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A N I N T E R N A T I O N A L J O U R N A L

Seasonal abundance of *Henosepilachna vigintioctopunctata* (Fab.) on *Solanum melongena* L. and natural occurrence of its two hymenopteran parasitoids

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ABSTRACT

The 28-spotted hadda beetle Henosepilachna vigintioctopunctata Fab. (Coleoptera: Coccinellidae) is a poly-phagous pest, commonly infesting solanacious crops including brinjal, Solanum melongena L. Upon its severe infestation on brinjal, it causes considerable damage to the foliage and also to the calyx of fruits. The studies were made to record the seasonal abundance of hadda beetle and identification of its natural enemies present in the region for two consecutive years. The pooled data for two years showed that the maximum number of H. vigintioctopunctata egg clusters on brinjal were recorded in the 27th (0.40 egg cluster/ plant), followed by grub population in 35th (3.78 grubs/ plant), pupae in 33rd and 39th (0.83 pupae/ plant) and adult beetles in 36th (5.48 adults/ plant) standard meteorological weeks, respectively. It was observed that the key meteorological factors had 35.9%, 87.3%, 66.8% and 81.9% effect on the abundance of egg clusters, grubs, pupae and adults respectively in summer planted brinjal crop. Two natural enemies of hadda beetle viz. Tetrastichus sp. (egg parasitoid) and Pediobius foveolatus (pupal parasitoid) were recorded. The maximum parasitisation by Tetrastichus sp. and P. foveolatus on the egg clusters and pupae was recorded 22.64% and 6.62% respectively, during the month of August (34th and 35th standard meteorological week respectively). Further, the morphometric parameters of these two adult parasitoids were recorded and greater morphometric variability was observed in P. foveolatus in comparison to Tetrastichus sp.

Key words: Bio-control, hadda beetle, *Pediobius foveolatus*, seasonal incidence, *Tetrastichus* sp.

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INTRODUCTION

The beetles belonging to the family Epilachninae, constitute 1/6th of the known species of coccinellidae[1]. Epilachninae is considered as the chief plant-feeding sub-family within family Coccinellidae. They are among the most economically significant pests in Australia, North America, East Indies, East Asia, Central Asia, Sri Lanka, Malaysia, China and India. The genus *Henosepilachna* alone has nearly 500 phyto-phagous species[2]**,** out of which 28-spotted hadda beetle is one of the most destructive pests. The 28-spotted hadda beetle, *Henosepilachna vigintioctopunctata* (Fab.) (Synonym: *Epilachna vigintioctopunctata* L.) is a polyphagous pest and is considered as voracious foliage feeder of many cultivated and wild plants belonging mainly to the families solanaceae and cucurbitaceae[3] in Jammu and Kashmir[2] and also in other parts of India[4-5].
The family solanaceae includes vegetables and medicinal plants of high economic importance, therefore it is pivotal to study the extent of economic losses caused in them by hadda beetle. Some naturally occurring wild plants of solanaceae have also been recorded as the reservoir for hadda beetle throughout the year[6]. A large number of plants from family solanaceae have been recorded as the favourable hosts of hadda beetle which include *Withania somnifera*[7], *Lycopersicon esculentum*[8], *Solanum nigrum*[9], *S. tuberosum*[10], and *S. melongina*[11].
S. melongena L. (Brinjal) is a widely grown crop of Asia, Africa and some parts of Europe. Brinjal is native to South America; however, India is regarded as one of the rich centers of its diversity[12-13]. It is among one of the chief vegetable crops in India[11]. However, it is highly prone to hadda beetle infestation. Brinjal is one of the most favourable plant host of hadda beetle. Among the various host plant tested, we have previously described brinjal as the best oviposition choice for the female hadda beetles[2]. Further, among other major host plants the average incubation period of eggs was shortest on brinjal and development of grubs was quickest[8]. Because of these reasons it is the most favourable host for hadda beetle in the region. Hadda beetles have huge economic impact on the crop which sometimes may go up as high as 100 %[14].
For designing a viable pest management strategy, it is a pre-requisite to study the seasonal incidence, population build up of the pest, precise identification of its natural enemies, if any and the environmental factors affecting it. Keeping this in mind, the present study was conducted to record the seasonal incidence and abundance of various developmental stages of hadda beetle on brinjal in relation to key meteorological factors. The major natural enemies of the pest in the region were recorded and identified subsequently. Further, the time of maximum parasitisation and the morphometric parameters of these natural enemies were also recorded. The present study provides baseline information that might help in designing the suitable strategy for control of this polyphagous pest by using its natural enemies along with the knowledge of its seasonal abundance.

