LR-4672
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RESEARCH ARTICLE Legume Research- An International Journal, Volume Issue : ()

Incidence of Groundnut Leafminer (GLM), *Aproaerema modicella* (Deventer) (Lepidoptera: Gelechiidae) and its Parasitic Fauna on Alternate Leguminous Hosts in Tamil Nadu, India

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10.18805/LR-4672

ABSTRACT

Background: The groundnut leafminer (GLM), *Aproaerema modicella* is an important pest of several legume crops which causes 50 to 100 per cent yield loss in India. The exploration of indigenous natural enemies is crucial to the success of every biological control strategy. Besides, alternative host plants act as a source of both herbivorous pests and their natural enemies. In this view, occurrence of GLM and their parasitic fauna on groundnut, alternate leguminous hosts *viz.,* redgram and babchi were recorded.

Methods: Survey on damage potential of GLM and their parasitic fauna were recorded on groundnut at Sivagangai and Coimbatore districts of Tamil Nadu, India during 2016 to 2018. Survey was also conducted to find the damage potential of *A. modicella* on alternate leguminous hosts *viz.,* redgram, babchi and their parasitic fauna at Coimbatore district. The damage potential of *A. modicella*, per cent parasitization and parasitoid emergence were assessed from *A. modicella* infested groundnut, redgram and babchi leaves.

Result: Severe incidence of *A. modicella* was recorded as 98.10% (2016 to 2017) and 98.45% (2017 to 2018) at Sivagangai district. The parasitization of GLM was also found higher at Sivagangai recording 46.67% in both the years which was positively related with the pest population. 13 hymenopteran parasitoids belonging to eight families were recorded. Among them, *Avga choaspes* Nixon recorded high per cent parasitoid emergence (20.00%). Furthermore, GLM incidence on redgram and babchi indicated the highest damage potential of 38.20 and 34.50 per cent and parasitization of 33.33 and 20.00 per cent, respectively during 2017 to 2018.

Key words: Alternate leguminous hosts, *Aproaerema modicella, Avga choaspes*, Damage potential, Groundnut, Parasitic fauna.

INTRODUCTION

The groundnut leafminer (GLM), *Aproaerema modicella* (Deventer) (Lepidoptera: Gelechiidae) is a serious pest of groundnut and other leguminous host plants in South and South-East Asia (Wightman *et al.,* 1990). The larvae construct blister-like mines in the mid-rib on the dorsal side of the leaf. The entire leaf eventually turns brown, rolls up and dries out. When there is a severe infestation, the crop appears to be burned up in appearance (Ranga Rao and Rameshwar Rao, 2013). *A. modicella* feeding limits the photosynthetically active leaf area, resulting in yield losses ranging from 50 to 100 per cent (Namara *et al.,* 2019). Because of concealed nature of the pest, biological control based on natural enemies may be an environmentally and economically sound approach for the management of *A. modicella* than synthetic insecticides. In this context, it is critical to have an understanding on the indigenous natural enemies in order to build sustainable pest control tactics.

The parasitoid ecosystem associated with *A. modicella* is extensive and diverse, with atleast two trophic levels, involved (Shanower *et al.,* 1993). Many species of parasitoids of *A. modicella viz., Avga choaspes* Nixon, *Stenomesius japonicus* (Ashmead), *Sympiesis* sp. and *Tetrastichus* sp., *Chelonus* sp., *Bracon* sp., *Brachymeria* sp., *Temelucha* sp. and *Goniozus* sp. are reported from Asia (Shekarappa *et al*., 1990; Basha *et al*., 2012; Murugasridevi *et al.,* 2019). Over 40 primary and secondary parasitoids belonging to 12 families have been cultured from *A. modicella* and found to parasitize up to 50 per cent of *A. modicella* larvae in a single generation (Shanower *et al.,* 1993; Kenis and Cugala, 2006). Success of any biological control programme depends on the exploration of indigenous natural enemies. In this respect, extensive surveys were carried out in Sivagangai and Coimbatore districts of Tamil Nadu on the occurrence of GLM, *A. modicella* and its parasitic fauna during 2016 to 2018.

