproaerema modicella* (Deventer)

Y. Peeru Saheb[1*], K. V. Hari Prasad[1], K. Swarajya Lakshmi[2] and J. Sailaja Rani[3]

[1*&2]Department of Entomology, S. V. Agricultural College, Tirupati- 517 502

[3]Department of Entomology, [4]Department of Plant Pathology, Agricultural College, Mahanandi - 518 502, Acharya N. G. Ranga Agricultural University, India

*Corresponding Author E-mail: peeru9@gmail.com

Received: 15.11.2019 | Revised: 23.12.2019 | Accepted: 31.12.2019

ABSTRACT

Leaf miner, Aproaerema modicella (Deventer) and leaf bud borer, Anarsia ephippias (Meyrick) are the two insect pests belonging to the family Gelechiidae causing considerable yield losses. An experiment was conducted to study the mechanisms of resistance on different groundnut genotypes towards groundnut leafminer. Groundnut genotypes tested for their reaction to leaf miner revealed that the proteins had shown significant negative correlation with incubation period, fourth instar duration, fifth instar duration, and total larval duration and total life span, phenols showed a significant positive correlation with third instar duration, fourth instar duration, total larval duration and total life span and reducing sugars showed positive correlation with incubation period and total life span.

Keywords: *Groundnut leaf miner, Proteins, Phenols, Reducing sugars.*

INTRODUCTION

Host plant resistance is an important management tool within the framework IPM that requires no additional cost inputs to the farmers. Host plant resistance being a seed borne technology gives a promising way of managing the insect pest which is cost effective to the farmers and environmental friendly. A significant contribution in development of resistant or tolerant groundnut genotypes for *A. modicella* has been made by ICRISAT for the past several years. Some of the genotypes developed by ICRISAT were being used as a parent material by many NARI and SAUs for developing location specific groundnut varieties. ICRISAT (1986), ICRISAT (1991). Though much work has been done on screening of groundnut genotypes for plant resistance to gelechiidae insect pests, not enough focus has been given on studying the mechanism of plant resistance involved in groundnut genotypes to gelechiidae insect pests' complex.

Cite this article: Peeru Saheb, Y., Hari Prasad, K.V., Lakshmi, K.S., & Sailaja Rani, J. (2020). Mechanisms of Resistance in Groundnut Genotypes against Groundnut Leaf Miner, *Aproaerema modicella* (Deventer), *Ind. J. Pure App. Biosci. 8*(1), 74-85. doi: http://dx.doi.org/10.18782/2582-2845.7912

MATERIALS AND METHODS

Studies on biology, larval and ovipositional preference of groundnut leaf miner on selected genotypes (under laboratory conditions)

Biology of groundnut leaf miner was studied on selected groundnut genotypes (that were grouped into resistant, moderately resistant and susceptible based on the per cent infestation data from the field) under laboratory conditions at the Insectray, Dept. of Entomology, S.V. Agricultural College, Tirupati during *rabi* 2015 at 24±1° C and humidity of 85±2 %.

Stock culture:

Groundnut leaf miner larvae were collected from the field and were placed in Petri plates of nine centimeter diameter, and were provided daily with tender leaflets. After the larvae have reached pupal stage, the pupae were separated and placed in the Perspex cages of 30×30×30 cm. The emerging adults were provided with fresh twigs of groundnut for oviposition. The twigs along with eggs were collected and placed in Petri plates till the eggs hatch. Neonates from this nucleus culture were used for further experiments. The emerging neonate larvae were provided with fresh twigs of selected genotypes and observations were recorded on a number of larval instars, duration of larval instars, pupal duration, adult longevity, duration of total life cycle, pre-oviposition, oviposition and post-oviposition periods.

Larval preference studies (free choice)

Tender leaflets of selected seven groundnut genotypes (two highly resistant, one moderately resistant and four susceptible genotypes) were placed together and radially arranged along the periphery of a Petri plate of nine centimeter diameter. Fifteen third instar larvae of groundnut leaf miner were released at the centre of the Petri plate and the number of larvae found inside the tender leaflets of each genotype after 24 hours of release, were counted and the data was used to indicate index of larval preference. The experiment was repeated thrice and per cent larval preference was calculated.

Oviposition preference studies (free choice)

Seven selected genotypes (two highly resistant, one moderately resistant and four susceptible genotypes) were tested for adult ovipositional preference. Fresh tender twigs of test genotypes with their stalks dipped in water in conical flask were placed in Perspex cages of 30×30×30 cm. Five pairs of freshly emerged moths were released into the oviposition cage for oviposition. Number of eggs laid on leaves and stems of selected genotypes were counted and fresh twigs were replaced daily until the moths were dead. The experiment was repeated thrice. The data was subjected to statistical analysis using SPSS software (SPSS, 2014).

Studies on biophysical characters

Trichome density

The trichome density was measured on the adaxial surfaces of the leaves of selected groundnut genotypes. The leaf was cut into 0.25 cm^2 area and the number of trichomes present were counted under binocular microscope (MAGNUS Stereoscopic binocular microscope Model MS 24 Alpha with objective (2x & 4x) and eyepiece 10x (F.N.22) having with in-built Light Stand (Incident: 6V15W Lamp/ Transmitted: 5W Fluorescence Lamp and expressed as number of trichomes per 0.25 cm^2. The data was recorded on six numbers of leaves in selected genotypes.

Leaf area

From each genotype three leaves were taken and leaf area with leaf area meter was taken and expressed as cm^2.