MATERIALS AND METHODS

Population dynamics of *H. vigintioctopunctata*

To assess the grub and adult populations of hadda beetle on brinjal the studies were carried out during the two consecutive years. The experimental plot size was maintained at 12 × 7.5 m^2 and the inter-row and inter-plant distance was maintained at 50 cm × 60 cm. The agronomic practices for raising the brinjal crop recommended by Sher-e-Kashmir University of Agricultural Sciences and Technology, Jammu were strictly followed. Observations regarding the presence of developmental stages of hadda beetle were recorded on three leaves (one leaf each from top, middle and bottom canopy of twenty randomly selected plants), which were tagged and observed at one week intervals for pest population and their associated natural enemies for the entire duration of the crop. The density and distribution of developmental stages of the pest were also monitored by random leaf sampling in the field, which commenced two weeks after transplanting. In addition, the collection of parasitized life stages of the pest was done. The weekly data on atmospheric temperature (both maximum and minimum, in ˚C), relative humidity (both morning and evening, in %), and rainfall (in mm) was obtained from the Agro meteorological section, Division of Agronomy, Sher-e-Kashmir University of Agricultural Sciences and Technology, Jammu. Pearson's correlation and multiple regression analysis were performed to determine the cumulative and individual effects of weather factors on population build up of hadda beetle.

Natural parasitisation

Various developmental stages of the hadda beetle (eggs, grubs, pupae and adult) were collected from the crop fields and brought to the laboratory weekly for recording natural parasitisation by the various types of parasitoids present in the crop. The collected developmental stages of hadda beetle were reared on host leaves to observe the extent of natural parasitisation. The number of adult parasitoids thus emerged were collected for their subsequent species identification.

Extent of *H. vigintioctopunctata* parasitization by the adult parasitoids

The percent parasitisation of various developmental stages of hadda beetle by the parasitoid species was recorded. Twenty samples of various developmental stages of hadda beetle were collected every week during the peak activity/infestation of the pest from twenty randomly selected host plants. The number of various developmental stages of hadda beetle from which the parasitoids emerged among the total number collected from the field were also recorded, thus the percent parasitization of various life stages of hadda beetle by the parasitoids was worked out.

Morphometrics of the adult parasitoids

For morphometric parameters, twenty specimens of both the adults of both the species of perasitoids were collected for measurement of body dimensions. The length and breadth of eyes, head, their antennal length, length and breadth of fore and hind wings, thorax and abdomen, length of legs and length of the ovipositor was measured by using a Stereozoom microscope (Leica Microsystems, India).

Statistical analysis

To determine the role of environmental factors on the number of different developmental stages of hadda beetle on brinjal, the data was analyzed using correlation and regression analysis. Pearson's correlations were calculated between different developmental stages of hadda beetle (eggs, grubs, pupae and adults) individually and various abiotic factors like temperature (both maximum and minimum), relative humidity (both morning and evening) and rainfall.

To determine the joint effect of different (independent) variables on the population built up of different development stages of hadda beetle, multiple correlation coefficients were calculated and multiple linear regression equation was fitted. Adequacy of best fitted regression equations were judged with the help of coefficient of determinations (R^2). The effect of various environmental factors on population built up of various developmental stages of hadda beetle was estimated by using multiple linear regression analyses with the prediction equations given as:

$\hat{y} = a + b_1x_1 + b_2x_2 + b_3x_3 + b_4x_4 + b_5x_5$

Where $\hat{y}$ represents the various developmental stages of hadda beetle individually, 'a' is the constant and b_1 to b_5 are the estimated regression coefficients associated with x_1 to x_5 respectively.

