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Seasonal incidence of hymenopteran parasitoids of *Henosepilachna* spp.

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Abstract
Studies on population dynamics of two hymenopteran parasitoids (i.e. *Pediobius foveolatus* (Crawford) and *Tetrastichus* sp. (Hymenoptera: Eulophidae) of *Henosepilachna* spp. were carried out for two successive years (2015 and 2016) on various crops *viz.*, brinjal, bitter guard, tomato and winter cherry, in an experimental field of Department of Plant Protection, Aligarh Muslim University, Aligarh, India. Observations were taken on 4 randomly selected plants from each plot by collecting various developmental stages (i.e. eggs, grubs, pupae and adults) of *Henosepilachna* spp. These developmental stages were brought to the laboratory and continuously kept under watch for the emergence of any parasitoids from parasitized hosts. After emergence of parasitoid from parasitized stages of *Henosepilachna* spp., they were collected in glass vials separately and samples were identified by the experts. Results of the study showed that temperature range of 29.10 to 31.81 ºC, relative humidity between 61.86 to 85.07% and rainfall between 0 to 50.80mm, favoured the population of *P. foveolatus* and *Tetrastichus* sp. to maximize the percentage of grub parasitization of *Henosepilachna* spp. on all tested host plants. From the present study, it can be concluded that the sufficient knowledge of biotic and abiotic factors affecting the seasonal incidence of natural enemies of pest is an important part of Integrated Pest Management (IPM) program, which helps growers/farmers to check the population of pests at below economic threshold level by using natural enemies as a mean of pest control tactics, thereby reducing the use of synthetic pesticides.

Keywords: Abiotic factors, hadda beetle, IPM, natural enemies, population dynamics

1. Introduction

The knowledge of the population dynamics of natural enemies is as important as the knowledge of population dynamics of pest species. Sufficient number of natural enemies regulates and keeps the population of pests under control. Therefore, understanding of seasonal emergence, correct time of peak parasitization, and time of activity of natural enemies helps to utilize the natural enemies as a mean of eco-friendly control measures of pest.

Natural enemies of *Henosepilachna* spp. have been recorded from various parts of the country [1-3] and also outside India [4]. Immature stages of *Henosepilachna* spp. are subjected to attack by number of parasitoids *viz*., *Pediobius foveolatus* (Crawford) (Hymenoptera: Eulophidae), *Pleurotropis epilachnae* Rhower (Hymenoptera: Eulophidae), *T. ovulorum* Ferriera (Hymenoptera: Eulophidae), *Chrysocharis appannai* (Hymenoptera: Eulophidae) etc [5]. Among the various natural enemies which attack *H. vigintioctopunctata*, two parasitoids i.e. *Tetrastichus* sp. and *P. foveolatus* are of great importance and have been extensively reviewed many times in literature [6-8]. Therefore, keeping in views the importance of natural enemies to regulate the population density of *Henosepilachna* spp., the studies on population dynamics of parasitoids of *Henosepilachna* spp. have been carried out.

2. Materials and methods

2.1. Studies on the population dynamics of parasitoids of *Henosepilachna* spp.

The experiments on the population dynamics of parasitoids of *Henosepilachna* spp. were done in 2015 and 2016 on four crops *viz*., brinjal, bitter guard, tomato and winter cherry. A periodic survey was carried out on weekly basis during the respective cropping seasons in experimental field of Department of Plant protection, Aligarh Muslim University, Aligarh, India. Aligarh district is located in the western part of Uttar Pradesh and lies between the latitude (27º 34'N to 28º 11'N) and longitude (77º 29'E to 78º 38'E).

These crops were chosen to study the population dynamics of parasitoids of *Henosepilachna* spp. based on the farmer's field survey in Aligarh district, India, because farmers generally cultivate brinjal, bitter guard and tomato as an income source. Brinjal and bitter guard were sown as a summer and monsoon season crop, tomato was sown as spring season crop and winter cherry was sown as monsoon season crop. All recommended agronomic practices were followed. All crops were sown in complete randomized block design (CRD) and observations were made on weekly basis for the presence of any parasitoid parasitizing various developmental stages (i.e. eggs, grubs, pupae and adults) of *Henosepilachna* spp. on 36 randomly selected plants. Eggs, larvae and pupae of *Henosepilachna* spp. were collected from each respected host plant and brought to the laboratory for the emergence of parasitoids. After emergence of parasitoid from parasitized stages of *Henosepilachna* spp. they were collected in glass vials separately and samples were forwarded to the experts for correct identifications.