Leaf thickness

From each genotype three leaves were taken and were dried in hot air oven for three days and weights of them were taken and expressed as cm^2/g. Roderick[13] mentioned Specific Leaf Area (SLA) is a mean area of leaf displayed per unit of leaf weight (In a sense a measure of leaf density or relative thickness).

Measurement of chlorophyll content of leaves:

The chlorophyll content of leaves was measured using the Chlorophyll meter SPAD 502. Third opened leaves of each groundnut

genotype were used for estimating the chlorophyll content. Six replications were used.

Studies on biochemical constituents:

The biochemical constituents such as protein Lowry[8] total phenol Malick and Singh[9] and total reducing sugars Somogyi (1952) of the leaves of selected genotypes were estimated using the standard protocols. For each genotype three replications were taken.

Statistical analysis

The data was subjected to statistical analysis using SPSS software (SPSS, 2014)

RESULTS AND DISCUSSION

Based on results from the field experiment, the genotypes were grouped into resistant, moderately resistant and susceptible for their reaction to leaf miner. These genotypes were again tested in the laboratory for confirming their resistance rankings.

Table 1: Cumulative data on infestation of groundnut leaf miner based on first and second plantin

Character	Highly resistant	Moderately resistant	Highly susceptible
Per cent leaf miner infestation (no. of leaf mines) per plant (First and second planting)	ASK-2013-2, ASK-2013-5, TCGS-894, TCGS-1186 and TCGS-1097	K-1501, K-1559, ASK-2013-1, TCGS-1146 and TCGS-1342	Dharani, K-4, K-1563, Narayani and TCGS-341

Studies on Biology of groundnut leaf miner on selected genotypes:

Shortest incubation period of eggs of *A. modicella* (2.33 ± 0.51) was observed on Dharani followed by Narayani (2.50 ± 0.54) (on par with each other). Longest incubation period was observed on ASK-2013-1 and K-1563 (3.33 ± 0.51) (on par with each other). The incubation period on other groundnut genotypes were in between these two groups. The durations of first instar and second instar larvae of leaf miner *A. modicella* were not significantly different when reared on selected genotypes of groundnut. The shortest third instar larval duration of *A. modicella* (2.33 ± 0.51) was observed, when larvae of was reared on Dharani, K-1563, followed by K-4 (2.50 ± 0.54), Narayani and TCGS – 894 (2.67 ± 0.51) (on par with each other). The longest third instar larval duration of *A. modicella* was observed when larvae were reared on TCGS-1097 (3.50 ± 0.54) followed by ASK-2013-1 (3.00 ± 0.89). The shortest third instar larval duration of *A. modicella* (2.33 ± 0.51) was observed, when larvae of was reared on Dharani, K-1563, followed by K-4 (2.50 ± 0.54), Narayani and TCGS – 894 (2.67 ± 0.51) (on par with each other). The longest third instar larval duration of *A. modicella* was observed when larvae were reared on TCGS-1097 (3.50 ± 0.54) followed by ASK-2013-1 (3.00 ± 0.89). The shortest fourth instar larval duration of *A. modicella* was observed, when larvae were reared on Narayani (2.50 ± 0.54) followed by Dharani (2.83 ± 0.40) (on par with each other). The longest fourth instar larval duration of *A. modicella* (4.17 ± 1.16) was observed on TCGS-1097 followed by ASK-2013-1 (3.83 ± 0.75) (on par with each other). Fourth instar larval duration on remaining genotypes were in between these two groups. The shortest fifth instar larval duration of *A. modicella* was observed, when larvae were reared on Narayani (2.67 ± 0.51), followed by Dharani and K-1563 (3.00 ± 0.63) (on par with each other). The longest fifth instar larval duration of *A. modicella* was observed, when larvae were reared on ASK-2013-1 (3.67 ± 0.81) followed by TCGS 1097, TCGS 894 and K-4 (3.50 ± 0.54) (on par with each other). The shortest total larval duration of *A. modicella* was observed, when larvae were reared on Narayani (12.83 ± 1.83), followed by Dharani (13.00 ± 0.63), K-1563 (13.33 ± 1.33) and TCGS-894 (14.50 ± 1.04) (on par with each other). The longest total larval duration of *A. modicella* was observed, when larvae were reared on TCGS-1097 (16.50 ±

1.04), ASK-2013-1 (16.17 ± 1.94) and K – 4 (15.00 ± 1.09). The pre-oviposition, oviposition and post-oviposition, pupal, adult duration of *A. modicella* was not significantly different when reared on selected genotypes of groundnut. Shortest total life span of *A. modicella* was observed, when they were reared on Dharani, Narayani (26.83 ± 0.98) followed by K-1563 (28.17 ± 1.94) and K-4 (29.00 ± 1.26) (on par with each other). Longest total life span of *A. modicella* was observed, when they were reared on was on TCGS-1097 (31.83 ± 1.72) followed by ASK-2013-1 (30.67 ± 2.58) and TCGS-894 (30.17 ± 1.16) (on par with each other).

Based on the larval duration it was found that groundnut leaf miner larvae took more time to complete its larval duration on TCGS-1097 (16.50 days) and ASK-2013-1 (16.17 days) as compared to Narayani (12.83 days) and Dharani (13.00 days) giving them the status of resistant (poor) and susceptible (preferred) genotypes.