The parasitoid morphometrics data was analyzed statistically as described by (Snedecor and Cochrane 1980). SPSS software for WINDOWS version 16.0 (SPSS, USA) and Microsoft Office Excel 2003 (Microsoft, USA) were used to conduct the statistical analysis.

RESULTS AND DISCUSSIONS

Population fluctuation due to materiological factors

The population dynamics of various developmental stages of hadda beetle was recorded on the brinjal plants grown at experimental field at SKAUST, Jammu (Fig. 1), for two consecutive years in relation to the key meteorological parameters (Fig. 2). First observation for egg clusters was made during the 14th standard meteorological week (average max. temp. 27.29°C, min. temp. 14.62°C, morning RH 80.43 %, evening RH (relative humidity) 46.57 % and rainfall 7.44 mm for two consecutive years). During this week 0.10 egg clusters/ plant were recorded. Their highest number was recorded to be 0.40 egg clusters/ plant during the 27th standard meteorological week (average max. temp. 36.38°C, min. temp. 24.15°C, morning RH 74.65 %, evening RH 49.57 % and rainfall 104.40 mm) (Fig. 3). Correlation coefficients between number of egg clusters and weather factors revealed that max. temp. ($r = 0.223$), min. temp. ($r = 0.383$), evening RH ($r = 0.139$) and rainfall ($r = 0.528$) had non-significant (Pearson's correlation coefficient, $p \leq 0.05$) but positive effect on the number of egg clusters present in the field but relative morning RH ($r = -0.071$) had a negative non-significant effect on the number of egg clusters. Regression studies revealed that the weather factors had 35.9 % contribution to the number of egg clusters in the brinjal field.

Figure 1: Experimental field for brinjal trial at SKUAST, Jammu research farms

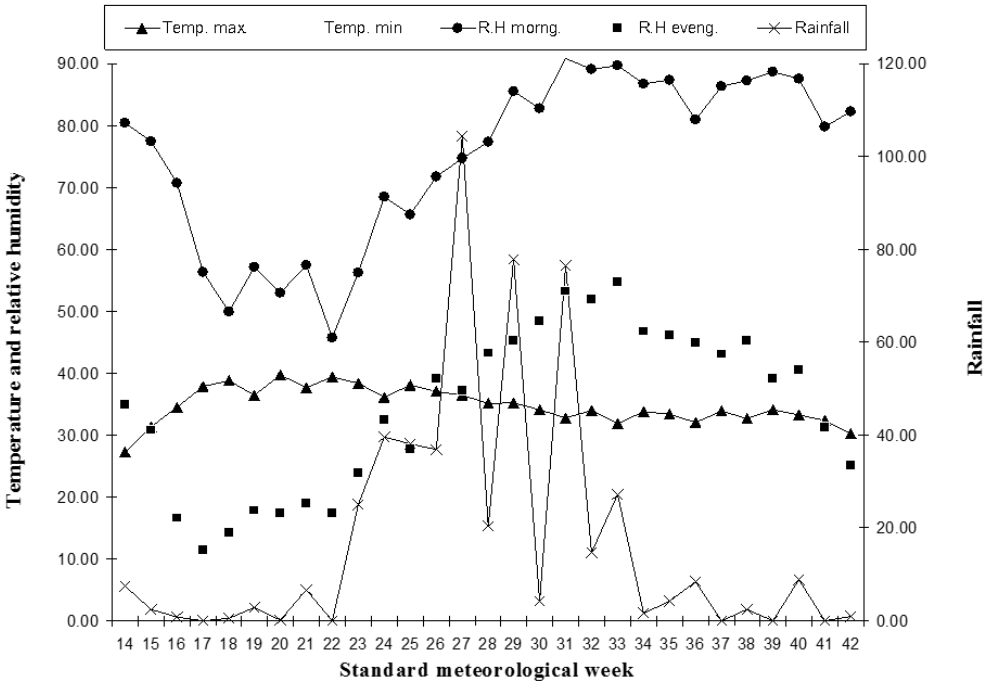

Figure 2: Fluctuation of key meteorological factors during the field trial (pooled for two years).

