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Mechanisms of resistance in groundnut genotypes against leaf bud borer, *Anarsia ephippias* (Meyrick)

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Abstract
A study was conducted to evaluate plant resistance in groundnut genotypes to groundnut leaf bud borer, *Anarsia ephippias* (Meyrick) (Gelechiidae; Lepidoptera), an emerging insect pest of groundnut. Out of forty one genotypes that were screened, the genotypes ASK-2013-1, K-1563 and TCGS-894 were found to be resistant; TCGS-1156 and K-1628 were found to be moderately resistant and Narayani and K-6 were found to be susceptible for their reaction to leaf bud borer. Biology, larval preference and ovipositional preference of leaf bud borer on these groundnut genotypes were studied and were correlated to plant biophysical and biochemical characters.

Keywords: Groundnut leaf bud borer, biology, biochemical characters, biophysical characters, resistant, moderately resistant, susceptible

1. Introduction

The low level productivity of groundnut in India is largely because the crop is rainfed and is exposed to various abiotic and biotic stresses. The estimated loss in groundnut due to pest attack is around Rs. 150 crores. Sahayaraj and Amalraj [20] reported that among the major pests reported on groundnut, *Aproaerma modicella* Dev., *Helicoverpa armigera* Hubner and *Spodoptera litura* Fabricius are the major defoliators.

The groundnut leaf webber, *Anarsia ephippias* (Meyerick), was first reported to be feeding on the groundnut crop by Lefroy [12]. During the *kharif* in 1969, it was recorded on the groundnut crop in the Punjab. It makes shot holes in the shoots and causes the webbing of young leaves, called it as leaf-roller, but considering the nature of damage it is more appropriate to designate it as the groundnut leaf Webber. Bhaketia [2] who reported that the infestation of groundnut by this pest was observed upto 100 per cent in some of the varieties grown at the Research Farm of the Punjab Agricultural University, Ludhiana. In general, the varieties of the bunch group were more damaged than that of the spreading and semi-spreading groups. Gangrade [5] Bhattacharya and Rathore [3] reported *Anarsia ephippias* (Meyerick), is an important leaf webber of soybeans in India. It appears from July to April. Singh and Dhamdhere [21] reported the larvae of this pest were found to defoliate the young leaves of soybean, groundnut, pigeonpea, greengram, cowpea and black gram from July to April. Wightman and Ranga Rao [26] reported the groundnut leaf bud borer *Anarsia ephippias* (Meyrick) has been reported from northern India where it was considered to be a minor pest. 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. An attempt was made in the present investigation to evaluate the groundnut genotypes for their reaction to leaf bud borer.

2. Material and Methods

The present investigation on reaction of different genotypes of groundnut, (*Arachis hypogaea* L.) to leaf bud borer was carried out in the field number 144 of S. V. Agricultural College, Farm, Tirupati, Andhra Pradesh which is situated at an altitude of 182.90 m above mean sea level, 13°N latitude and 79°E longitude, during 2014 *kharif*. Forty one genotypes of groundnut were procured from Agricultural Research Station, Kadiri and Regional Agricultural Research Station, Tirupati and were used in the present investigation(TCGS-1073, TCGS-1157, TCGS-1156, TCGS-1157 (A), TCGS-1097, TCGS-1186, TCGS-1119, TCGS-894, TCGS-1146, TCGS-341, Tirupathi-4, Tirupathi-3, TCGS-1342, TCGS-1343, TCGS-1345, TCGS-1375,

TCGS-1550, Dharani, Narayani, ASK-2013-1, ASK-2013-2, ASK-2013-5 K-1563, K-1662, K-1452, K-1628, K-1660, K-5, K-1454, K-8, K-7 (BOLD), K-4, K-1501, K-1609, K-1468, K-9, K-1620, K-1559, K-6, Anantha, Kadiri Harithandra). All the genotypes were sown in 2 rows of 4 m length with a spacing of 45 cm between the rows and 15 cm within the row and there were two replications. The experimental area for each genotype was 3.6 m^2. A row of popular groundnut genotype Narayani was planted around the experiment plot as an infester row 10 days before sowing of experimental material of each genotype to favour the buildup of insect pest population. There were two dates of sowing one on 8-7-2014 and second on 8-8-2014.

Per cent infestation of leaf bud borer (under field conditions)

For each genotype, total number of plants and number of plants with leaf bud borer larvae were counted in the experimental plot and per cent infestation was calculated.

$$\text{Per cent infestation} = \frac{\text{Total number of plants in in the experimental area}}{\text{Number of plants with leaf bud borer larvae}} \times 100$$

All the observations were taken at weekly intervals from 30 DAS to 60 DAS.

The per cent values were converted with help of Arc sine values before subjecting them to statistical analysis. Later the data was analyzed using ANOVA technique and subjected to DMRT (Duncan's Multiple Range Test) with the help of SPSS software (SPSS, 2014).

Studies on biology of leaf bud borer on selected genotypes (under laboratory conditions)

Biology of leaf bud borer 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

Leaf bud borer larvae were collected from the field and were placed in Petri plates of nine cm 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 (three highly resistant, two moderately resistant, one susceptible and one popular genotype) were placed together and radially arranged along the periphery of a Petri plate of nine centimeter diameter. Fifteen third instar larvae of leaf bud borer 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 (three resistant, two moderately resistant, one susceptible and one popular genotype) 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. Males and females were identified on the basis of presence of projected labial palp in case of females which were absent in males Jothi and Tandon [8].

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 [19] 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) [13] total phenol (Malick and Singh) [14] and total reducing sugars (Somogyi) [22] 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).

3. Results and Discussion

Per cent infestation of leaf bud borer (*A. ephippias*) on different groundnut genotypes (first planting)

At 39 and 46 DAS, no significant differences were observed among different genotypes of groundnut in terms of per cent leaf bud borer infestation.

At 53 DAS, lowest per cent leaf bud borer infestation was found in K-1452 (4.63± 0.40), followed by TCGS-1375 (4.78 ± 0.87), K-1563 (5.85 ± 4.12), K-1501 (6.25 ± 0.13), TCGS-1097 (6.98 ± 0.05) (on par with each other). Highest per cent leaf bud borer infestation was found in Dharani (TCGS-1043) (23.85 ± 0.30) followed by Narayani (21.91 ± 9.04), K-6 (20.90 ± 0.44), TPT-4 (18.28 ± 10.39) and TCGS-341 (17.03 ± 6.95) (on par with each other). The per cent leaf bud borer infestations of other genotypes were in between the group of genotypes having lowest and highest per cent leaf bud borer infestation.

At 60 DAS, lowest per cent leaf bud borer infestation was found in K-1454 (4.98± 0.80), followed by ASK-2013-1 (5.36 ± 0.85), K-1559 (5.44 ± 1.88), K-1628 (6.06 ± 1.00), TCGS-1157(A) (6.30 ± 1.33) (on par with each other). Highest per cent leaf bud borer infestation was found in Narayani (29.91 ± 5.63), followed by Dharani (TCGS-1043) (28.45 ± 1.66), TPT-4 (22.41 ± 11.81), K-6 (21.70 ± 5.73) (on par with each other) and K-1468 (17.74 ± 4.56) (significantly different with each other). The per cent leaf bud borer infestations of other genotypes were in between the group of genotypes having lowest and highest per cent leaf bud borer infestation.

From the mean data, percentage infestation of leaf bud borer was found lowest in TCGS-1375 (3.59 ± 0.31), followed by K-1563 (4.61 ± 3.40), ASK-2013-1 (4.63 ± 0.74), TCGS-1146 (4.90 ± 0.33) and K-1454 (5.12 ± 2.57) (on par with each other). Highest per cent leaf bud borer infestation was found in Dharani (TCGS-1043) (18.61 ± 5.75) followed by Narayani (15.27 ± 5.75), K-6 (14.80 ± 5.85), TPT-4 (12.24 ± 6.26) and K-5 (10.35 ± 2.46) (on par with each other). The per cent leaf bud borer infestations of other genotypes were in between the group of genotypes having lowest and highest per cent leaf bud borer infestation (Table 1).