In the present investigation, the durations of incubation period, first, second, third, fourth and fifth instar larvae, total larval period and pupal period of *A. modicella* reared on different varieties of groundnut ranged from 2.33 - 3.33, 2.33 -2.67, 2.50 -3.00, 2.33-3.50, 2.50 -4.17, 2.67-3.67, 12.83 -16.17 and 5.00-6.17 days. These results were supported by Kothai (1974) who recorded egg period of groundnut leaf miner as 3 to 5 days, and larval period of first instar as 2 to 2.5 days. Second instar and third instar as 2 to 3days, fourth instar as 2 to 3.5 days, fifth instar as 2.5 to 3.5 days and pupal period as 4 to 7 days.

The present results were also in accordance with Murthy (1985) who studied the biology of leaf miner on TMV 2 groundnut and observed the duration of each stage as: incubation of egg 3.98 days, first instar 2.6 days, second instar 2.96 days, third instar 3.24 days, fourth instar 3.38 days, fifth instar 3.76 days and pupa 4.99 to 5.3 days during the months of August and October.

Table 2: Biology of groundnut leaf miner (*Aproaerema modicella*) on highly resistant, moderately resistant and susceptible genotypes of groundnut in no choice technique

Genotype	Incubation Days (Mean ± SD)	I Instar Days (Mean ± SD)	II Instar Days (Mean ± SD)	III Instar Days (Mean ± SD)	IV Instar Days (Mean ± SD)	V Instar Days (Mean ± SD)	Total larval duration Days (Mean ± SD)
TCGS-894 (Highly resistant)	3.17^{b} ± 0.40	2.33^{a} ± 0.51	2.67^{a} ± 0.51	2.67^{a} ± 0.51	$3.33ab^{cd}$ ± 0.81	3.50^{b} ± 0.54	14.50^{ab} ± 1.04
TCGS-1097 (Highly resistant)	3.17^{b} ± 0.40	2.67^{a} ± 0.51	2.67^{a} ± 0.51	3.50^{b} ± 0.54	4.17^{d} ± 1.16	3.50^{b} ± 0.54	16.50^{c} ± 1.04
ASK-2013-1 (Moderately resistant)	3.33^{b} ± 0.51	2.67^{a} ± 0.81	3.00^{a} ± 0.63	3.00^{ab} ±0.89	3.83^{cd} ± 0.75	3.67^{b} ± 0.81	16.17^{c} ± 1.94
K-1563 (Susceptible)	3.33^{b} ± 0.51	2.33^{a} ± 0.51	2.50^{a} ± 0.54	2.33^{a} ± 0.51	3.17^{abc} ± 0.40	3.00^{ab} ±0.63	13.33^{a} ± 1.36
K-4 (Susceptible)	3.17^{b} ± 0.40	2.67^{a} ± 0.51	2.83^{a} ± 0.40	2.50^{a} ± 0.54	3.50^{bcd} ± 0.54	3.50^{b} ± 0.54	15.00^{bc} ± 1.09
Narayani (Susceptible)	2.50^{a} ± 0.54	2.50^{a} ± 0.54	2.50^{a} ± 0.54	2.67^{a} ± 0.51	2.50^{a} ± 0.54	2.67^{a} ± 0.51	12.83^{a} ± 1.83
Dharani (Susceptible)	2.33^{a} ± 0.51	2.33^{a} ± 0.51	2.50^{a} ± 0.54	2.33^{a} ± 0.51	2.83^{ab} ± 0.40	3.00^{ab} ±0.63	13.00^{a} ± 0.63
Grand Mean	3.00 ± 0.58	2.50 ± 0.55	2.67 ± 0.52	2.71 ± 0.67	3.33 ± 0.84	3.26 ± 0.66	14.48 ± 1.87

Biology of groundnut leaf miner (*Aproaerema modicella*) on highly resistant, moderately resistant and susceptible genotypes of groundnut in no choice technique

Genotype	Pupal duration Days (Mean ± SD)	Adult duration Days (Mean ± SD)	Pre-ovipositin Days (Mean ± SD)	Oviposition Days (Mean ± SD)	Post-oviposition Days (Mean ± SD)	Total life span Days (Mean ± SD)
TCGS-894 (Highly resistant)	$6.17^{a} \pm 0.75$	$6.33^{a} \pm 0.51$	$1.67^{a} \pm 0.81$	$3.33^{b} \pm 0.81$	$1.33^{a} \pm 0.51$	$30.17^{bcd} \pm 1.16$
TCGS-1097 (Highly resistant)	$6.00^{ab} \pm 0.89$	$6.17^{a} \pm 1.16$	$2.17^{a} \pm 0.75$	$2.33^{a} \pm 0.51$	$1.67^{a} \pm 0.51$	$31.83^{d} \pm 1.72$
ASK-2013-1 (Moderately resistant)	$5.17^{ab} \pm 1.16$	$6.00^{a} \pm 0.89$	$2.00^{a} \pm 0.00$	$2.50^{a} \pm 0.54$	$1.50^{a} \pm 0.54$	$30.67^{cd} \pm 2.58$
K-1563 (Susceptible)	$5.50^{ab} \pm 0.54$	$6.00^{a} \pm 1.26$	$2.33^{a} \pm 0.51$	$2.17^{a} \pm 0.40$	$1.50^{a} \pm 0.54$	$28.17^{ab} \pm 1.94$
K-4(Susceptible)	$5.17^{ab} \pm 0.75$	$5.67^{a} \pm 1.36$	$1.83^{a} \pm 0.75$	$2.33^{a} \pm 0.51$	$1.50^{a} \pm 0.54$	$29.00^{abc} \pm 1.26$
Narayani(Susceptible)	$5.67^{ab} \pm 0.81$	$5.83^{a} \pm 0.75$	$1.67^{a} \pm 0.51$	$2.83^{ab} \pm 0.75$	$1.33^{a} \pm 0.51$	$26.83^{a} \pm 2.56$
Dharani(Susceptible)	$5.00^{a} \pm 0.63$	$6.50^{a} \pm 1.04$	$2.17^{a} \pm 0.75$	$2.67^{ab} \pm 0.81$	$1.67^{a} \pm 0.51$	$26.83^{a} \pm 0.98$
Grand Mean	5.25 ± 0.86	6.07 ± 0.99	1.98 ± 0.64	2.60 ± 0.70	1.50 ± 0.50	$29.07^{abc} \pm 2.48$