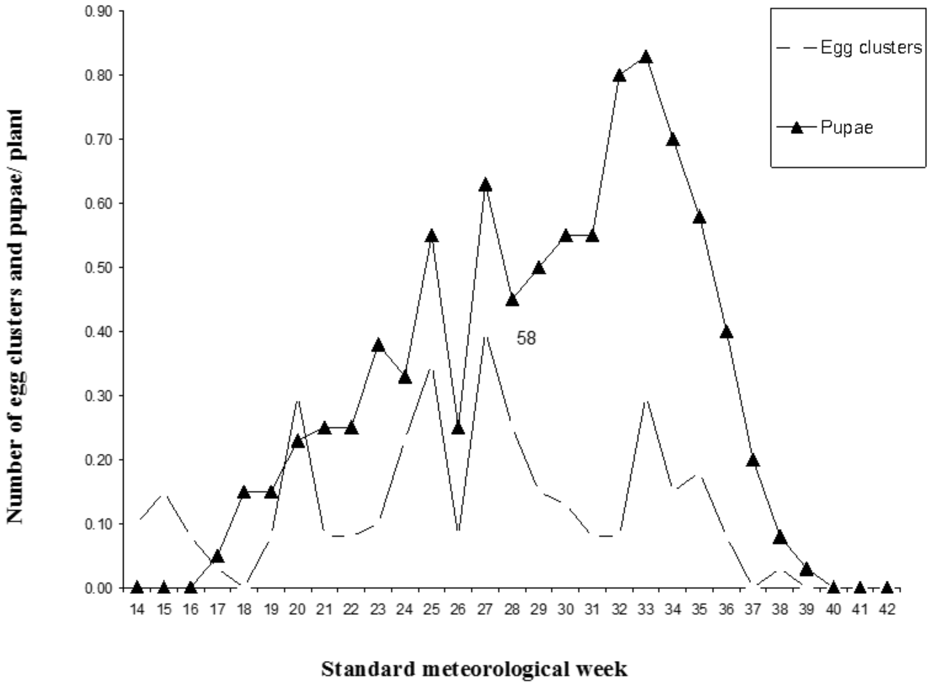

Figure 3: Seasonal incidence of egg clusters and pupal stage of *H. vigintioctopunctata* on brinjal (pooled for two years)

A pooled study for two consecutive years witnessed a grub population of 0.45 grubs/ plant in the 14th standard meteorological week when the average maximum and minimum atmospheric temperatures, morning and evening relative humidity and rainfall were 27.29 and 14.62°C, 80.43 and 46.57 % and 7.44 mm respectively. The population varied greatly during the study period under the influence of varying meteorological factors. The grub population reached maximum during 35th standard meteorological week (3.78 grubs/ plant) when the corresponding average maximum and minimum atmospheric temperatures, morning and evening relative humidity and rainfall were 33.37 and 23.74°C, 87.36 and 61.50 % and 4.20 mm respectively (Fig. 4). Correlation studies between different abiotic factors and grub population revealed that minimum atmospheric temperature (r = 0.617), morning relative humidity (r = 0.667) and evening relative humidity (r = 0.840) had significant positive effect on the grub population. However maximum atmospheric temperature (r = -0.312) had significant negative effect, only rainfall (r = -0.018) had a negative but non-significant effect on the grub population. Regression analysis revealed that the weather factors had 87.3 % contribution towards the changes in grub population.