Meteorological data for two consecutive years (2015 and 2016) were collected from the Meteorological station, Department of Physics, Aligarh Muslim University, Aligarh.

2.2. Statistical analysis

The population of parasitoids of *Henosepilachna* spp., for two consecutive years on four crops was analyzed statistically by using one way analysis of variance (ANOVA) at 0.05 probability level. Meteorological data i.e. mean maximum and minimum and average temperature (ºC), mean maximum and minimum and average relative humidity (%) and average rain fall (mm) for two study years were summarized in figure and its correlation with the population of parasitoid was computed by the Pearson's correlation. Further comparisons were made using box plot between the years 2015 and 2016 to know whether the populations of parasitoids, increased or decreased on each examined host plant by computing the Mann Whitney U test for independent samples. The statistical analysis and graphic presentation was done by using the language program R 2.10.1 [9].

3. Results

3.1. Population dynamics of parasitoids of *Henosepilachna* spp.

Studies on population dynamics of parasitoids of *Henosepilachna* spp. was carried out for two consecutive years (2015 and 2016) on four crops *viz*., brinjal, bitter guard, tomato and winter cherry. The density of egg parasitoid, *Tetrastichus* spp. and grub parasitoid, *Pediobius foveolatus* of *Henosepilachna* spp. fluctuated depending upon crop types and weather conditions.

A significant variation was determined in the mean density of egg parasitoid *Tetrastichus* spp. on brinjal (*F = 5.82; df = 27,35; P<0.05*), bitter guard (*F = 9.25; df = 25,35; P<0.05*), tomato (*F = 6.28; df = 7,35; P<0.05*) and winter cherry (*F = 8.29; df = 13,35; P<0.05*) in the study year, 2015 (Table 1). Density of *Tetrastichus* spp. depends upon the crop duration and crop type. On brinjal and tomato, *Tetrastichus* spp first appeared on 16th standard week (std. wk here after) of the year, 2015. On bitterguard and winter cherry it was first appeared on 18th and 31st std. wk, respectively. On brinjal, bitterguard, tomato and winter cherry the peak density of *Tetrastichus* spp. was noted on 35th, 32nd, 20th and 33rd std. wk of 2015, respectively. The temperature ranged between 29.37 to 33.74ºC, relative humidity ranged between 31 to 73.42% and rainfall ranged between 0 to 70mm favoured the population of *Tetrastichus* spp. to maximize the percentage of egg parasitization of *Henosepilachna* spp. (Fig. 1).

Analyzed results (Table-2) showed that the density of *Tetrastichus* spp was not significantly correlated with average temperature, average relative humidity and average rainfall (*Pearson's correlation* "r" = *NS*) on each tested crop except on tomato where population showed a negative and significant correlation with average relative humidity (*r = -0.769; P<0.026*) and negative and non-significant correlation with average rainfall (*r = -0.32; P<0.44*).

Similarly, population of *Pediobius foveolatus* showed a significant variation on brinjal (*F = 8.28; df = 27,35; P<0.05*), bitter guard (*F = 15.2; df = 25,35; P<0.05*), tomato (*F = 6.20; df = 8,35; P<0.05*) and winter cherry (*F = 5.18; df = 8,35; P<0.05*) in the study year, 2015 (Table 1). On brinjal, bitterguard, tomato and winter cherry, the population of *P. foveolatus* first appeared on 18th, 20th, 18th and 35th std. wk here after of 2015, respectively. However, on brinjal, bitterguard, tomato and winter cherry the peak density of *P. foveolatus* was noted on 37th, 33rd, 22nd and 38th std. wk of 2016, respectively. The temperature ranged between 29.37 to 33.48ºC, relative humidity ranged between 40 to 73.42% and rainfall ranged between 0 to 12.40mm favoured the population of *P. foveolatus* to maximize the percentage of grub parasitization of *Henosepilachna* spp. (Fig. 1).