*Values followed by same letter are not significantly different as per DMRT

Larval preferences of groundnut leaf miner (*Aproaerema modicella*) on different genotypes of groundnut in free choice experiment

Lowest number of leaf miner larvae (1.33 ± 0.57) was observed on TCGS-894 and TCGS-1097, followed by ASK-2013-1 (1.67 ± 0.57) and K-4 (2.00 ± 0.57) (on par with each other). Highest number of leaf miner larvae was observed on Narayani (3.33 ± 0.57) followed by K-1563 (3.00 ± 0.00) and Dharani (2.33 0.57) (on par with each other).

The results are supported by Rao (2002) who screened artificially nine groundnut genotypes against groundnut leaf miner, *A. modicella* in glasshouses and screen houses and found that the susceptible genotype ICG -221 had higher number of larvae and pupae per plant.

Table 3: Larval preferences of groundnut leaf miner (*Aproaerema modicella*) on different genotypes of groundnut in free choice experiment

Genotype	Number of larvae remained after 24 hours (Mean ± SD)
TCGS-894 (Highly resistant)	1.33^{a} ± 0.57 (1.14)
TCGS-1097 (Highly resistant)	1.33^{a} ± 0.57 (1.14)
ASK-2013-1 (Moderately resistant)	1.67^{a} ± 0.57 (1.28)
K-1563 (Susceptible)	3.00^{bc} ± 0.00 (1.73)
K-4(Susceptible)	2.00^{a} ± 0.57 (1.28)
Narayani (Susceptible)	3.33^{c} ± 0.57 (1.82)
Dharani (Susceptible)	2.33^{ab} ± 0.57 (1.52)
Grand Mean	2.10 ± 0.88 (1.41)

Ovipositional preferences of (*A. modicella*) on different genotypes of groundnut in free choice experiment

Lowest number of eggs were laid on test genotype K-1563 (14.67 ± 9.29) followed by Narayani (15.67 ± 8.73) and K-4 (27 ± 6.24) (on par with each other). Highest number of eggs (90.33 ± 14.74) was observed on Dharani (significantly different from the eggs laid on other genotypes (Table 4.19). Eggs laid on other genotypes were in between these two groups.

The results are supported by Rao (2002) who screened artificially nine groundnut genotypes against groundnut leaf miner, *A. modicella* in glasshouses and screen houses. ICG-5040 was more preferred for egg laying as result of its hairiness.

Table 4: Ovipositional preferences of groundnut leaf miner (*Aproaerema modicella*) on different genotypes of groundnut in free choice experiment

Genotype	Number of eggs laid on different genotypes (Mean ± SD)
TCGS-894 (Highly resistant)	32.33^{ab} ± 12.22 (5.61)
TCGS-1097 (Highly resistant)	36.67^{b} ± 6.80 (6.04)
ASK-2013-1 (Moderately resistant)	32.67^{ab} ± 9.01 (5.68)
K-1563 (Susceptible)	14.67^{a} ± 9.29 (5.17)
K-4 (Susceptible)	27.00^{ab} ± 6.24 (5.17)
Narayani (Susceptible)	15.67^{a} ± 8.73 (3.83)
Dharani (Susceptible)	90.33^{c} ± 14.74 (9.48)
Grand Mean	35.62 ± 25.66 (5.64)

*Values followed by same letter are not significantly different as per DMRT

*Values in parenthesis are square root transformed

Studies on physical characters and biochemical constituents' groundnut genotypes

Physical characters

Trichome density

The lowest trichome density was found on leaves of K-1563 (19.25 ± 3.98) followed by K-4 (19.25 ± 9.44), ASK-2013-1 (24.00 ± 4.71) and TCGS-1097 (25.83 ± 4.68) (on par with each other). The highest trichome density was found on leaves of Narayani (54.17 ± 16.09), which was significantly different from rest of the other genotypes. Trichome density of TCGS-894 (34.42 ± 8.26) and Dharani (33.33 ± 12.91) were in between these two groups (on par with each other).

Leaf area

The lowest leaf area was found in leaves of ASK-2013-1 (11.44 ± 1.70) followed by TCGS-1097 (19.08 ± 2.66) (on par with each other), K-1563 (19.32 ± 6.73), TCGS-894 (20.45 ± 1.03), K-4 (22.55 ± 12.32) (on par with each other). Highest leaf area was found in leaves of Narayani (31.59 ± 7.07) followed by Dharani (29.36 ± 4.00) (on par with each other).

Leaf thickness

The lowest leaf thickness was found on leaves of TCGS-1097 (147.02 ± 2.27) followed by ASK-2013-1 (156.71 ± 27.83) (on par with each other), followed by TCGS-894 (183.85 ± 27.71), K-1563 (190.72 ± 46.63) (on par with each other). The highest leaf thickness was found on leaves of Narayani (243.23 ± 4.34) followed by Dharani (236.02 ± 29.22), K-4 (231.84 ± 44.47) (on par with each other).