On the other hand, alternative host plants with including cultivated and weed species, not only harbor herbivorous pests but also beneficial predators and parasitoids,

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How to cite this article: Murugasridevi, K., Jeyarani, S. and Kumar, S.M. (2021). Incidence of Groundnut Leafminer (GLM), *Aproaerema modicella* (Deventer) (Lepidoptera: Gelechiidae) and its Parasitic Fauna on Alternate Leguminous Hosts in Tamil Nadu, India. Legume Research. DOI: 10.18805/LR-4672.

Submitted: 24-05-2021 **Accepted:** 27-10-2021 **Online:** 04-12-2021

especially during the inter-harvest period (Saeed *et al.,* 2015). GLM were found to feed on leguminous host plants *viz.,* groundnut, pigeon pea, soybean, green gram, alfafa, hairy indigo, rice bean, egyptian clover, snout bean and weed plants *viz.,* Babchi, *Psorelea coryfolia* L., Red spiderling, *Boerhavia diffusa* L. and Slender amaranth, *Amaranthus viridis* L., (Shanower *et al.,* 1993). Hence, ascertaining the significance and extent of alternative host plants on both cultivated and weed species can be crucial in avoiding polyphagous pest populations from forming on a 'main' or 'focal' agricultural species (Tabashnik *et al.,* 1991). For instance, alternative host plants can serve as pest reservoir during off season of main hosts, with pests subsequently migrating back onto the main host plants (Clementine *et al.,* 2005). They can also be agriculturally advantageous when they host natural enemies populations (Naveed *et al.,* 2007). Taking this into consideration, incidence of *A. modicella* and its parasitoids were recorded in other alternate leguminous hosts of *A. modicella viz.,* redgram and babchi.

MATERIALS AND METHODS

Extensive surveys were conducted during 2016 to 2018 (July to October) in Sivagangai and Coimbatore districts of Tamil Nadu, India to document the damage potential of *A. modicella* on Groundnut and its associated parasitoids. In addition, incidence of *A. modicella* and its parasitoids were recorded in other alternate leguminous hosts *viz.,* redgram (*Cajanus cajan* L.) and babchi (*Psorelea corylifolia* L.) at Coimbatore district of Tamil Nadu (Fig 1c).

Assessment of damage potential of *A. modicella*

Damage potential was assessed in twenty five randomly selected plants from each location based on symptoms (detected by the presence of small brown blotches on (or) in the leaves and the webbing of leaflets) by relative sampling. The per cent damage was calculated from top twenty fully opened leaflets from the central axis of each plant and percent damage was worked out by adopting the procedure described by Muthiah and Kareem (2000).

Assessment of parasitization of leafminers

To assess the per cent parasitization of GLM, twenty five plants were selected at random from each location and infested leaves with live and parasitized larvae were brought to the laboratory and observed for the emergence of parasitoids (Muthiah and Kareem, 2000). Absolute counts were made for working out the per cent parasitization and parasitoid (different) species emergence. A sample size of 30 larvae per location was maintained. From the sample size, per cent parasitization and parasitoid (different) species emergence were worked out by the following formula.

$$\text{Parasitization (\%)} = \frac{\text{Number of larvae parasitized}}{\text{Total number of larva collected}} \times 100$$

$$\text{Parasitoid (different) species emergence (\%)} = \frac{\text{Number of larvae from which particular species of parasitoids emerged}}{\text{Total number of larvas collected}} \times 100$$

The parasitoids emerged from various hosts were preserved in 70 per cent ethanol and identified with the help of available literatures and by the taxonomic experts *viz.,* Dr. A.P. Ranjith, Ashoka Trust for Research in Ecology and the Environment (ATREE), Bengaluru, Karanataka and Dr. Santhosh Nair from Malabar Christian College, Calicut, Kerala.

RESULTS AND DISCUSSION

Endophagous herbivorous insects live within plants resulting in the formation of remarkable new plant architectures such as galls and mines. These insect-derived shelters

Fig 1a: Groundnut plant infested with *A. modicella*.

Fig 1b: Redgram leaf infested with *A. modicella*.