Pearson's correlation (Table-2) showed that the density of *P. foveolatus* was significantly and positively correlated with average temperature (*r = 0.044; P<0.04*) but with average relative humidity and average rainfall it was significantly and negatively correlated (*r = -671; P<0.01**RH and *r = -0.443; P<0.039**rain fall) on brinjal. However, on other tested host crop the population of *P. foveolatus* was not significantly correlated (*P = NS*).

In the study year, 2016 population of *Tetrastichus* spp. exhibited a significant variation on brinjal (*F = 6.76; df = 27, 35; P<0.05*), bitter guard (*F = 8.5; df = 22,35; P<0.05*), tomato (*F = 5.2; df = 7,35; P<0.05*) and winter cherry (*F = 9.29; df = 12,35; P<0.05*) (Table 3). Population of *Tetrastichus* spp. started to appear on 16th, 21st, 17th and 31st std. wk of 2016 on brinjal, bitterguard, tomato and winter cherry, respectively. On brinjal, bitterguard, tomato and winter cherry the peak density of *Tetrastichus* spp. was noted on 32nd, 35th, 21st and 36th std. wk of 2016, respectively. The temperature ranged between 29.10 to 31.81ºC, relative humidity ranged between 61.86 to 85.07% and rainfall ranged between 0 to 50.80mm favoured *Tetrastichus* spp. to increase its population. (Fig. 2).

Results of Pearson's analysis (Table 4) showed that the density of *Tetrastichus* spp. was not significantly correlated with average temperature (*Pearson's correlation* "r" = *NS*) on each tested crop. However, the population of *Tetrastichus* spp. showed a negative and non-significant correlation with average relative humidity (*r = -0.054; P<0.69*) on brinjal and negative and significant correlation (*r = -0.0657; P<0.012*) on tomato. Moreover, population of *Tetrastichus* spp. exhibited significant and positive correlation with average relative humidity (*r = 0.57; P<0.025*) on winter cherry.

Pediobius foveolatus showed a significant variation in population density on brinjal (*F = 6.25; df = 27,35; P<0.05*), bitter guard (*F = 15.15; df = 23,35; P<0.05*), tomato (*F = 5.25; df = 8,35; P<0.05*) and winter cherry (*F = 4.16; df = 12,35; P<0.05*) in the study year, 2016 (Table 3). On brinjal, bitterguard, tomato and winter cherry, the population of *P. foveolatus* was first appeared on 18th, 19th, 18th and 36th std. wk of 2016, respectively. The peak density of *P. foveolatus* was noted on 35th, 32nd, 21st and 39th std. wk of 2016, on brinjal, bitterguard, tomato and winter cherry, respectively. The temperature ranged between 29.10 to 31.81 ºC, relative humidity ranged between 61.86 to 85.07% and rainfall ranged between 0 to 50.80mm favoured the population of *P. foveolatus* to maximize the percentage of grub parasitization of *Henosepilachna* spp. (Fig 2).

Pearson's correlation (Table 4) showed that the density of *P. foveolatus* was significantly and positively correlated with average temperature (*r = 0.021; P<0.05**brinjal and *r = 0.456; P<0.040**winter cherry) but with average relative humidity and average rainfall it was significantly and negatively correlated (*r = -528; P<0.021**RH and *r = -0.321; P<0.045**rain fall) on brinjal. However, on other tested host crops the population of *P. foveolatus* was not significantly correlated (*P = NS*).

Further a comparison was made in overall density of *Tetrastichus* spp. and *P. foveolatus* between the study years (2015 and 2016) on each tested host plant using Mann-Whitney U test. The test statistics indicating a non-significant difference in population densities of *Tetrastichus* spp. (*U = 345.2; N = 27;27; P<0.521* on brinjal, *U = 267.8; N = 22,22; P<0.621* on bitterguard, *U = 189.5; N = 7;7; P<0.68* on tomato, *U = 212; N = 13,12; P<0.75* on winter cherry) and *P. foveolatus* (*U = 330.20; N = 27,27; P<0.521* on brinjal, *U = 345; N = 28,23; P<0.420* on bitterguard, *U = 198.7; N = 8,8; P<0.563* on tomato, *U = 263.7; N = 8,12; P<0.505* on winter cherry) on each test crop between 2015 and 2016 (Fig 3).