Chlorophyll

The lowest chlorophyll was found on leaves of TCGS-894 (32.10 ± 2.08) followed by K-4 (35.27 ± 6.33), Narayani (36.23 ± 0.86) (on par with each other). The highest chlorophyll was found on leaves of K-1563 (47.46 ± 4.15) followed by Dharani (44.67 ± 1.88), ASK-2013-1 (44.2 ± 1.72) and TCGS-1097(42.53 ± 1.88) (on par with each other).

Table 5: Physical characters of highly resistant, moderately resistant and susceptible genotypes of groundnut with relation groundnut leaf miner(*Aproaerema modicella*)

Genotype	Trichomes ($0.25cm^2$) (Mean ± SD)	Leaf area(cm^2) (Mean ± SD)	Leaf thickness (cm^2/g) (Mean ± SD)	Chlorophyll (SCMR) (Mean ± SD)
TCGS-894 (Highly resistant)	34.42^{c} ± 8.26 (5.80)	20.45^{abc} ± 1.03	183.85^{ab} ± 27.71	32.10^{a} ± 2.08
TCGS-1097 (Highly resistant)	25.83^{ab} ± 4.68 (5.10)	19.08^{ab} ± 2.66	147.02^{a} ± .27.83	42.53^{b} ± 1.88
ASK-2013-1 (Moderately resistant)	24.00^{a} ± 4.71 (4.83)	11.44^{a} ± 1.70	156.71^{a} ± 27.83	44.2^{b} ± 1.72
K-1563 (Susceptible)	19.25^{a} ± 3.98 (4.43)	19.32^{ab} ± 6.73	190.72^{abc}±46.63	47.46^{b} ± 4.15
K-4 (Susceptible)	19.25^{a} ± 9.44 (4.49)	22.55^{abc} ±12.32	231.84^{bc} ±44.47	35.27^{a} ± 6.33
Narayani (Susceptible)	54.17^{d} ± 16.09 (7.39)	31.59^{c} ± 7.07	243.23^{c} ± 4.34	36.23^{a} ± 0.86
Dharani (Susceptible)	33.33^{bc} ± 12.91 (5.88)	29.36^{bc} ± 4.00	236.02^{bc} ±29.22	44.67^{b} ± 1.88
Grand Mean	30.4 ± 14.67 (5.42)	21.97 ± 8.29	198.48 ± 45.12	40.27 ± 6.37

*Values followed by same letter are not significantly different as per DMRT

*Values in parenthesis are square root transformed

Biochemical constituents

Protein

Lowest amount of protein was observed in the leaves of TCGS-894 (180.61 ± 10.26 mg/g), followed by ASK-2013-1 (184.19 ± 3.76 mg/g) (on par with each other), followed by TCGS-1097 (194.86 ± 4.08 mg/g) (significantly different). The highest amount of protein was observed in the leaves of Narayani (223.42 ± 5.98 mg/g) followed by Dharani (222.68 ± 6.03 mg/g) (on par with each other) followed by K-4 (204.51 ± 9.17 mg/g) and K-1563 (205.50 ± 4.24 mg/g) (on par with each other).

Phenol

Lowest amount of phenols was found in leaves of Narayani (62.00 ± 0.30 mg/g). The highest amount of phenols was in TCGS-894 (90.30 ± 0.36 mg/g). (The phenolic content of all the genotypes are significantly different from each other)

Reducing sugars

The lowest amount of reducing sugars was found in leaves of Narayani (1.15 ± 0.06 mg/g) was recorded in (highly susceptible). The highest amount of reducing sugars was found in leaves of TCGS-894 (2.92 ± 0.06 mg/g) (The reducing sugars content of all the genotypes are significantly different from each other).

Table 6: Biochemical characters of highly resistant, moderately resistant and susceptible genotypes of groundnut with relation to groundnut leaf miner (*Aproaerema modicella*)

Genotype	Proteins (mg/g) (Mean ± SD)	Phenols (mg/g) (Mean ± SD)	Reducing sugars (mg/g) (Mean ± SD)
TCGS-894 (Highly resistant)	180.61^{a} ± 10.26	90.30^{g} ± 0.36	2.92^{g} ± 0.06
TCGS-1097 (Highly resistant)	194.86^{bc} ± 4.08	84.23^{f} ± 0.19	1.99^{d} ± 0.08
ASK-2013-1 (Moderately resistant)	184.19^{ab} ± 3.76	76.49^{e} ± 0.46	2.26^{e} ± 0.05
K-1563 (Susceptible)	205.50^{c} ± 4.24	64.46^{b} ± 0.53	2.57^{f} ± 0.05
K-4 (Susceptible)	204.51^{c} ± 9.17	68.88^{c} ± 0.45	1.57^{c} ± 0.05
Narayani (Susceptible)	223.42^{d} ± 5.98	62.00^{a} ± 0.30	1.15^{a} ± 0.06
Dharani (Susceptible)	222^{d} ± 6.03	72.95^{d} ± 0.35	1.36^{b} ± 0.03
Grand Mean	202.25 ± 17.04	74.19 ± 9.79	1.97 ± 0.62

*Values followed by same letter are not significantly different as per DMRT

Correlation of groundnut leaf miner (*A. modicella*) performance on selected genotypes with their biophysical characters and biochemical constituents

Incubation period

Incubation period, on different groundnut genotypes was negatively correlated with thickness (r= -0.638), trichome density (r= -0.633) and proteins (r= -0.671) whereas, a positive correlation was observed with reducing sugars (r=0.602). (All are significant at 0.01 level).