Table 1: Per cent infestation of leaf bud borer (*Anarsia ephippias*) on different groundnut genotypes (first planting)

	Per cent infestation				
Genotype	**39 DAS (Mean ± SD)**	**46 DAS (Mean ± SD)**	**53 DAS (Mean ± SD)**	**60 DAS (Mean ± SD)**	**Average (Mean ± SD)**
ASK-2013-1	0.00 ± 0.00	3.92 ± 3.43	9.24^{abcde} ± 0.40 (17.69)	5.36^{a} ± 0.85 (13.37)	4.63^{ab} ± 0.74 (12.40)
ASK-2013-2	1.40 ± 1.99	5.76 ± 3.79	9.61^{abcde} ± 1.63 (18.02)	8.77^{abcdef} ± 1.53 (17.20)	6.38^{ab} ± 1.42 (14.59)
ASK-2013-5	3.25 ± 1.72	4.47 ± 6.33	9.85^{abcde} ± 3.38 (18.16)	8.08^{abcde} ± 2.99 (16.38)	6.41^{ab} ± 0.42 (14.67)
K-4	4.61 ± 6.52	2.30 ± 3.26	11.85^{abcdef} ± 2.81 (20.07)	$12.55^{abcdefg}$ ± 1.82 (20.72)	7.83^{abcd} ± 3.60 (16.04)
K-5	7.31 ± 1.06	3.23 ± 2.26	14.63^{cdefg} ± 0.16 (22.49)	16.22^{defg} ± 6.7 (23.52)	10.35^{abcde} ± 2.46 (18.70)
K-7	0.89 ± 1.26	1.38 ± 1.96	8.23^{abcd} ± 4.06 (16.42)	10.71^{abcdef} ± 2.52 (19.04)	5.30^{ab} ± 1.82 (13.22)
K-8	8.45 ± 7.158	4.39 ± 1.42	11.84^{abcdef} ± 2.36 (20.08)	15.39^{cdefg} ± 4.98 (22.96)	10.02^{abcde} ± 3.98 (18.28)
K-9	8.24 ± 9.64	4.91 ± 1.13	7.02^{abc} ± 2.18 (15.28)	6.96^{abc} ± 1.77 (15.24)	6.78^{abc} ± 2.02 (15.02)
K-1452	3.71 ± 2.94	7.28 ± 8.24	4.63^{a} ± 0.40 (12.42)	8.44^{abcde} ± 0.35 (16.89)	6.02^{ab} ± 1.33 (14.16)
K-1454	2.77 ± 3.92	5.59 ± 5.83	7.14^{abc} ± 0.28 (15.50)	4.98^{a} ± 0.80 (12.87)	5.12^{ab} ± 2.57 (12.88)
K-1468	0.80 ± 1.14	4.83 ± 6.84	13.71^{bcdefg} ± 3.42 (21.65)	17.74^{fg} ± 4.56 (24.82)	9.27^{abcd} ± 3.99 (17.53)
K-1501	1.58 ± 2.24	5.43 ± 3.19	6.25^{abc} ± 0.13 (14.47)	7.76^{abcd} ± 4.24 (15.88)	5.25^{ab} ± 1.26 (13.21)
K-1559	3.42 ± 4.84	7.66 ± 1.14	9.87^{abcde} ± 0.41 (18.31)	5.44^{a} ± 1.88 (13.39)	6.60^{abc} ± 0.34 (14.88)
K-1563 (VG)	1.75 ± 2.48	2.63 ± 3.72	5.85^{ab} ± 4.12 (13.55)	8.20^{abcde} ± 3.28 (16.42)	4.61^{a} ± 3.40 (11.95)
K-1609	1.67 ± 0.19	3.63 ± 5.14	10.21^{abcde} ± 3.56 (18.50)	10.83^{abcdef} ± 0.09 (19.22)	6.59^{abc} ± 2.24 (14.77)
K-1620	10.00 ± 4.71	4.44 ± 3.14	9.44^{abcde} ± 0.78 (17.89)	$12.50^{abcdefg}$ ± 1.17 (20.69)	9.09^{abcd} ± 0.49 (17.55)
K-1628	0.89 ± 1.26	4.46 ± 6.31	12.18^{abcdef} ± 0.44 (20.42)	6.06^{ab} ± 1.00 (14.23)	5.90^{ab} ± 1.75 (13.98)
K-1660	0.84 ± 1.19	6.57 ± 9.30	11.75^{abcde} ± 9.43 (19.22)	9.03^{abcdef} ± 1.60 (17.45)	7.05^{abc} ± 3.98 (15.09)
K-1662	3.68 ± 2.49	2.83 ± 1.43	7.43^{abc} ± 2.34 (15.72)	8.44^{abcde} ± 1.65 (16.85)	5.59^{ab} ± 0.43 (13.68)
TCGS-341	0.00 ± 0.00	4.54 ± 6.42	17.03^{defg} ± 6.95 (24.15)	16.57^{efg} ± 4.15 (23.94)	9.53^{abcd} ± 1.16 (17.97)
TCGS-894	4.91 ± 6.95	3.15 ± 2.49	7.82^{abc} ± 5.16 (15.79)	7.57^{abcd} ± 0.88 (15.95)	5.86^{ab} ± 3.87 (13.62)
TCGS-1073	5.84 ± 5.53	7.31 ± 10.34	11.60^{abcdef} ± 2.62 (19.86)	8.98^{abcdef} ± 4.54 (17.16)	8.43^{abcd} ± 4.45 (16.59)
TCGS-1097	4.20 ± 3.98	7.52 ± 6.71	6.98^{abc} ± 0.05 (15.32)	7.16^{abc} ± 2.27 (15.43)	6.46^{ab} ± 3.25 (14.50)
TCGS-1119	2.63 ± 0.09	10.25 ± 14.50	10.46^{abcde} ± 3.33	11.07^{abcdef} ± 6.10	8.60^{abcd} ± 5.95