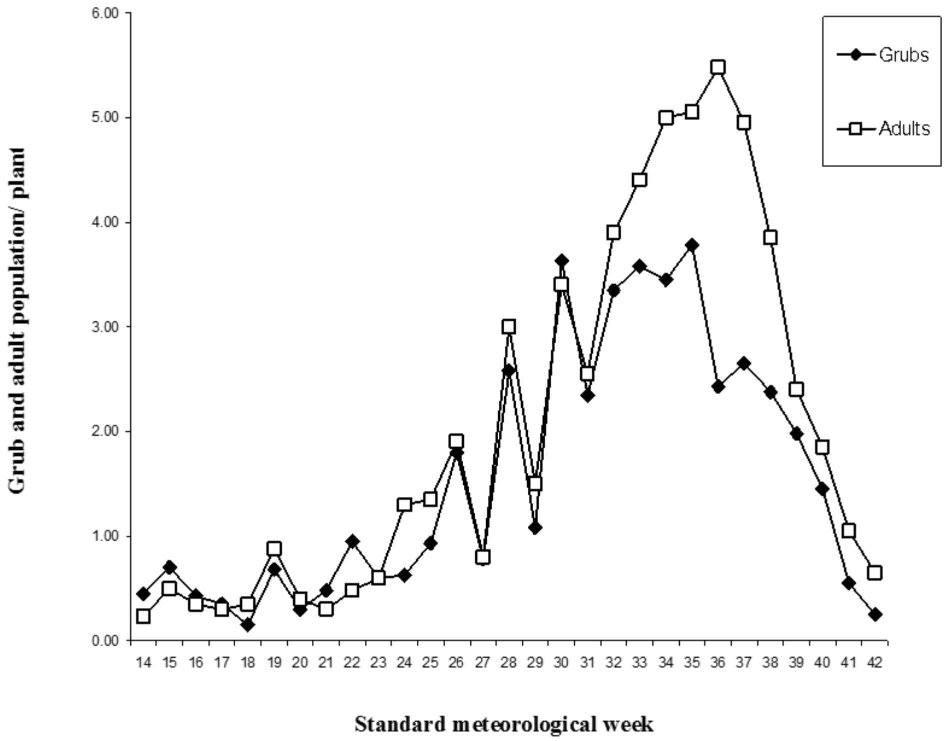

Figure 4: Seasonal incidence of grub and adult stages of *H. vigintioctopunctata* on brinjal (pooled for two years)

Pupae of *E. vigintioctopunctata* were visible in the 17th standard meteorological week (0.05 pupa/ plant) when the corresponding average maximum and minimum atmospheric temperatures, morning and evening relative humidity and rainfall were 37.88 and 17.77°C, 56.29 and 15.29 % and 0.00 mm, respectively. The maximum number of pupae was recorded during the 33rd standard meteorological week (0.83 pupae/ plant) corresponding to average maximum and minimum atmospheric temperatures, morning and evening relative humidity and rainfall were 31.88 and 24.95°C, 89.65 and 73.00 % and 27.3 mm respectively (Fig. 3). Only two abiotic factors *viz.*, minimum atmospheric temperature (r = 0.752) and evening relative humidity (r = 0.586) had significant positive effect on pupal population, rest all the factors including maximum atmospheric temperature (r = 0.108), morning relative humidity (r = 0.265) and rainfall (r = 0.491) had a positive but non-significant effect on the number of pupae. Regression analysis of pooled data for both the years showed that the weather factors had 66.8 % contribution towards the field presence of pupae. It was further observed that grubs and adults were the two most voracious foliage feeding stages of hadda beetle. Population data of adult hadda beetles suggested that the infestation of brinjal by *H. vigintioctopunctata* was first visible during 14^{th} standard meteorological week (0.23 adult/ plant) corresponding to the average maximum and minimum atmospheric temperatures, morning and evening relative humidity and rainfall of 27.29 and 14.62°C, 80.43 and 46.57 % and 7.44 mm respectively. The maximum number of adult hadda beetles was recorded during 36^{th} standard meteorological week (5.48 adults/ plant) under the effect of coinciding maximum and minimum atmospheric temperatures, morning and evening relative humidity and rainfall of 32.08°C and 21.46°C, 80.93 and 59.86 % and 8.39 mm respectively (Fig. 4). Studies on correlation among various abiotic factors and seasonal incidence of adult beetle population revealed that morning relative humidity (r = 0.669), evening relative humidity (r = 0.796) and minimum atmospheric temperature (r = 0.515) showed significant positive effect on adult beetles population. Also, the maximum atmospheric temperature (r = -0.351) had a significant negative effect, whereas rainfall (r = -0.070) had a negative non-significant effect on the adult beetles population. The regression analysis showed that various metrological factors had 81.9 % effect on the buildup of adult beetle population.