Larval instar duration:

No significant correlations were observed between first instar larval duration, second instar larval with their biophysical and biochemical constituents.

Third instar larval duration

Third instar larval duration, when reared on different groundnut genotypes was negatively correlated with trichome density (r= -0.434) and whereas positively correlated with phenols (0.456). (All at 0.05 significant level).

Fourth instar larval duration

Fourth instar larval duration, when reared on different groundnut genotypes was negatively correlated with thickness (r= -0.607), trichomes (r= -0.613) (significant at 0.01 level) and proteins (r= -0.474) whereas positively correlated with phenols (r=0.453). (Significant at 0.05 level).

Fifth instar larval duration: Fifth instar larval duration, when reared on different groundnut genotypes was negatively correlated with proteins (-0.571) whereas positively correlated with phenols (0.460) and reducing sugars (0.531). (Significant at 0.01 and 0.05level).

No significant correlation was observed between pupal duration, adult duration, pre oviposition, ovipositionand post oviposition with biophysical and biochemical constituents.

Total larval duration

Total larval duration, when reared on different groundnut genotypes was negatively correlated with thickness (r= -0.568), trichomes (r= -0.576) (significant at 0.01 level) and proteins (r= -0.519) (significant at 0.01 level) whereas positively correlated with phenols (r=0.519). (Significant at 0.05 level).

Total life span

Total life span was negatively correlated, when reared on different groundnut genotypes with thickness (r= -0.592), trichome density (r= -0.602) and proteins (r= -0.647) (significant at 0.01 level) whereas positively correlated with phenols(r= 0.630) and reducing sugars(r= 0.454) (significant at 0.05 level).

Table 7: Correlation study of groundnut leaf miner (*Aproaerema modicella*) performance on selected genotypes with their biophysical characters and biochemical constituents

Insect growth regulators	Correlations	Thickness (cm2/g)	Trichomes	Chlorophll (SCMR)	Proteins (mg/g)	Phenols (mg/g)	Reducing sugars (mg/g)
Larval preference	Pearson Correlation	0.13	0.112	0.071	0.009	0.001	0.025
	Significance	0.575	0.629	0.759	0.969	0.997	0.916
Ovipositional preference	Pearson Correlation	0.131	0.114	0.071	0.009	0.001	0.024
	Significance	0.571	0.624	0.76	0.968	0.997	0.918
Incubation	Pearson Correlation	-.638(**)	-.633(**)	0.12	-.671(**)	0.252	.602(**)
	Significance	0.002	0.002	0.603	0.001	0.27	0.004
I Instar	Pearson Correlation	-0.32	-0.318	-0.381	-0.059	0.016	-0.137
	Significance	0.158	0.161	0.089	0.8	0.944	0.554
II Instar	Pearson Correlation	0.025	0.02	0.004	-0.363	0.141	0.098
	Significance	0.913	0.93	0.985	0.105	0.542	0.672
III Instar	Pearson Correlation	-0.419	-.434(*)	-0.008	-0.305	.456(*)	0.083
	Significance	0.059	0.05	0.974	0.179	0.038	0.722
IV Instar	Pearson Correlation	-.607(**)	-.613(**)	0.16	-.474(*)	.453(*)	0.34
	Significance	0.004	0.003	0.489	0.03	0.039	0.132
V Instar	Pearson Correlation	-0.415	-0.416	0.211	-.571(**)	.531(*)	0.371
	Significance	0.061	0.061	0.359	0.007	0.013	0.098
Total larval duration	Pearson Correlation	-.568(**)	-.576(**)	0.047	-.560(**)	.519(*)	0.273
	Significance	0.007	0.006	0.841	0.008	0.016	0.231
Pupal duration	Pearson Correlation	-0.28	-0.291	0.184	-0.303	0.356	0.315
	Significance	0.219	0.201	0.425	0.181	0.113	0.164
Adult Duration	Pearson Correlation	0.201	0.195	0.143	0.058	0.221	0.053
	Significance	0.383	0.398	0.537	0.803	0.335	0.819
Pre-oviposition	Pearson Correlation	0.01	0.006	0.033	0.079	-0.087	0.062
	Significance	0.965	0.978	0.886	0.734	0.707	0.79
Oviposition	Pearson Correlation	0.254	0.258	0.134	0.002	0.366	0.108
	Significance	0.266	0.259	0.562	0.993	0.103	0.64
Post-oviposition	Pearson Correlation	0.03	0.017	0.056	0.021	0.026	-0.116
	Significance	0.899	0.943	0.808	0.928	0.911	0.615
Life Span	Pearson Correlation	-.592(**)	-.602(**)	0.165	-.647(**)	.630(**)	.454(*)
	Significance	0.005	0.004	0.476	0.002	0.002	0.039

No significant correlations were observed between larval preference (orientation) with that of biophysical and biochemical constituents of different genotypes of groundnut.

In our present investigations, trichomes had shown a negative correlation with larval duration groundnut leaf miner. This probably could be due to the fact that presence of trichomes might have given shelter for the larvae from abiotic conditions and larvae might have completed their larval period much faster than on susceptible genotypes.

Review on effect of trichomes on biological parameters such as larval duration, pupal duration are scanty and hence the present investigations were discussed in light of effect of trichomes on other biological parameters such as larval and pupal mortality. Visalakshi (1997) reported that on groundnut resistant lines ICGV 86031 and ICGV 87160, the larval and pupal mortality was high as compared to susceptible line TMV 2 which could have been contributed by higher trichome density on resistant lines compared to susceptible lines.