Fig 1c: Babchi leaf infested with *A. modicella*.

Fig 1: Groundnut Leafminer, *A. modicella* infested groundnut and alternate leguminous hosts.

presumably offer protection from natural enemies and hostile environmental conditions, but they are also thought to enable the resident to feed selectively on tissues with high nutrient content and low defense responses. However, leafminers were found to support more species of parasitoids than insects in any other feeding niche (Hawkins *et al.,* 1997). Lack of mobility of leafminer larvae, high visibility of the mines and scant physical protection offered by the leaf epidermis make them more susceptible to their parasitoids (Hawkins, 1994).

In view of the above facts, pest management strategy based on parasitoids may be safe, sustainable and a well known biological control approach against arthropod pests in agricultural ecosystems. In this situation, faunistic surveys of parasitoids could constitute the baselines upon which further applicative studies can be integrated (Tomanović *et al.,* 2014; Petrović *et al.,* 2019).

The survey conducted during 2016 to 2017 revealed maximum occurrence of *A. modicella* in Pirankulam (98.10%) and Alagapuri village of Sivagangai district (96.40%) followed by Department of Oilseeds, Tamil Nadu Agricultural University (TNAU) of Coimbatore district (94.30%) and Arunagiri village of Sivagangai district (93.20%) (Table 1 and 2).

Observations on the natural parasitization revealed highest parasitization at Pirankulam village of Sivagangai district (46.67%) followed by Alagapuri village of Sivagangai district (43.33%), Department of Oilseeds, TNAU, Coimbatore (40.00%) and Arunagiri village of Sivagangai district (40.00 %) (Table 1 and 2).

The survey during the period of 2017 to 2018 revealed highest damage by *A. modicella* in Alagapuri (98.45%) and Pirankulam village (88.70%) of Sivagangai district followed by S. Vagaikulam (85.80%), Arunagiri village of Sivagangai district (85.50%) and also at the Department of Oilseeds, TNAU, Coimbatore (85.40%) (Table 3 and 4).

Similarly, the highest parasitization was also recorded at Alagapuri village of Sivagangai district (46.67%) followed by Pirankulam village of Sivagangai district (36.67%), S. Vagaikulam (33.33%), Arunagiri village of Sivagangai district (33.33%) and also at the Department of Oilseeds, TNAU, Coimbatore (33.33%) (Table 3 and 4).

This is in corroboration with the findings of Muthiah and Kareem (2000) who documented higher incidence of *A. modicella* with 90.10 per cent leaflet damage and 28.00 per cent parasitism at Dharmapuri district. However, in the present investigation, *A. modicella* incidence and its parasitization was comparatively higher than the earlier documentation. It may be due to the continuous and staggered cropping of groundnut which might have favoured increased incidence of *A. modicella* in rainfed conditions. Since, rainfed zones practice limited insecticidal sprays, higher *A. modicella* incidence might have favoured higher parasitization than the earlier reports. Similarly, Shekharappa *et al.* (1990) also reported positive correlation between *A. modicella* population and their associated natural enemies. Likewise, Murugasridevi *et al.* (2019) also reported increased parasitization with the increased availability of *A. modicella* larvae at various groundnut growing areas of Tamil Nadu.

Sivagangai district, being a rainfed zone, the insecticides usage is very minimum and hence, it might have favoured the continuous availability of *A. modicella* population for the establishment of high parasitic fauna in this location. This is also in accordance with Cherian and Basheer (1942), Logiswaran (1984) and Muthiah (1995) who reported maximum *A. modicella* damage on rainfed groundnut than the irrigated crop in Tamil Nadu.