			(18.76)	(19.08)	(16.53)
TCGS-1146	0.73 ± 1.03	2.80 ± 0.19	7.01^{abc} ± 0.48 (15.34)	9.07^{abcdef} ± 0.36 (17.53)	4.90^{ab} ± 0.33 (12.79)
TCGS-1156	5.33 ± 3.92	9.32 ± 5.92	10.46^{abcde} ± 3.33 (18.76)	14.38^{bcdefg} ± 5.04 (22.13)	9.87^{abcde} ± 0.36 (18.314)
TCGS-1157	4.19 ± 2.39	4.41 ± 6.23	11.39^{abcdef} ± 1.55 (9.70)	9.41^{abcdef} ± 0.83 (17.85)	7.35^{abcd} ± 1.55 (15.69)
TCGS-1157(A)	1.78 ± 2.52	6.08 ± 6.55	8.64^{abcde} ± 2.12 (17.03)	6.30^{ab} ± 1.33 (14.49)	5.70^{ab} ± 1.40 (13.76)
TCGS-1186	1.40 ± 1.99	5.15 ± 3.31	13.68^{bcdefg} ± 5.40 (21.51)	10.63^{abcdef} ± 0.89 (19.02)	7.72^{abcd} ± 1.45 (16.09)
TCGS-1342	4.77 ± 1.69	7.15 ± 2.54	8.19^{abcd} ± 1.03 (16.62)	7.15^{abc} ± 2.54 (15.39)	6.82^{abc} ± 1.43 (15.09)
TCGS-1343	2.63 ± 3.72	4.38 ± 6.20	7.89^{abcd} ± 1.24 (16.29)	9.64^{abcdef} ± 3.72 (17.93)	6.14^{ab} ± 3.10 (14.11)
TCGS-1345	3.34 ± 1.00	0.00 ± 0.00	9.31^{abcdef} ± 1.70 (17.73)	10.59^{abcdef} ± 7.34 (18.42)	5.81^{ab} ± 2.01 (13.85)
TCGS-1375	0.00 ± 0.00	2.06 ± 1.00	4.78^{a} ± 0.87 (12.61)	7.54^{abcd} ± 1.11 (15.92)	3.59^{a} ± 0.31 (10.93)
TCGS-1550	0.00 ± 0.00	4.97 ± 2.54	8.31^{abcd} ± 5.02 (16.37)	9.95^{abcdef} ± 5.09 (18.10)	5.81^{ab} ± 3.16 (13.68)
TPT-3	4.34 ± 0.48	8.00 ± 11.31	10.68^{abcde} ± 1.85 (19.04)	6.34^{ab} ± 2.34 (14.49)	7.34^{abcd} ± 3.75 (15.46)
TPT-4	1.56 ± 2.20	6.69 ± 5.04	18.28^{efg} ± 10.39 (24.86)	22.41^{gh} ± 11.81 (27.85)	12.24^{bcde} ± 6.26 (20.16)
Anantha	9.10 ± 5.56	4.62 ± 1.66	10.24^{abcde} ± 0.14 (18.66)	8.65^{abcdef} ± 0.05 (17.11)	8.15^{abcd} ± 1.78 (16.55)
Dharani	11.11 ± 15.71	11.04 ± 5.33	23.85^{g} ± 0.30 (29.23)	28.45^{h} ± 1.66 (32.23)	18.61^{e} ± 5.75 (25.431)
KH	1.69 ± 2.39	4.23 ± 5.99	7.99^{abcd} ± 4.11 (16.15)	9.63^{abcdef} ± 0.76 (18.02)	5.89^{ab} ± 1.25 (14.00)
Narayani	2.66 ± 1.10	6.60 ± 9.33	21.91 ^{fg} ± 9.04 (27.66)	29.91^{h} ± 5.72 (33.10)	15.27^{de} ± 5.75 (22.82)
K-6	8.33 ± 11.78	8.26 ± 5.45	20.90^{fg} ± 0.44 (27.20)	21.70^{gh} ± 5.73 (27.66)	14.80^{cde} ± 5.85 (22.42)
Grand Mean	3.56 ± 4.38	5.23 ± 4.71	10.69 ± 5.11	11.14 ± 6.36	7.65 ± 3.73

*Values in parenthesis are arc sine transformed values

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

Per cent infestation of leaf bud borer (*A. ephippias*) on different groundnut genotypes (second planting)

At 39 DAS, lowest per cent leaf bud borer infestation was found in ASK-2013-1 (6.64± 0.56), followed by TCGS-894 (6.89 ± 0.06), K-1563 (8.31± 2.17), TCGS-1157(A) (8.48± 5.67) and K-8 (8.53 ± 3.86) (on par with each other). Highest per cent leaf bud borer infestation was found in K-6 (44.97 ± 3.84), followed by Narayani (40.87± 1.62), TCGS-341 (29.67 ± 0.72), K-4 (29.22± 1.81) and Dharani (TCGS-1043) (29.08± 0.45) (on par with each other). The per cent leaf bud borer infestations of other genotypes were in between the group of genotypes having lowest and highest per cent bud borer infestation.

At 46 DAS, lowest per cent leaf bud borer infestation was found in TPT-3

(4.22± 0.00), followed by TCGS-1157 (4.41 ± 2.32), K-1452 (6.22 ± 0.94), K-1620 (6.33 ± 0.47) and K-1563 (6.35 ± 3.00) (on par with each other). Highest per cent leaf bud borer infestation was found in K-6 (37.41 ± 2.86), followed by Narayani (31.5 ± 5.31), Dharani (TCGS-1043) (30.94 ± 0.55), K-4 (24.70 ± 13.82) and K-1628 (23.11± 0.98) (on par with each other). The per cent bud borer infestations of other genotypes were in between the group of genotypes having lowest and highest per cent bud borer infestation.

At 53 DAS, lowest per cent leaf bud borer infestation was found in TCGS-894

(5.56± 1.81), followed by ASK-2013-1 (5.98 ± 3.83), K-1563 (6.10 ± 1.32), K-8 (7.27 ± 1.83), TCGS-1550 (7.60 ± 5.31) (on par with each other). Highest per cent leaf bud borer infestation was found in K-6 (40.76 ± 1.08), followed by Narayani (36.34 ± 5.58), K-4 (26.67 ± 1.29), Dharani (TCGS-1043) (26.10 ± 1.07) and TCGS-341 (24.72 ± 3.10) (on par with each other). The per cent leaf bud borer infestations of other genotypes were in between the group of genotypes having lowest and highest per cent bud borer infestation.

At 60 DAS, lowest per cent leaf bud borer infestation was found in TPT-3

(7.97± 1.02) followed by TCGS-1157 (8.31 ± 1.50), K-1452 (9.61 ± 1.29), K-8 (11.13 ± 1.39), K-1620 (11.20 ± 1.46) (on par with each other). Highest per cent leaf bud borer infestation was found in K-6 (35.95 ± 4.38), followed by Dharani (TCGS-1043) (35.60 ± 1.86), Narayani (35.41 ± 5.63), K-4 (28.38 ± 14.43) and K-1628 (26.86± 0.78) (on par with each other). The per cent leaf bud borer infestations of other genotypes were in between the group of genotypes having lowest and highest per cent leaf bud borer infestation.

From the mean data, lowest per cent leaf bud borer infestation was found in TCGS-894 (7.90 ± 1.45) followed by K-1563 (8.02 ± 0.84), ASK-2013-1 (8.35 ± 0.87), K-8 (8.71 ± 0.76) and TCGS-1146 (9.64 ± 2.55) (on par with each other). Highest per cent leaf bud borer infestation was found in K-6 (39.77 ± 1.61), followed by Narayani (36.04 ± 4.54), Dharani (TCGS-1043), (30.43 ± 0.98), K-4 (27.24 ± 7.84) and TCGS-341 (23.25 ± 3.70) (on par with each other). The per cent leaf bud borer infestations of other genotypes were in between the group of genotypes having lowest and highest per cent bud borer infestation (Table 2).

Table 2: Per cent infestation of leaf bud borer (*Anarsia ephippias*) on different groundnut genotypes (total plot) (second planting)