The studies on population dynamics of grubs and adults suggested that their population increases with increase in minimum temperature, morning and evening relative humidity. Out of various meteorological factors temperature and humidity have major contribution towards the seasonal abundance of hadda beetle population. The first vision of adults was recorded in 14^{th} standard meteorological week and it was earlier than the first vision of pupae (17^{th} standard meteorological week). It can be attributed to the drift of hadda population from its wild hosts *i.e. Solanum nigrum*[2] growing in the vicinity of the crop fields. The early appearance of both egg clusters and grubs than pupae was recorded on brinjal. These two stages (egg clusters and grubs) well coincided with the appearance of adult stage but pupal stage appeared three weeks later that may be attributed to the insect's developmental progression.

The regression equations for various life stages of hadda beetle were calculated (Table 1) in relation to key meteorological factors affecting its seasonal abundance with respective R^2 values.

Table 1: Regression analysis of hadda beetle life stages with key meteorological factors

LIFE STAGE	REGRESSION EQUATION	R^2 value
Eggs	$\hat{y} = 0.512 – 0.009x_1 + 0.008x_2 – 0.005x_3 + 0.002x_4 + 0.002x_5$	0.359^{*}
Grubs	$\hat{y} = -6.314 + 0.126 x_1 + 0.021x_2 – 0.005x_3 + 0.082x_4 – 0.020x_5$	0.873^{**}
Pupae	$\hat{y} = -0.338 + 0.020 x_1 + 0.003x_2 – 0.012x_3 + 0.018x_4 + 0.002x_5$	0.668^{**}
Adults	$\hat{y} = -12.904 + 0.363x_1 – 0.172x_2 – 0.004x_3 + 0.150x_4 – 0.031x_5$	0.819^{**}

Where variables x_1 = Maximum Temperature, x_2 = Minimum Temperature, x_3 = Relative humidity morning, x_4 = Relative humidity evening and x_5 = Rainfall

*Significant at 5 per cent probability level.

** Significant at 1 per cent probability level.

Parasitization by natural enemies

The natural enemies of 28-spotted hadda beetle were identified as *Tetrastichus* sp. (egg parasitoid) and *P. foveolatus* (pupal parasitoid) (Fig. 5). The mean maximum parasitization of *H. vigintioctopunctata* egg clusters by *Tetrastichus* sp. was observed as 22.64 % in August (34^{th} standard meteorological week) whereas the minimum parasitization was observed as 4.14 % in November (47^{th} standard meteorological week). The mean maximum parasitization of *H. vigintioctopunctata* pupae by *P. foveolatus* was observed as 6.62 % in August (35^{th} standard meteorological week) whereas the minimum was recorded as 0.82 % in November (48^{th} standard meteorological week). Similar natural enemies of hadda have also been recorded from other parts of the country[16-19] and also outside India[20]. *Tetrastichus sp.* was recorded as a more virulent parasitoid of *H. vigintioctopunctata* (in terms of % parasitization) than *P. foveolatus* in the Jammu region of J&K, India. Previous studies also reported the presence of *Tetrastichus ovulorum*, *P. foveolatus*, besides two other parasitoids on various life stages of *H. vigintioctopunctata* (*Uga menoni* and *Bracon* sp.) in Punjab[16]. In their study *P. foveolatus* population was found highest during June-September, and the adult parasitoids emerged out of the grubs after making holes in their bodies. Pupal parasitoid, *P. foveolatus* has been recorded to cause a high level of parasitization in hadda beetles feeding on *W. somnifera* plants in India[17]**.** It has been observed that *P. foveolatus* is a dominant and gregarious parasitoid of hadda beetle and has the capability to parasitize both larval and pupal stages[20]. However, in our study *Tetrastichus* sp. was found to have higher percentage parasitization of hadda beetle compared to *P. foveolatus*. Therefore *Tetrastichus* sp. might be more prevalent parasitoid of hadda beetle in our study area due to differences in agro-climatic conditions.