Leaf thickness

Leaf thickness had shown negative correlation larval duration for leaf miner. Our results are in contradictory with the results of Rao (1991) who reported that the resistant groundnut lines *viz*, ICGV 86162, FDRS 10, ICGV 86011 and NCAc 17090 had thicker leaflets as compared to susceptible genotypes and Visalakshi (1997) who reported that groundnut resistant lines had thicker leaves compared to susceptible lines.

This difference in the results could be probably due to the methodologies used for calculating the leaf thickness. The leaf thickness in our present investigations, were calculated as = leaf area in cm2 / leaf dry weight in g.

The outcome of the present results were presumably because susceptible genotypes had more leaf area as compared to resistant genotypes and the larvae had opportunity to feed on more leaf biomass and complete the larval period much faster as compared to resistant genotypes that had less leaf area.

Chlorophyll

A positive correlation was observed between chlorophyll (SCMR values) and total life span of leaf miner (non-significant). This could be due to the fact chlorophyll has increased the resistance of host plant to leaf miner, where more chlorophyll content has resulted in less feeding by the larvae and took more days to complete the life cycle.

Similar results were reported by Bhole et al. (1984) who found that JL 50 a mutant of JL 24 had smaller and intense dark green leaves, which were tolerant to the leaf miner.

It was also found in the present investigations, groundnut genotypes that showed resistance reaction to leaf miner had dark green leaves as compared to susceptible genotypes that had light green leaves (personal observation).

Proteins

Proteins had shown a significant negative correlation with instar larval durations and total life span of leaf miner.

This may be due to the palatability of the proteins present in the tested genotypes. The susceptible genotypes had significantly higher amounts of protein, that fulfils the dietary requirement of the larvae at much shorter period of feeding and larvae completed its larval period and total life span at much faster rate as compared to the resistant genotypes, that had lower amounts of proteins and the insect took more time to complete its larval and total life span.

These results are supported by Ambenagare et al. (2011) who determined the biochemical basis of *A. modicella* resistance in 7 soyabean cultivars (MAUS-81, JS-98-63, MAUS-71, MAUS-158, JS-335, MACS-1055 and Bragg). High protein per cent (21.15%) were observed from the susceptible control, Bragg.

The results of present investigations are also in tune with Halder[3] reported about 6 biochemical parameters, *i.e.*, total sugar, reducing sugar, non-reducing sugar, amino acids, proteins and phenols in pods in relation to the expression of varietal reaction towards the spotted pod borer *M. vitrata* in 10 mung bean cultivars (LGG-450, LGG-460, LGG-492, LGG-485, LGG-483, LGG-489, LGG-407, LGG-523, MGG-348 and LGG-497), conducted in Andhra Pradesh, India, during the 2003/04 *rabi* season, that the highly susceptible cultivar LGG-450 had highest protein (23.44%) compared to the highly tolerant cultivar LGG-497 which had (18.56%).

The results are also in agreement with Sujithra and Srinivasan (2012) that highly susceptible cultivar AVT-FB(80) 15-6-4 had highest amount of protein (28.9%), compared to tolerant cultivar TCR-137 which had 19.

Phenols

Phenols had shown a significant positive correlation with instar larval durations and total life span of leaf miner.

Negative effect of phenols on insect herbivores has been reported earlier by many workers. Some of the results of earlier works which are in accordance with the present investigations are presented below.

The results are supported by Ambenagare et al. (2011) determined the biochemical basis of *A. modicella* resistance in 7 soyabean cultivars (MAUS-81, JS-98-63, MAUS-71, MAUS-158, JS-335, MACS-1055 and Bragg). Significantly high phenol content (90.00 mg/g) was noted in leaves of JS-98-63 while it was the lowest in leaves of Bragg (susceptible) (50.00 mg/g).

The results are also in agreement with Halder et al. (2006) reported about 6 biochemical parameters, *i.e.*, total sugar, reducing sugar, non-reducing sugar, amino acids, proteins and phenols in pods in relation to the expression of varietal reaction towards the spotted pod borer *M. vitrata* in 10 mung bean cultivars (LGG-450, LGG-460, LGG-492, LGG-485, LGG-483, LGG-489, LGG-407, LGG-523, MGG-348 and LGG-497), conducted in Andhra Pradesh, India, during the 2003/04 *rabi* season, phenols were highest in the resistant cultivar LGG-497 (21.03 mg/g) than the susceptible cultivar LGG-450 (20.00 mg/g).

The results are supported by Halder and Srinivasan (2007) biochemical parameters, viz., total sugar, reducing sugar, nonreducing sugar, amino acids, proteins and phenols in pods, in relation to the expression of varietal reaction to *M. vitrata* in urd bean (Vigna mungo) LBG-17, LBG-22, LBG-623, LBG-402, LBG-20, T-9, LBG-685, PBG-1, PBG-107 and LBG-611. Phenols were highest (21.72 mg/g) in the resistant cultivar LBG-611 than the susceptible cultivar LBG-17 (20.41 mg/g).

Reducing sugars

Reducing sugars had shown a significant positive correlation withincubation period and total life span of leaf miner.

The results are in contradiction with Sujithra and Srinivasan (2012) studied the biochemical characters in 84 genotypes of field bean that confers resistance to *M.vitrata* and observed that highly susceptible cultivar AVT-FB(80) 15-6-4 had higher amount of reducing sugar (1.72 %) as compared to tolerant cultivar TCR-137 which had 1.05 % of reducing sugars.