Genotype	39 DAS (Mean ± SD)	46 DAS (Mean ± SD)	53 DAS (Mean ± SD)	60 DAS (Mean ± SD)	Per cent incidence mean observation (Mean ± SD)
ASK-2013-1	$6.64^{a} \pm 0.56$ (14.93)	$8.31^{abcd} \pm 0.35$ (16.76)	$5.98^{a} \pm 3.83$ (13.79)	$12.46^{abcde} \pm 1.22$ (20.66)	$8.35^{ab} \pm 0.87$ (16.78)
ASK-2013-2	$12.32^{abc} \pm 2.14$ (20.52)	$10.07^{abcdef} \pm 3.19$ (18.39)	$9.72^{abc} \pm 1.96$ (18.12)	$16.41^{abcdefg} \pm 2.68$ (23.86)	$12.13^{abcd} \pm 0.44$ (20.38)
ASK-2013-5	$17.65^{abc} \pm 11.02$ (24.29)	$8.51^{abcd} \pm 3.96$ (16.74)	$15.21^{abcd} \pm 11.11$ (22.22)	$13.30^{abcde} \pm 6.14$ (21.12)	$13.67^{abcde} \pm 8.06$ (21.25)
K-4	$29.22^{cde} \pm 1.81$ (32.71)	$24.70^{fghi} \pm 13.82$ (29.34)	$26.67^{cde} \pm 1.29$ (31.09)	$28.38^{gh} \pm 14.43$ (31.82)	$27.24^{efgh} \pm 7.84$ (31.35)
K-5	$24.34^{abcde} \pm 7.39$ (29.43)	$19.76^{cdefgh} \pm 3.70$ (26.34)	$21.78^{abcde} \pm 7.58$ (27.65)	$23.02^{defgh} \pm 3.86$ (28.63)	$22.22^{cdefg} \pm 1.85$ (28.12)
K-7 (BOLD)	$10.29^{abc} \pm 2.07$ (18.66)	$10.37^{abcdef} \pm 0.10$ (18.78)	$8.27^{abc} \pm 1.15$ (16.70)	$13.74^{abcdef} \pm 0.14$ (21.75)	$10.67^{abcd} \pm 0.87$ (19.05)
K-8	$8.53^{ab} \pm 3.86$ (16.77)	$7.93^{abc} \pm 1.25$ (16.33)	$7.27^{ab} \pm 1.83$ (15.58)	$11.13^{abcd} \pm 1.39$ (19.47)	$8.71^{ab} \pm 0.76$ (17.16)
K-9	$10.59^{abc} \pm 1.41$ (18.97)	$9.96^{abcdef} \pm 1.61$ (18.37)	$7.93^{abc} \pm 1.25$ (16.33)	$13.01^{abcde} \pm 1.51$ (21.12)	$10.37^{abcd} \pm 0.11$ (18.79)
K-1452	$19.03^{abc} \pm 21.02$ (23.69)	$6.22^{ab} \pm 0.94$ (14.42)	$19.03^{abcd} \pm 16.96$ (24.62)	$9.61^{abc} \pm 1.29$ (18.04)	$13.47^{abcd} \pm 10.05$ (20.79)
K-1454	$12.27^{abc} \pm 0.57$ (20.50)	$13.89^{abcdef} \pm 2.57$ (21.84)	$9.38^{abc} \pm 0.86$ (17.83)	$17.18^{abcdefg} \pm 1.96$ (24.47)	$13.18^{abcde} \pm 1.49$ (21.27)
K-1468	$15.74^{abc} \pm 6.54$ (23.15)	$21.56^{defghi} \pm 3.55$ (27.63)	$12.45^{abc} \pm 6.39$ (20.34)	$25.53^{efgh} \pm 4.68$ (30.30)	$18.82^{abcdef} \pm 5.29$ (25.60)
K-1501	$14.25^{abc} \pm 4.44$ (22.05)	$8.57^{abcd} \pm 5.79$ (16.53)	$11.97^{abc} \pm 4.81$ (20.05)	$11.76^{abcd} \pm 5.58$ (19.79)	$11.64^{abcd} \pm 0.53$ (19.94)
K-1559	$14.79^{abc} \pm 7.83$ (22.26)	$13.38^{abcdef} \pm 0.24$ (21.45)	$11.35^{abc} \pm 7.90$ (19.10)	$19.48^{abcdefg} \pm 0.73$ (26.19)	$14.75^{abcde} \pm 3.81$ (22.50)
K-1563 (VG)	$8.31^{a} \pm 2.17$ (16.69)	$6.35^{ab} \pm 3.00$ (14.39)	$6.10^{a} \pm 1.32$ (14.26)	$11.30^{abcd} \pm 3.86$ (19.51)	$8.02^{a} \pm 0.84$ (16.44)
K-1609	$13.73^{abc} \pm 8.01$ (21.31)	$9.37^{abcde} \pm 2.70$ (17.74)	$12.49^{abc} \pm 3.75$ (20.59)	$13.01^{abcde} \pm 3.17$ (21.07)	$12.15^{abcd} \pm 1.47$ (20.38)
K-1620	$19.46^{abcd} \pm 11.29$ (25.69)	$6.33^{ab} \pm 0.47$ (14.57)	$16.16^{abcd} \pm 11.07$ (23.05)	$11.20^{abcd} \pm 1.46$ (19.53)	$13.29^{abcd} \pm 5.84$ (21.14)
K-1628	$15.57^{abc} \pm 4.34$ (23.14)	$23.11^{efghi} \pm 0.98$ (28.73)	$16.24^{abcd} \pm 9.28$ (23.32)	$26.86^{fgh} \pm 0.78$ (31.21)	$20.44^{bcdef} \pm 2.96$ (26.85)
K-1660	$13.54^{abc} \pm 7.36$ (21.21)	$13.01^{abcdef} \pm 10.32$ (20.30)	$10.79^{abc} \pm 7.18$ (18.65)	$16.44^{abcdefg} \pm 10.95$ (23.30)	$13.44^{abcd} \pm 8.95$ (20.93)
K-1662	$14.67^{abc} \pm 6.18$ (22.29)	$15.58^{bcdefg} \pm 3.04$ (23.20)	$12.74^{ab} \pm 5.16$ (20.71)	$19.92^{bcdefg} \pm 2.46$ (26.49)	$15.73^{abcde} \pm 4.21$ (23.27)
341	$29.67^{cde} \pm 0.72$ (33.00)	$16.52^{bcdefg} \pm 10.02$ (23.47)	$24.72^{bcde} \pm 3.10$ (29.79)	$22.08^{cdefgh} \pm 8.60$ (27.81)	$23.25^{defg} \pm 3.70$ (28.79)
TCGS-894	$6.89^{a} \pm 0.06$ (15.22)	$7.73^{abc} \pm 3.19$ (15.98)	$5.56^{a} \pm 1.81$ (13.55)	$11.41^{abcd} \pm 4.35$ (19.57)	$7.90^{a} \pm 1.45$ (16.29)
TCGS-1073	$13.78^{abc} \pm 5.10$ (21.62)	$9.55^{abcde} \pm 3.26$ (17.88)	$10.69^{abc} \pm 5.37$ (18.80)	$13.76^{abcdef} \pm 4.91$ (21.62)	$11.94^{abcd} \pm 0.57$ (20.22)
TCGS-1097	$18.74^{abcd} \pm 14.55$ (24.75)	$7.56^{abc} \pm 1.42$ (15.93)	$16.01^{abcd} \pm 14.44$ (22.36)	$11.63^{abcd} \pm 0.05$ (19.93)	$13.48^{abcde} \pm 6.90$ (21.21)
TCGS-1119	$16.96^{abc} \pm 14.57$ (23.22)	$12.72^{abcdef} \pm 0.85$ (20.89)	$17.27^{abcd} \pm 5.57$ (24.42)	$19.71^{abcdefg} \pm 1.37$ (26.35)	$16.67^{abcdef} \pm 4.47$ (24.00)
TCGS-1146	$10.68^{abc} \pm 3.88$ (18.93)	$7.82^{abc} \pm 1.79$ (16.19)	$7.88^{abc} \pm 4.07$ (16.03)	$12.18^{abcde} \pm 0.44$ (20.42)	$9.64^{abc} \pm 2.55$ (18.01)
TCGS-1156	$17.61^{abcd} \pm 2.91$ (24.77)	$19.74^{cdefgh} \pm 2.21$ (26.36)	$14.01^{abc} \pm 3.74$ (21.89)	$25.18^{efgh} \pm 2.73$ (30.10)	$19.14^{abcdef} \pm 2.90$ (25.91)
TCGS-1157	$17.60^{abc} \pm 15.20$ (23.67)	$4.41^{a} \pm 2.32$ (11.92)	$15.18^{abc} \pm 15.50$ (21.30)	$8.31^{ab} \pm 1.50$ (16.72)	$11.38^{abcd} \pm 8.63$ (18.99)
TCGS-1157(A)	$8.48^{a} \pm 5.67$ (16.46)	$10.93^{abcdef} \pm 4.74$ (19.09)	$8.67^{abc} \pm 3.69$ (16.94)	$14.25^{abcdefg} \pm 4.93$ (22.03)	$10.58^{abcd} \pm 4.76$ (18.76)
TCGS-1186	$23.46^{abcd} \pm 24.53$ (27.01)	$11.37^{abcdef} \pm 4.53$ (19.52)	$20.83^{abcd} \pm 23.57$ (24.76)	$17.18^{abcdefg} \pm 2.78$ (24.45)	$18.21^{abcdef} \pm 13.85$ (24.41)
TCGS-1342	$11.69^{abc} \pm 0.60$ (19.99)	$13.96^{abcdef} \pm 0.16$ (21.94)	$8.97^{abc} \pm 0.56$ (17.42)	$17.42^{abcdefg} \pm 0.04$ (24.67)	$13.01^{abcd} \pm 0.26$ (21.14)
TCGS-1343	$10.70^{abc} \pm 0.79$ (19.09)	$10.18^{abcdef} \pm 4.30$ (18.41)	$8.017^{abc} \pm 0.78$ (16.43)	$13.53^{abcdef} \pm 4.79$ (21.43)	$10.61^{abcd} \pm 1.88$ (18.97)
TCGS-1345	$10.92^{abc} \pm 1.98$ (19.26)	$16.07^{bcdefg} \pm 4.77$ (23.52)	$8.15^{abc} \pm 2.40$ (16.50)	$19.62^{abcdefg} \pm 4.57$ (26.22)	$13.69^{abcde} \pm 3.43$ (21.64)
TCGS-1375	$13.28^{abc} \pm 9.94$ (20.63)	$9.67^{abcd} \pm 4.56$ (17.88)	$13.06^{abc} \pm 9.34$ (20.52)	$13.93^{abcdef} \pm 3.47$ (21.84)	$12.48^{abcd} \pm 6.83$ (20.32)