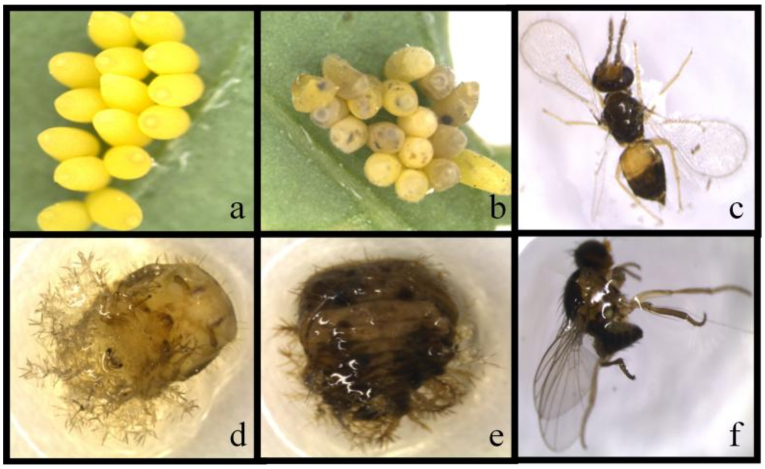

Figure 5: Parasitoids on various life stages of *H. vigintioctopunctata* **a.)** Healthy egg clusters **b.)** egg clusters parasitized by *Tetrastichus* sp. **c.)** adult egg parasitoid *Tetrastichus sp.* **d.)** healthy pupa **e.)** pupa parasitized by *P. foveolatus* and **f.)** adult pupal parasitoid *P. foveolatus*

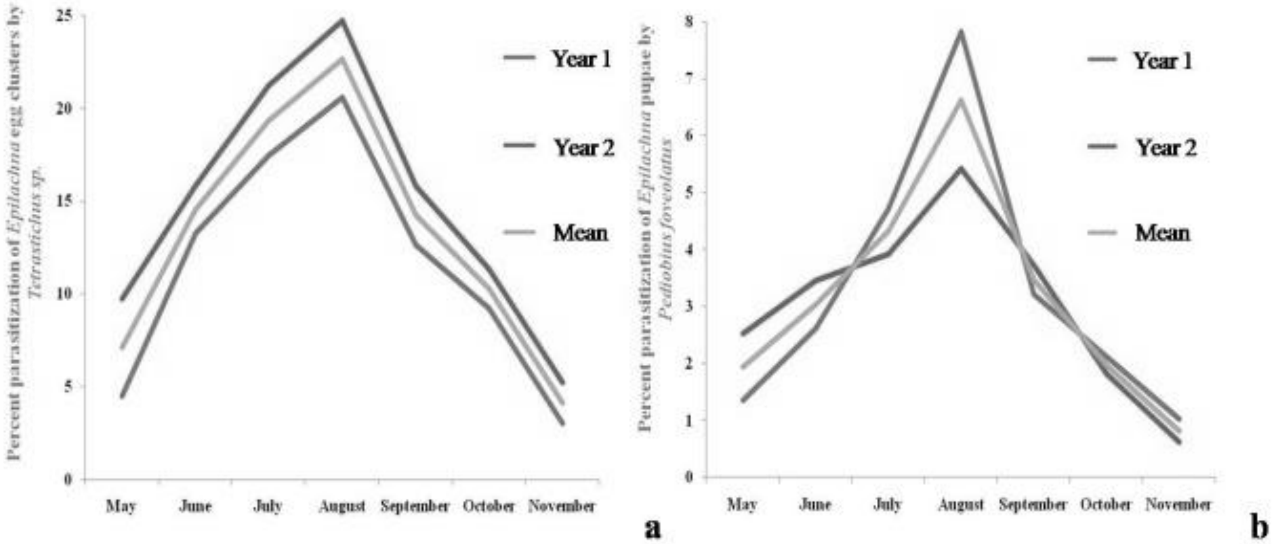

Figure 6: Percent parasitisation of *H. vigintioctopunctata* **a.)** egg clusters by *Tetrastichus* sp. and **b.)** pupae by *P. foveolatus*

Morphometrics of *Tetrastichus* sp. and *P. foveolatus*

The morphometric data of the adult parasitoids (both egg and pupal parasitoid) is presented in Table 2. The measurement of head capsule length and width of *Tetrastichus* sp. was recorded as 0.90 ± 0.33 mm and 1.30 ± 0.21 mm respectively, with an antennae length of 2.47 ± 0.78 mm. The length and width of the thorax was recorded 1.57 ± 0.33 and 1.25 ± 0.25 mm respectively. The length and width of forewing was measured as 3.71 ± 0.84 mm and 1.80 ± 0.44 mm respectively. The length and width of hind wing was measured as 3.00 ± 0.47 mm and 0.35 ± 0.07 mm respectively. The length and width of abdomen was measured as 1.90 ± 0.39 mm and 1.14 ± 0.29 mm respectively. The measurement of the overall body length and width was recorded as 4.37 ± 0.35 mm and 3.69 ± 0.25 mm respectively.