These results are also in contradiction with Halder et al. (2006) have studied the 6 biochemical parameters, *i.e.*, total sugar, reducing sugar, non-reducing sugar, amino acids, proteins and phenols in pods in relation to the expression of varietal reaction towards the spotted pod borer *M. vitrata* in 10 mung bean cultivars (LGG-450, LGG-460, LGG-492, LGG-485, LGG-483, LGG-489, LGG-407, LGG-523, MGG-348 and LGG-497), conducted in Andhra Pradesh, India, during the 2003/04 *rabi* season, and observed that the highly susceptible cultivar LGG-450 had highest amount of reducing sugar 0.59 mg/g, compared to the highly tolerant cultivar LGG-497 which had 0.48 mg/g.

Halder and Srinivasan (2007) recorded the six biochemical parameters, *viz.*, total sugar, reducing sugar, non-reducing sugar, amino acids, proteins and phenols in pods, in relation to the expression of varietal reaction to *M. vitrata* in urd bean (*Vigna mungo*) genotypes LBG-17, LBG-22, LBG-623, LBG-402, LBG-20, T-9, LBG-685, PBG-1, PBG-107 and LBG-611. The highly susceptible cultivar LBG-17 had the highest amount reducing sugar (0.62 mg/g) and the lowest values were recorded in the highly tolerant cultivar L.

CONCLUSION

Studies on correlation with physical characters of groundnut genotypes tested for their reaction to leaf miner revealed that the trichomes had shown negative correlation with incubation period, third instar duration, fourth

instar duration, total larval duration and total life span, thickness had shown negative correlation with incubation period, fourth instar duration, total larval duration and life span and chlorophyll had not shown any significant correlation with any characters.

Studies on correlation with biochemical constituents of groundnut genotypes tested for their reaction to leaf miner revealed that the proteins had shown significant negative correlation with incubation period, fourth instar duration, fifth instar duration, and total larval duration and total life span, phenols showed a significant positive correlation with third instar duration, fourth instar duration, total larval duration and total life span and reducing sugars showed positive correlation with incubation period and total life span.

REFERENCES

Ambenagare, R.M., Shetgar, S.S., & Thankar, V.G. (2011). Biochemical basis of resistance in soybean cultivars to leaf miner, *Aproaerema modicella* (Deventer). *Indian Journal of Entomology*. *73*(1), 93-94.

Bhole, G. R., Patil, S. S., & Deokar, A. B. (1984). Intense dark green small leaf mutant in groundnut. *Journal of Oilseeds Research*. *1*, 85-87.

Halder J, Srinivasan S., & Murali Krishna T. (2006). Biochemical basis of resistance to spotted pod borer *Maruca vitrata*(Geyer) in mungbean. *Journal of Entomological Research*. *30*(4), 313-316.

Halder, J., & Srinivasan, S. (2007). Biochemical basis of resistance against *Maruca vitrata*(Geyer) in urd bean. *Annals of Plant Protection Sciences*. *15*(2), 287-290.

ICRISAT (International Crops Research Institute for the Semi-Arid Tropics). (1986). Annual Report. Patancheru, Andhra Pradesh 502324, India.

ICRISAT (International Crops Research Institute for the Semi-Arid Tropics). (1991). Legumes programme Annual Report. Patancheru, Andhra Pradesh. 502324, India.

Kothai, K. (1974). Bionomics and chemical control of the groundnut leaf miner, *Stomopteryx subsecivella* (Zeller). *M. Sc. (Ag.)* Thesis, University of Agricultural Sciences, Bangalore. 76.

Lowry, O.H., Rosebrough, N.J., Farr, A.L., & Ramdall, R.J. (1951). Estimation of total proteins. *Journal of Biological Chemistry*. 193-265.

Malick, C.P., & Singh, M.B. (1980). Plant Enzymology and Histo Enzymology. *Kalyani Publishers New Delhi*.281.

Murthy, K.S. (1985). Studies on seasonal incidence, biology and bionomics and chemical control of the groundnut leafminer, *Aproaerema modicella* (Deventer). M. Sc. (Ag.) thesis, Andhra Pradesh Agricultural University, Hyderabad.

Rao, R.G.V. (1991). Studies on the seasonal occurrence and host preference of the groundnut leaf miner, *Aproaerema modicella* (Deventer) in some selected groundnut lines. *Ph.D.* Thesis, submitted to Andhra Pradesh Agricultural University, Hyderabad.

Rao, R.V.S. (2002). Method of screening for resistance to leaf miner, *Aproaerema modicella* (Deventer) under greenhouse conditions. *Annals of Plant Protection Sciences*. *10*(1), 38-41.

Roderick, H. (1978). Plant Growth Analysis. *The Camelot press ltd, Southhampton*. 21-22.

Somogyi, M. (1952). Notes on sugar determination. *Journal of Biological Chemistry*. *195*, 19-24.

Sujithra, M., & Srinivasan, S. (2012). Bio-physical and bio-chemical factors influencing plant resistance in pod borers on field bean, *Lablab purpureus var. lignosus* Medikus. *Annals of Plant Protection Sciences*. *20*(2), 329-333.

Vislakshi, M. (1997). Non-Preference mechanism of resistance in groundnut cultures to the leaf miner *Aproaerema modicella* (Deventer). *Journal of Oilseeds Research*. *14*(2), 265-268.