TCGS-1550	$10.78^{abc} \pm 7.24$ (18.63)	$8.3^{abcd} \pm 1.09$ (16.74)	$7.60^{ab} \pm 5.31$ (15.50)	$13.83^{abcdef} \pm 0.16$ (21.83)	$10.13^{abc} \pm 3.45$ (18.43)
TPT-3	$18.58^{abcd} \pm 9.07$ (25.20)	$4.22^{a} \pm 0.00$ (11.86)	$16.42^{abcd} \pm 9.09$ (23.49)	$7.97^{a} \pm 1.02$ (16.38)	$11.80^{abcd} \pm 4.28$ (19.93)
TPT-4	$12.63^{abc} \pm 5.01$ (20.63)	$15.08^{abcdef} \pm 6.10$ (22.64)	$9.94^{abc} \pm 5.22$ (18.07)	$18.74^{abcdefg} \pm 5.63$ (25.53)	$14.10^{abcde} \pm 5.49$ (21.86)
ANANTHA	$10.65^{abc} \pm 1.32$ (19.03)	$9.23^{abcd} \pm 4.86$ (17.39)	$8.63^{abc} \pm 0.26$ (17.09)	$13.82^{abcdef} \pm 2.66$ (21.78)	$10.58^{abcd} \pm 1.48$ (18.96)
DHARANI	$29.08^{bcde} \pm 0.45$ (32.63)	$30.94^{ghi} \pm 0.55$ (33.80)	$26.10^{bcde} \pm 1.07$ (30.72)	$35.60^{h} \pm 1.86$ (36.63)	$30.43^{fgh} \pm 0.98$ (33.48)
KH	$15.41^{abc} \pm 0.74$ (23.11)	$19.63^{bcdefgh} \pm 21.42$ (24.17)	$12.15^{abc} \pm 1.81$ (20.37)	$24.61^{defgh} \pm 21.75$ (28.45)	$17.95^{abcdef} \pm 10.15$ (24.62)
NARAYANI	$40.87^{de} \pm 1.62$ (39.74)	$31.53^{hi} \pm 5.31$ (34.12)	$36.34^{de} \pm 5.58$ (37.04)	$35.41^{h} \pm 5.63$ (36.48)	$36.04^{gh} \pm 4.541$ (36.87)
K-6	$44.97^{e} \pm 3.84$ (42.11)	$37.41^{i} \pm 2.86$ (37.70)	$40.76^{e} \pm 1.087$ (39.68)	$35.95^{h} \pm 4.38$ (36.82)	$39.77^{h} \pm 1.61$ (39.10)
Grand Mean	16.45 ± 10.10	13.45 ± 8.48	14.11 ± 9.43	17.56 ± 8.23	15.39 ± 8.00

*Values in parenthesis are arc sine transformed values
*Values followed by same letter are not significantly different as per DMRT

Cumulative data on infestation of leaf bud borer based on first and second planting

Based on per cent infestation of leaf bud borer larvae (60 DAS in 1st planting (highest infestation of leaf bud borer larvae on most susceptible popular genotypes Narayani, and Dharani (Table 1); 53 DAS and 60 DAS in 2nd planting (highest infestation of leaf bud borer larvae on most susceptible popular genotypes Narayani, and Dharani (Table 2)) different genotypes of groundnut were grouped into following plant resistance categories as resistant, moderately resistant and susceptible to their reacting to leaf bud borer (Table 3).

Table 3: Cumulative data on infestation of leaf bud borer based on first and second planting

Character	Leaf bud borer per cent infestation (first planting)			Leaf bud borer per cent infestation (second planting)		
	Resistant	**Moderately resistant**	**Susceptible**	**Resistant**	**Moderately resistant**	**Susceptible**
Per cent infestation	ASK-2013-1 K-1563 TCGS-894 TCGS-1375 TCGS-1146	KH K-1628 TCGS-1156 TCGS-1157(A) ASK-2013-5	Dharani, K-6 K-5 Narayani TPT-4	ASK-2013-1 K-1563 TCGS-894 K-8 TCGS-1146	KH TCGS-1156 K-1628 K-1452 TPT-3	Dharani K-6 K-4 Narayani TCGS-341

The genotypes ASK-2013-1, TCGS-894 and K-1563 that were consistent in their reaction to leaf bud borer infestation in both first planting and second planting and hence were designated as resistant genotypes. The genotypes TCGS-1156 and K-1628; Narayani and K-6 were designated as moderately resistant susceptible genotypes as their reaction towards leaf bud borer were consistent in both first and second planting (Table 3).

These selected genotypes were further experimented in the laboratory in no choice and free choice experiments, to confirm their resistant rankings that were observed under the field condition.

Studies on the biology of leaf bud borer on selected genotypes

Incubation Duration (days)

The lowest incubation period (2.50 ± 0.54) of eggs of leaf bud borer was observed on groundnut genotype Narayani, followed by K-1628 (2.83 ± 0.75). Highest incubation period was observed on K-1563 (3.83 ± 0.40), followed TCGS -894 (3.67 ± 0.51). The incubation periods on other genotypes were in between these two groups.

Except for the incubation period, no significant differences were observed in other biological characters of bud borer *viz*., larval instar duration, total larval duration, pupal duration, pre-oviposition, oviposition, post-oviposition durations and total life span, when the larvae were reared on different groundnut genotypes.

Though not statistically significant, the total larval duration of leaf bud borer on ASK-2013-1(14.00 days) and K-1563 (14.17 days) were considerably longer as compared to total larval duration on K-6 (12.83 days) and Narayani (13.17 days) giving them ranking of highly resistant and susceptible. Kumar [11] found that the resistant groundnut cultures NCAc 17090 and ZM 208 prolonged the larval period of groundnut leaf miner, but no striking differences were observed in the size of larvae/pupae and on the per cent adult emergence between the ones reared on resistant and susceptible groundnut cultivars. He also found that mortality of the larvae in the resistant cultivars (NCAc 17090 and ZM 208) was mainly confined to only early instars (first and second)

Rao [16] who found that the resistant groundnut lines viz., ICGV 86162, FDRS 10, ICGV 86011 and NCAc 17090 prolonged the larval period of the leaf miner and the resistant lines ICGV 86162 and FDRS 10 prolonged the duration of pupae compared to the susceptible lines TMV 2 and Robut 33-1.The authors estimated bio-chemical constituents of different groundnut lines and found that the susceptible lines *viz*., TMV 2 and Robut 33-1 had lower amounts of amino nitrogen and higher amounts of total soluble sugars compared to the resistant lines and the total phenol content in the groundnut lines was erratic.