Table 2 - Morphometrics of parasitoids, *Tetrastichus* sp. and *P. foveolatus* parasitizing *H. vigintioctopunctata*

	***Tetrastichus* sp. (egg parasitoid)**				***P. foveolatus* (pupal parasitoid)**			
	Length		**Width**		**Length**		**Width**	
Body parts	**Range**	**Mean***	**Range**	**Mean***	**Range**	**Mean***	**Range**	**Mean***
Antennae	1.69-3.25	2.47±0.78	0.07-0.17	0.12±0.05	2.11-3.33	2.72±0.61	0.10-0.22	0.16±0.06
Eyes	0.34-0.82	0.58±0.24	0.19-0.45	0.32±0.13	0.42-1.10	0.76±0.34	0.22-0.70	0.46±0.24
Head capsule	0.57-1.23	0.90±0.33	1.09-1.51	1.30±0.21	1.02-1.48	1.25±0.23	1.36-1.56	1.46±0.10
Thorax	1.24-1.90	1.57±0.33	1.00-1.50	1.25±0.25	1.10-2.94	2.02±0.92	1.25-1.69	1.47±0.22
Legs	3.39-5.01	4.20±0.81	0.37-0.83	0.60±0.23	5.63-6.05	5.84±0.21	0.34-0.76	0.55±0.21
Fore wing	2.87-4.55	3.71±0.84	1.36-2.24	1.80±0.44	3.64-6.06	4.85±1.21	1.87-2.37	2.12±0.25
Hind wing	2.53-3.47	3.00±0.47	0.28-0.42	0.35±0.07	3.35-5.75	4.55±1.18	1.37-2.15	1.76+0.21
Abdomen	1.51-2.29	1.90±0.39	0.85-1.43	1.14±0.29	1.67-2.79	2.23±0.56	0.86-1.60	1.23±0.37
Ovipositor	0.41-0.51	0.46±0.05	----	----	0.79-0.92	0.85±0.07	----	----
Body measurement	3.32-5.42	4.37±0.35	2.94-4.44	3.69±0.25	3.79-7.21	5.50±0.57	3.47-4.85	4.16±0.23

*Mean and standard error for twenty random observations (n=20) in mm.

The measurement of head capsule length and width of *P. foveolatus* adults was recorded as 1.25 ± 0.23 mm and 1.46 ± 0.10 mm respectively with an antennae length of 2.72 ± 0.61 mm. The length and width of the thorax was recorded as 2.02 ± 0.92 mm and 1.47 ± 0.22 mm respectively. The length and width of forewing and hind wing was measured as 4.85 ± 1.21 mm and 2.12 ± 0.25 mm, 4.55 ± 1.18 mm and 1.76 ± 0.21 mm, respectively. The length and width of abdomen was measured as 2.23 ± 0.56 mm and 1.23 ± 0.37 mm respectively. The measurement of the overall body length was recorded as 5.50 ± 0.57 mm and width 4.16 ± 0.23 mm respectively. High morphological variability was recorded in the body measurements of *P. foveolatus* than *Tetrastichus* sp.

CONCLUSION

The present study was conducted to study the seasonal population abundance and occurrence of natural enemies if any associated with hadda beetle. It was found that minimum temperature morning and evening relative humidity played key role in seasonal population changes of *H. vigintioctopunctata*, among various weather parameters studied. Further, the natural enemies *Tetrastichus* sp. and *P. foveolatus* were observed to significantly suppress the pest population, hence insight into the morphology, biology and ecology of these two parasitoids will be useful for the management of hadda beetle population in an ecologically sustainable manner. The naturally occurring population of these two parasitoids can play a vital role in devising integrated pest management strategies against hadda beetle.

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