Survey on the parasitoid fauna of *A. modicella* indicated that the larvae of *A. modicella* were parasitized by 13 species of hymenopteran parasitoids belonging to eight families. Among the 13 species, four species of braconids *viz., Chelonus blackburni* Cameron, *Avga choaspes* Nixon, *Apanteles* spp. and *Bracon hebetor* Say, three eulophids *viz., Stenomesius* spp., *Aprostocetes* spp. and *Sympiesis* spp., one each in Ichneumonid, (*Temelucha* spp.), Eurytomid, (*Eurytoma* spp.), Pteromalid, (*Pteromalus* spp.), Eupelmid, (*Eupelmus* spp.), Bethylid, (*Goniozus* spp.) and Chalcid (*Brachymeria* spp.) were recorded. The parasitoids were mostly larval parasitoids except *C. blackburni*, which is an egg-larval parasitoid. The present findings are in accordance with the reports of Praveena (2010) who documented 15 parasitoids of GLM belonging to seven families *viz.,* bethylidae, braconidae, chalcididae, eulophidae, eupelmidae, eurytomidae and ichneumonidae at ARS, Bagalkot. Similarly, Shekharappa *et al.* (1990) recorded 16 species of hymenopterous parasitoids on GLM during Kharif, 1989. Sumithramma (1998) have reported 41 species of hymenopteran parasitoids attacking *A. modicella* however, the decrease in occurrence of parasitoid species in the present study may be due to the dynamic nature of parasitoid community structure, with composition and dominant changing throughout the year.

Among the different parasitoids recorded, *A. choaspes* was found to be prevalent with adult emergence of 20.00 per cent at Sivagangai and Coimbatore districts during 2016 to 2018. Previous reports have also indicated higher relative density of *A. choaspes* at Sivagangai (22.03%) and Coimbatore districts (16.55%) (Murugasridevi *et al.,* 2021). In addition, the abundance of *A. choaspes* may be due to the specific relationship that these parasitic wasps have with their host and the host plants (Pérez-Rodríguez *et al.,* 2013) and which also often correlates with host population (Kishinevsky *et al.* 2017). Since, the percent emergence of parasitoid adults is the main indicator of success in augmentative biological control (Elbehery *et al.,* 2020), the parasitic efficiency of *A. choaspes* can be verified against gelechiid leafminers and included in the biological control programme.

Furthermore, *A. modicella* and their associated parasitoids recorded on the alternate leguminous hosts *viz.,* redgram and babchi indicated the higher damage of 38.20 and 34.50 per cent by *A. modicella* and parasitization of 33.33 and 20.00 per cent, respectively during 2017 to 2018.

Table 1: Occurrence of *A. modicella* and parasitic fauna on groundnut in Sivagangai district, Tamil Nadu (2016-2017).

Location	Variety	Latitude	Longitude	Altitude (ft)	Crop stage	Leaflet damage (%)	Total Parasitization (%)(n=30)	Parasitoids species diversity	Different Parasitoid species adulte mergence (%)
Alagapuri	TMV 7	9.710°N	78.285°E	299	Pegging stage	96.40	43.33	*Stenomesius* spp.	6.67
								C. blackburni	10.00
								A. choaspes	20.00
								Temelucha spp.	3.33
								Eurytoma spp.	3.33
								Pteromalus spp.	3.33
								Sympiesis spp.	3.33
Arunagiri	TMV 7	9.666°N	78.265°E	276	Flowering stage	93.20	40.00	*Stenomesius* spp.	10.00
								Goniozus spp.	3.33
								C. blackburni	10.00
								Apanteles spp.	6.67
Uchanenthal	CO 3	9.676°N	78.305°E	295	Flowering stage	56.64	16.67	*Stenomesius* spp.	6.67
								B. hebetor	10.00
S. Vagaikulam	CO 3	9.676°N	78.306°E	262	Pod formation stage	80.54	30.00	*Stenomesius* spp.	16.67
								Temelucha spp.	6.67
								Eurytoma spp.	3.33
Pattanenthal	TMV 7	9.687°N	78.242°E	243	Flowering stage	58.80	20.00	*B. hebetor*	10.00
								Goniozus spp.	3.33
								Temelucha spp.	6.67
Odathur	CO 3	9.693°N	78.235°E	276	Flowering stage	42.70	13.33	*Brachymeria* spp.	3.33
Pirankulam	TMV 7	9.699°N	78.244°E	279	Flowering stage	98.10	46.67	*Eupelmus* spp.	3.33
								A. choaspes	16.67
								Stenomesius spp.	6.67
								Sympiesis spp.	3.33
								C. blackburni	10.00
								Temelucha spp.	6.67
Senthanathi	CO 3	9.738°N	78.251°E	272	Pegging stage	74.80	26.67	*Temelucha* spp.	6.67
								Eupelmus spp.	3.33
								C. blackburni	10.00
Kundukulam	CO 3	9.722°N	78.248°E	269	Pod formation stage	85.60	33.33	*C. blackburni*	6.67
								Stenomesius spp.	6.67
								A. choaspes	16.67

Table 2: Occurrence of *A. modicella* and parasitic fauna on groundnut in Sivagangai district, Tamil Nadu (2017-2018).