As the earlier reports on biology of leaf bud borer on groundnut were not available, the results of the present investigation were discussed in light of biology of bud borer on other field crops.

Results of present investigation, revealed that the larvae of bud borer had 5 larval instars and the duration of different instars ranged from 2.33 - 3.00; 2.33 - 2.83; 2.33 - 3.17; 2.33 - 2.83 and 2.33 - 3.17 days for first, second, third, fourth and fifth larval instars on different genotypes of groundnut (Table 4). Gujrati and Singh [6] supported these results who studied

biology of soybean leaf webber (*A. ephippias*) (Meyrick) under laboratory conditions and reported that the larval stage passed through five instars and I, II, III, IV and V instar period on an average lasted for 2.84, 1.76, 2.3, 2.44 and 3.82 days respectively. The egg period, larval period and pupal period of bud borer in the present investigation ranged from 2.50-3.83; 12.83 to 14.17 and 6.00 - 6.67 days on different groundnut genotypes (Table 4) which were in close resemblance with results of Gujrati and Singh [6] who reported that *A. ephippias* had egg, larval and pupal periods as 2.76, 12.76 and 5.64 days, on soyabean.

The adult longevity and total life span of bud borer on different groundnut genotypes in the present investigation was recorded as 5.50 - 7.00 and 27.67 - 29.83 days, which were in tune with Gujrati and Singh [6] who reported that *A. ephippias* had duration of total life cycle as 22.2 days with 7.32 days of adult longevity.

Table 4: Biologyof leaf budborer (*A. ephippias*) 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)	3.67bc ± 0.51	2.50a ± 0.83	2.83a ± 0.75	2.33a ± 0.81	2.67a ±0.81	3.17a ±0.75	13.50a ± 1.76
ASK-2013-1 (Highly resistant)	3.33abc ± 0.51	2.67a ± 1.21	2.67a ± 0.51	3.00a ± 0.89	2.67a ±0.81	3.00a ± 0.89	14.00a ± 2.28
K-1563 (Highly resistant)	3.83c ± 0.40	2.50a ± 0.54	2.50a ± 0.54	3.17a ± 0.75	2.83a ±0.40	3.17a ± 0.75	14.17a ± 0.98
TCGS-1156 (Moderately resistant)	3.50bc ± 0.83	2.33a ± 0.51	2.83a ± 0.40	3.17a ± 0.75	2.33a ±0.51	2.67a ± 0.81	13.33a ± 0.51
K-1628 (Moderately resistant)	2.83ab ± 0.75	2.50a ± 0.83	2.67a ± 0.51	3.17a ± 0.40	2.50a ±0.54	2.67a ± 0.81	13.50a ± 1.64
NARAYANI (Susceptible)	2.50a ± 0.54	3.00a ± 0.63	2.33a ± 0.51	2.67a ± 0.81	2.83a ±0.75	2.33a ± 0.51	13.17a ± 1.42
K-6 (Susceptible)	3.17abc± 0.98	2.50a ± 0.54	2.50a ±0.54	3.00a ± 0.00	2.50a ±0.54	2.33a ± 0.51	12.83a ± 0.98
Grand Mean	3.26 ± 0.76	2.57 ± 0.73	2.62 ±0.53	2.93 ±0.71	2.62 ± 0.62	2.76 ± 0.75	13.50± 1.43

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

Table 5: Biology of groundnut leaf miner (*Aproaerema modicella*) on highly resistant, moderately resistant and susceptible genotypes of groundnut in no choice technique (Continuation of the above table)

Genotype	Pupal Days (Mean ± SD)	Adult duration Days (Mean ± SD)	Pre- oviposition Days (Mean ± SD)	Oviposition Days (Mean ± SD)	Post-oviposition Days (Mean ± SD)	Total life span Days (Mean ± SD)
TCGS-894 (Highly resistant)	6.50^{a} ± 1.04	5.67^{a} ± 1.36	1.83^{a} ± 0.75	2.67^{ab} ± 0.51	1.17^{a} ± 0.40	29.33^{a} ± 3.14
ASK-2013-1 (Highly resistant)	6.67^{a} ± 1.03	5.50^{a} ± 1.04	1.83^{a} ± 0.40	2.33^{a} ± 0.51	1.33^{a} ± 0.51	29.50^{a} ± 2.07
K-1563 (Highly resistant)	6.33^{a} ± 0.81	5.50^{a} ± 1.04	1.67^{a} ± 0.51	2.50^{ab} ± 0.54	1.33^{a} ± 0.51	29.83^{a} ± 1.72
TCGS-1156 (Moderately resistant)	6.33^{a} ± 0.81	5.50^{a} ± 1.51	1.67^{a} ± 0.51	2.50^{ab} ± 0.83	1.33^{a} ± 0.51	28.67^{a} ± 1.36
K-1628 (Moderately resistant)	6.17^{a} ± 1.16	7.00^{a} ± 1.41	2.00^{a} ± 0.00	3.33^{b} ± 1.03	1.67^{a} ± 0.51	29.50^{a} ± 1.64
Narayani (Susceptible)	6.50^{a} ± 1.04	6.17^{a} ± 1.16	1.83^{a} ± 0.40	$2.6\ 7^{ab}$ ± 0.81	1.67^{a} ± 0.51	28.33^{a} ± 2.50
K-6 (Susceptible)	6.00^{a} ± 0.63	5.67^{a} ± 1.63	1.67^{a} ± 0.51	2.83^{ab} ± 0.75	1.50^{a} ± 0.54	27.67^{a} ± 1.96
Grand Mean	6.36± 0.90	5.86± 1.33	1.79 ± 0.4	2.69 ± 0.74	1.43 ± 0.50	28.98 ± 2.10
*Values followed by same letter are not significantly different as per DMRT						

Larval preferences of leaf bud borer *(A. ephippias)* on different genotypes of groundnut in free choice experiment

No significant differences were observed among the test genotypes in their performance for larval preference of leaf bud borer (*A. ephippias*)

Ovipositional preferences of leaf bud borer *(A. ephippias)* on different genotypes of groundnut in free choice experiment

The numbers of eggs laid by adults of *A. ephippias* on selected test groundnut genotypes were not significantly different in ovipositional free choice experiment.

Studies on physical characters and biochemical constituents' groundnut genotypes.

Physical Characters

Trichome Density

The lowest trichome density was found on leaves of K-6 (14.92 ± 6.08) followed by K-1536 (17.58 ± 4.81), ASK-2013-1 (22.17 ± 4.42) and K-1628 (22.25 ± 8.96) (on par with each other). The highest trichome density was observed on leaves of Narayani (52.33 ± 16.52) which was significantly different from the other test groundnut genotypes. Trichome density of leaves of TCGS 1156 and TCGS 894 were in between these two groups.

Leaf Area

The lowest leaf area was found on leaves of ASK-2013-1 (11.52 ± 1.92) followed by K-1628 (17.80 ± 2.00), K-1563 (18.23 ± 7.48), TCGS-894 (19.31 ± 1.42) and TCGS-1156 (19.97 ± 13.90) (on par with each other). The highest leaf area was found on leaves of Narayani (29.63 ± 7.25), followed by K-6 (27.08 ± 5.27) (on par with each other).

Leaf Thickness

The lowest leaf thickness was found on leaves of ASK-2013-1 (151.45 ± 27.56), followed by TCGS-894 (187.50 ± 8.49), K-1628 (194.57 ± 26.20), K-1563 (230.60 ± 89.03) (on par with each other). The highest leaf toughness was found on leaves of Narayani (247.17 ± 1.71), followed by K-6 (246.60 ± 46.30) TCGS-1156 (245.12 ± 47.38) (on par with each other).

Chlorophyll

The lowest chlorophyll content was found in leaves of K-6 (32.10 ± 2.08), followed by Narayani (37.48 ± 0.66), TCGS-1156 (44.60 ± 0.43) (significantly different from each other), followed by ASK-2013-1 (45.28 ± 2.45), K-1628 (45.53 ± 6.60), (on par with each other) and the highest chlorophyll content was found in leaves of TCGS894 (50.68 ± 4.18) followed by K-1563 (48.13 ± 2.21) (on par with each other) (Table 6).

Table 6: Physical characters of highly resistant, moderately resistant and susceptible genotypes of groundnut towards leaf budborer (*A. ephippias*)

Genotype	Trichome density/0.25cm2 (Mean ± SD)	Leaf area(cm2) (Mean ± SD)	Leaf thickness (cm2/g) (Mean ± SD)	Chlorophyll(SCMR) (Mean ± SD)
TCGS-894 (Highly resistant)	34.00d ± 10.02 (5.97)	19.31ab ± 1.42	187.50ab ± 8.49	50.68 ± 4.18
ASK-2013-1 (Highly resistant)	22.17ab ± 4.42 (4.50)	11.52a ± 1.92	151.45a ± 27.56	45.28 ± 2.45
K-1563 (Highly resistant)	17.58ab ± 4.81 (3.99)	18.23ab ± 7.48	230.60ab ±89.03	48.13 ± 2.21
TCGS-1156 (Moderately resistant)	31.00cd ± 13.46 (6.01)	19.97ab±13.90	245.12b ± 47.38	44.60 ± 0.43
K-1628 (Moderately resistant)	25.25bc ± 8.96 (5.02)	17.80ab ± 2.00	194.57ab ±26.60	45.53 ± 6.60
Narayani (Susceptible)	52.33e ± 16.52 (7.43)	29.63b ± 7.25	247.17b ± 1.71	37.48 ± 0.66
K-6 (Susceptible)	14.92a ± 6.08 (3.36)	27.08b ± 5.27	246.60b ± 46.30	32.10 ± 2.08
Grand Mean	28.18 ± 15.27 (5.18)	20.51 ± 8.19	214.71 ± 51.43	43.40 ± 6.72

*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 ASK-2013-1 (187.58 ± 3.36 mg/g) followed by K-1563(195.42 ± 1.56 mg/g)), TCGS-894 (202.29 ± 3.77 mg/g) (significantly different from each other). The highest amount of protein was observed in leaves of Narayani (232.63 ± 2.28 mg/g) (significantly different from each other) followed by K-6 (212.47 ± 3.83 mg/g) and K-1628 (212.02 ± 2.06 mg/g) (on par with each other)

Phenol

Lowest amount of phenols was found in leaves K-6 (61.49 ± 0.27 mg/g) and the highest amount of phenols was in ASK-2013-1 (91.48 ± 0.32 mg/g). (The phenol content of all the genotypes is significantly different among themselves).

Reducing Sugars

The lowest amount of reducing sugars was found in the leaves of Narayani (1.18 ± 0.08 mg/g). The highest amount of reducing sugars was found in the leaves of TCGS-894 (2.87 ± 0.10 mg/g) (the reducing sugars in the leaves of the genotypes were significantly different among themselves) (Table 7).

Table 7: Biochemical characters of highly resistant, moderately resistant and susceptible genotypes of groundnut with relation to leaf bud borer (*A. ephippias*)

Genotype	Proteins (mg/g) (Mean ± SD)	Phenols (mg/g) (Mean ± SD)	Reducing sugars (mg/g) (Mean ± SD)
TCGS-894 (Highly resistant)	202.29c ± 3.77	82.17f ± 0.56	2.87f ± 0.10
ASK-2013-1(Highly resistant)	187.58a ± 3.36	91.48g ± 0.32	2.32d ± 0.03
K-1563 (Highly resistant)	195.42b ± 1.56	77.81e ± 0.53	2.48e ± 0.09
TCGS-1156 (Moderately resistant)	207.45d ± 2.15	75.19d ± .43	2.20c ± 0.01
K-1628 (Moderately resistant)	212.02d ± 2.06	70.71c ± 0.27	2.09c ± 0.04
Narayani (Susceptible)	232.63e ± 2.28	66.97b ± 1.10	1.18a ± 0.08
K-6 (Susceptible)	212.47d ± 3.83	61.49a ± 0.27	1.89b ± 0.05
Grand Mean	207.12 ± 13.87	75.12 ± 9.46	2.14 ± 0.50

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

Correlation of groundnut leaf bud borer (*A. ephippias*) performance (biological parameters and preference) on selected genotypes with their biophysical characters and biochemical constituents

Incubation period

Incubation period on different groundnut genotypes was negatively correlated with proteins (r= -0.581) whereas, a positive correlation was observed with reducing sugars (r=0.678). (All are significant at 0.01 level).

Larval instar duration

No significant correlation was observed between first instar larval duration; second instar larval duration; third instar larval duration and fourth instar larval duration with biophysical and biochemical constituents.

Fifth instar larval duration

Fifth instar larval duration, when reared on different groundnut genotypes was negatively correlated with thickness (-0.511), trichome density (-0.514), proteins (0.474) whereas positively correlated with phenols (0.460) and reducing sugars

(0.487) (All are significant at 0.05 level).

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

Post-oviposition duration

Post-oviposition duration, when reared on different groundnut genotypes was positively correlated with reducing sugars. (-0.496). (At 0.05 level).

Total life span

Total life span, when reared on different groundnut genotypes was positively correlated with chlorophyll content (0.460) (Table 8).

Table 8: Correlation of groundnut leaf bud borer (*A. ephippias*) performance on selected genotypes with their biophysical and biochemical characters

Insect growth characters	Correlation s	Thicknes s (cm2/g)	Trichomes	Chlorophyl l (SCMR)	Proteins (mg/g)	Phenols(mg/g)	Reducing sugars (mg/g)
Larval preference	Pearson Correlation	-0.2	-0.181	-0.098	0.035	0.006	0.016
	Significance	0.384	0.433	0.674	0.879	0.98	0.944
Ovipositional preference	Pearson Correlation	-0.21	-0.19	-0.105	0.037	0.006	0.017
	Significance	0.362	0.41	0.652	0.873	0.978	0.941
Incubation	Pearson Correlation	-0.217	-0.219	0.362	-.581(**)	0.401	.678(**)
	Significance	0.346	0.34	0.107	0.006	0.071	0.001
I Instar	Pearson Correlation	0.072	0.069	-0.24	0.198	-0.022	-0.216
	Significance	0.757	0.767	0.294	0.39	0.926	0.348
II Instar	Pearson Correlation	-0.317	-0.299	0.256	-0.129	0.205	0.288
	Significance	0.162	0.188	0.263	0.576	0.372	0.205
III Instar	Pearson Correlation	0.197	0.173	-0.088	-0.151	-0.05	-0.019
	Significance	0.391	0.454	0.703	0.513	0.828	0.936
IV Instar	Pearson Correlation	0.052	0.034	0.064	-0.013	0.06	-0.053
	Significance	0.823	0.883	0.783	0.955	0.795	0.818
V Instar	Pearson Correlation	-.511(*)	-.514(*)	0.32	-.474(*)	.460(*)	.487(*)
	Significance	0.018	0.017	0.158	0.03	0.036	0.025
Larval duration	Pearson Correlation	-0.297	-0.315	0.165	-0.342	0.385	0.283
	Significance	0.19	0.164	0.474	0.129	0.085	0.213
Pupal duration	Pearson Correlation	-0.146	-0.134	0.375	-0.14	0.264	0.052
	Significance	0.528	0.562	0.094	0.545	0.247	0.822
Adult duration	Pearson Correlation	0.019	0.017	0.009	0.203	-0.212	-0.219
	Significance	0.936	0.943	0.969	0.377	0.356	0.341
Pre- oviposition	Pearson Correlation	-0.043	-0.063	0.061	-0.012	0.029	-0.073
	Significance	0.852	0.786	0.793	0.96	0.899	0.755
Oviposition	Pearson Correlation	-0.017	-0.006	0.004	0.169	-0.304	-0.106
	Significance	0.942	0.978	0.987	0.465	0.18	0.647
Post- oviposition	Pearson Correlation	0.173	0.176	-0.246	0.424	-0.368	-.496(*)
	Significance	0.454	0.445	0.282	0.055	0.101	0.022
Total life span	Pearson Correlation	-0.36	-0.369	.460(*)	-0.403	0.402	0.352
	Significance	0.109	0.099	0.036	0.07	0.071	0.117