Location	Variety	Latitude	Longitude	Altitude (ft)	Crop stage	Leaflet damage (%)	Total Parasitization (%) (n=30)	Parasitoids species diversity	Different Parasitoid species adult emergence (%)
Alagapuri	TMV 7	9.710°N	78.285°E	299	Pegging stage	98.45	46.67	*C. blackburni*	6.67
								Eupelmus spp.	3.33
								A. choaspes	20.00
								Temelucha spp.	10.00
								Apanteles spp.	3.33
								Aprostocetes spp.	3.33
Arunagiri	TMV 7	9.666°N	78.265°E	276	Flowering stage	85.50	33.33	*Stenomesius* spp.	6.67
								A. choaspes	13.33
								C. blackburni	6.67
								Eurytoma spp.	3.33
Uchanenthal	CO 3	9.676°N	78.305°E	295	Flowering stage	40.45	10.00	*Stenomesius* spp.	6.67
S.Vagaikulam	CO 3	9.676°N	78.306°E	262	Pod formation stage	85.80	33.33	*A. choaspes*	10.00
								Temelucha spp.	6.67
								B. hebetor	6.67
								Eurytoma spp.	3.33
Pattanenthal	TMV 7	9.687°N	78.242°E	243	Flowering stage	70.30	23.33	*B. hebetor*	3.33
								C. blackburni	6.67
								Temelucha spp.	6.67
Pirankulam	TMV 7	9.699°N	78.244°E	279	Flowering stage	88.70	36.67	*A. choaspes*	6.67
								C. blackburni	6.67
								Eurytoma spp.	3.33
								Temelucha spp.	6.67
								Eupelmus spp.	3.33
Odathur	CO 3	9.693°N	78.235°E	276	Flowering stage	40.80	10	*C. blackburni*	6.67
Senthanathi	CO 3	9.738°N	78.251°E	272	Pegging stage	80.30	30	*Temelucha* spp.	3.33
								A. choaspes	10.00
								C. blackburni	3.33
Kundukulam	CO 3	9.722°N	78.248°E	269	Pod formation stage	70.20	23.33	*C. blackburni*	6.67
								Temelucha spp.	6.67
								A. choaspes	3.33

Table 3: Occurrence of *A. modicella* and parasitic fauna on groundnut in Sivagangai district, Tamil Nadu (2016-2017)

Location	Variety	Latitude	Longitude	Altitude (ft)	Crop stage	Leaflet damage (%)	Total Parasitization (%)(n=30)	Parasitoids species diversity	Different Parasitoid species adult emergence (%)
Department of Oilseeds, TNAU, Coimbatore	CO 7	11.007º N	76.936º E	1417	Flowering stage	94.30	40.00	*Temelucha* spp.	3.33
								Goniozus spp.	10.00
								Stenomesius spp.	3.33
								A. choaspes	13.33
								C. blackburni	6.67
								Eupelmus spp.	3.33

Table 4: Occurrence of *A. modicella* and parasitic fauna on groundnut in Sivagangai district, Tamil Nadu (2017-2018)

Location	Variety	Latitude	Longitude	Altitude(ft)	Crop stage	Leaflet damage (%)	Total Parasitization (%)(n=30)	Parasitoids species diversity	Different Parasitoid species adult emergence (%)
Department of Oilseeds, TNAU, Coimbatore	CO 7	11.007º N	76.936º E	1417	Flowering stage	85.40	33.33	*Temelucha* spp.	3.33
								C. blackburni	6.67
								Stenomesius spp.	13.33
								A. choaspes	3.33
								B. hebetor	3.33
								Brachymeria spp.	3.33

Table 5: Occurrence of *A. modicella* and parasitic fauna on alternate leguminous hosts at Coimbatore (2016-2017).