****** Correlation is significant at the 0.01 level (2-tailed)

***** Correlation is significant at the 0.05 level (2-tailed)

Preference Studies

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

Though not statistically significant, there was a negative correlation between trichome density and oviposition preference of adults in the present investigations. Similar observations were found by Kumar [11] found that Groundnut leaf miner resistant groundnut lines were less preferred for oviposition compared to susceptible genotypes. He correlated resistance with hairiness and reported that resistant lines possessed more hairs on midrib and leaf lamina compared to susceptible lines. Visalakshi [25] reported that groundnut leaf

miner resistant lines had negative correlation between trichome density and number of eggs laid. However contradicting results were reported by Rao [17] who mentioned that groundnut lines having more hairy leaves were preferred by adults of groundnut leaf miner for oviposition.

Negative correlation between trichome density and adult oviposition preference were observed in other lepidopteran insects as well. Oghiakhe [15] who reported anatomical basis of resistance of Vigna vexillata (Acc. TVNu 72) to *Maruca vitrata* and observed that presence of more trichomes, confers resistance in TVNu 72, but not on that of the susceptible genotype, IT82D-716. Veeranna and Hussain [24] who recorded the different physical parameters in 45 cowpea genotypes for the resistant/susceptible to *M. vitrata* infestation and observed that the most resistant genotype (TVX-7) had a high trichome density (24.41/9 mm^2), while the most susceptible genotype (DPCL-216) had a low trichome density (12.82/9 mm^2).

In our present investigations, trichomes had shown a negative correlation with larval duration of 5th instar (Table 8). This probably could be due to the fact that the 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. This could also be due to the fact that presence of trichomes could had antibiosis effect on the larval feeding which might have forced the larvae to go to pupation thus reducing the larval duration.

Review on the effect of trichomes on biological parameters such as larval duration, pupal duration are scanty and hence the present investigations were discussed in light of the effect of trichomes on other biological parameters such as larval and pupal mortality. Visalakshi [25] reported that on groundnut resistant lines ICGV 86031 and ICGV 87160, the larval and pupal mortality were higher as compared to susceptible line TMV 2 which could have been contributed by the higher trichome density of resistant lines compared to susceptible lines.

Leaf Thickness

Leaf thickness had shown negative correlation larval duration for the leaf bud borer indicating that more the thickness less is the larval duration and vice versa. Our results are in conformity with the results of Rao [18] 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 [25] who reported that groundnut resistant lines had thicker leaves compared to susceptible lines.

Leaf thickness have a negative correlation with larval duration as reported by Hariprasad and Emden [10] who mentioned that field grown brassica plants were much tougher as compared to that of glasshouse grown plants which attributed resistance to larvae of *Plutella xylostella*. In the present investigations the thicker leaves in resistant varieties might be responsible for reducing the larval duration of feeding on them.

The outcome of the present results were presumably because susceptible genotypes had more leaf area as compared to resistant genotypes (Tables 5) and the larvae had the 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 bud borer (significant at 0.05) (Table 7). This could be due to the fact chlorophyll has increased the resistance of host plant to both leaf bud borer, 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 [4] 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 both leaf bud borer 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 incubation period and instar larval durations of leaf bud borer (Table 8).

This may be due to the palatability of the proteins present in the tested genotypes. The susceptible genotypes had significantly higher amounts of proteins (Table 8), that fulfills the dietary requirement of the larvae at much shorter period of feeding and larvae completed its larval period and total life span at a much faster rate as compared to the resistant genotypes, that had lower amounts of proteins (Table 8) and the insect took more time to complete its larval and total life span.

These results are supported by Ambenagare [1] who determined the biochemical basis of *Aproaerema modicella* resistance in 7 soyabean cultivars (MAUS-81, JS-9863, MAUS-71, MAUS-158, JS-335, MACS-1055 and Bragg). High protein per cent (21.15%) was observed from the susceptible control, Bragg.

The results of present investigations are also in tune with Halder [9] who while working on varietal reaction of mung bean cultivars towards the spotted pod borer *M. vitrata*, reported that the highly susceptible cultivar LGG-450 had the highest protein (23.44%) content compared to the highly tolerant cultivar LGG-497 which had the least (18.56%) protein content.

The results are also in agreement with Sujithra and Srinivasan [23] who reported that highly susceptible cultivar AVT-FB (80) 15-6-4 had the highest amount of protein (28.9%), compared to tolerant cultivar TCR-137 which had the lowest amount of protein (19%).

Phenols

Phenols had shown a significant positive correlation with fifth instar larval durations of leaf bud borer (Table 8).

Phenols are plant secondary metabolites that give resistance in plants towards herbivores including insects.

Phenols affect the biology of insects in so many different ways. It can act as feeding deterrants, antifeedents and also can cause mortality of early larval instars. In a similar way in the present investigation it was observed that phenols had significant positive correlation fifth instar larval duration indicating that the larvae took more time to feed on plants which are poor in nutritional quality.

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 [1] who determined

the biochemical basis of *Aproaerema modicella* resistance in 7 soyabean cultivars (MAUS-81, JS-9863, 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 and Srinivasan [7] who have studied the six 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, LGG460, 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).

Halder and Srinivasan [7] who supported the results six 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 with incubation period and instar larval durations of leaf bud borer (Table 8)

The results are in contradiction with Sujithra and Srinivasan [23] who 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 and Srinivasan [7] who 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, LGG460, 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 the highest amount of reducing sugar 0.59 mg/g, compared to the highly tolerant cultivar LGG-497 which had 0.48 mg/g.

Conclusion

The present study from field screening experiments revealed that groundnut genotypes ASK-2013-1, K-1563 and TCGS-894 were found as highly resistant, TCGS-1156 and K-1628 were found as moderately resistant and Narayani and K-6 were found as susceptible towards their reaction to leaf bud borer. Results from the studies of biology of leaf bud borer indicate that except for the incubation period, no significant differences were observed in the biological characters of leaf bud borer. The results of investigation of the ovipositional and larval preference infer that no significant differences were observed among the test genotypes in their performance for leaf bud borer, *A. ephippias*.

Studies on correlation with physical characters of groundnut genotypes tested for their reaction to leaf bud borer revealed that the trichomes had shown a negative correlation with fifth instar duration, thickness had shown negative correlation with fifth instar duration, chlorophyll content was positively correlated with total life span. Studies on correlation with biochemical constituents of groundnut genotypes tested for their reaction to leaf bud borer revealed that the proteins had a significant negative correlation with incubation period and fifth instar larval duration, phenols showed a significant positive correlation with fifth instar duration, reducing sugars showed positive correlation with incubation period, fifth instar duration and a negative significant correlation with post-oviposition period.

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