Crop	Variety	Latitude	Longitude	Altitude (ft)	Crop stage	Leaf damage(%)	Parasitization (%) (n=30)	Parasitoids species diversity	Parasitoid emergence(%)
Redgram (*C.cajan*)	CO 7	11.007º N	76.936º E	1417	Pod formation stage	36.50	30.00	*Temelucha* spp.	6.67
								Bracon hebetor	10.00
Babchi (*P. corylifolia*)	-	11.007º N	76.936º E	1417	Flowering stage	27.50	16.67	*Stenomesius* spp.	13.33

Table 6: Occurrence of *A. modicella* and parasitic fauna on alternate leguminous hosts at Coimbatore (2017-2018)

Crop	Variety	Latitude	Longitude	Altitude (ft)	Crop stage	Leafdamage (%)	Parasitization (%) (n=30)	Parasitoids species diversity	Parasitoid emergence(%)
Redgram(*C. cajan*)	CO 7	11.007° N	76.936° E	1417	Pod formation stage	38.20	33.33	*Temelucha* spp.	6.67
Babchi(*P. corylifolia*)	-	11.007° N	76.936° E	1417	Flowering stage	34.50	20.00	*Aulosaphes* spp.	6.67

The parasitoids *viz., Temelucha* spp. *Stenomesius sp., B. hebetor* and *Aulosaphes* spp. were found to parasitize *A. modicella* on alternate leguminous host plants, respectively at Coimbatore (Table 5 and 6). This is in accordance with Fletcher (1920), Manoharan and Chandramohan (1986) who have also reported the occurrence of GLM on *C. cajan* and *P. corylifolia,* respectively. Similarly, Arvind (2014) also noticed the severe incidence of *A. modicella* on *P. corylifolia.* The magnitude of damage caused by *A. modicella* and extent of parasitization by hymenopterous parasitoids in redgram shows that it may provide a favorable habitat for natural enemies because its bushy canopy provides both shelter and pollen during adverse environmental conditions and hosts the prey throughout the year (Saeed *et al.,* 2015). Despite the existence of natural enemies, redgram had the highest densities of *A. modicella* throughout the year and so appear to constitute key carry over sources of the pest. Apart from this, weed plants may play an excessively significant role in influencing pest dynamics. The magnitude of damage of *A. modicella* and parasitization in babchi shows that it may provide a favorable habitat for predatory arthropods due to relatively low exposure to pesticides.

In this respect, the presence of alternative host plants is detrimental, although this can be addressed if alternative host plants harbor natural enemies of *A. modicella*. The relative benefits and drawbacks of alternate leguminous host plants are thus difficult to assess, but our findings suggest that their damage incidence and parasitic fauna will have an impact on the ecological balance. In any case, both the alternate leguminous host plants can very well serve as an off-season reservoir for *A. modicella*. Hence, these hosts should be avoided in the vicinity of groundnut fields.

CONCLUSION

Altogether, the present study depicts that the parasitic fauna associated with *A. modicella* is abundant and diverse in rainfed zone. Amongst which, *A. choaspes* was discovered to be quite ubiquitous in both areas and exhibits host specificity, resulting in high parasitism rates against *A. modicella,* indicating that it might be employed successfully in augmentative biological control programmes. Hence, further research might be focused on using *A. choaspes* as a good candidate for augmentative biological control against gelechiid leafminers as it has a relatively higher density and a significant proportion of parasitoid emergence, making it amenable for mass culturing. Moreover, the current study shows that alternate leguminous host plants and weeds must be eliminated from groundnut fields and their surroundings to limit *A. modicella* damage. Future studies also must imply on the temporal occurrence of *A. modicella* on other alternate leguminous host plants.

ACKNOWLEDGEMENT

The Senior author wishes to thank Department of Science and Technology - INSPIRE, Ministry of Science and Technology, Government of India for supporting this research through research grants.

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