4. Discussion

Abiotic (temperature, rainfall, humidity, and light intensity) and biotic factors (host quality, texture of host plants and nutritional value of food) influence the temporal abundance of insect pest and its bio-control agent population [10]. Present study demonstrated that a considerable variation occurred in the mean density of egg parasitoid *Tetrastichus* spp. on various host plants. Density of *Tetrastichus* spp. depends upon the crop duration and crop type. The peak density of *Tetrastichus* spp. was noted in the month of May and August of both study years on all tested crops. The temperature ranged between 29.37 to 33.74ºC, relative humidity ranged between 31 to 73.42% and rainfall ranged between 0 to 70mm recorded in these months of year 2015. Similarly, highest rate of grub parasitization of *Henosepilachna* spp. by *Pediobius foveolatus* was noted in the month of May, August and September of both study years. The temperature ranged between 29.37 to 33.48ºC, relative humidity ranged between 40 to 73.42% and rainfall ranged between 0 to 12.40mm favoured the population of *P. foveolatus* to maximize the percentage of grub parasitization of *Henosepilachna* spp.

Similar to the present study, Dhamdhere & Dhingra [6] also noted that *Tetrastichus* sp. and *P. foveolatus* parasitizing *H. vigintioctopunctata* and demonstrated that the parasitoids remained active in the field from August to November. They have recorded percent parasitization of the eggs, grubs and pupae upto 10.3-45.5, 3.3-62.0 and 2.3-34.8%, respectively. Subsequent report showed the maximum natural parasitization of *H. vigintioctopunctata* in the month of August, November, and September [7]. Moreover, Munshi [11] reported that parasitism by *P. foveolatus* and *Tetrastichus* spp. ranged from 16.66 to 6.66%, respectively. Furthermore, Raghuraman & Veeravel [12] studied the seasonal incidence of *P. foveolatus*, parasitizing *H. vigintioctopunctata* during November, 1995-October, 1996 in India. The average time for development of the parasitoid from egg to adult was 10-16.5 days in the laboratory, with 11.0-22.6 parasitoids emerging per host. The greatest incidence of parasitism was observed during March (24.73%).

Nevertheless, Kaur & Mavi [1] also reported the presence of *Tetrastichus ovulorum* and *P. foveolatus*, besides two other parasitoids (i.e. *Uga menoni* and *Bracon* sp.) on various life stages of *H. vigintioctopunctata* in Punjab. 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 [2]. 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 [4].

Furthermore, Patnaik & Mohapatra [13] also monitored the incidence of natural enemies of *H. vigintioctopunctata* on brinjal, during 2003 in India, by collecting and rearing the egg masses from field until the emergence of grubs or adult parasitoids. Parasitization was highest (57.2%) during the second fortnight of August. The overall parasitization of the egg masses was 25.1% during the cropping period with 4.1 to 14.8% eggs per egg mass being parasitized.

Present study was also supported by Raju & Maheshwari [14] who have reported the natural enemies associated with *H. vigintioctopunctata* infesting brinjal revealed that *Tetrastichus* sp. exhibited 37.6-38.8% egg parasitization during November and December, while *P. foveolatus* recorded 52.50% pupal parasitization during December. Similarly, Venkatesha[2] also reported that the parasitoid *P. foveolatus* caused highest parasitization (51.94 ± 12.20%) of *H. vigintiocpunctata* pupae during August. Varma & Anandhi [3] on the other hand reported that the activities of all the parasitoids (*Tetrastichus* sp., *P. foveolatus* and *Brachymeria* sp.) were highest during February. *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 [15].

In a very recent study, Jamwal *et al.* [16] recorded two natural enemies of hadda beetle *viz*., *Tetrastichus* sp. and *P. foveolatus*. 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). Natural enemies contribute to a significant level of immature stage mortality of *H. vigintioctopunctata* and are potentially important in pest management in commercial vegetable cultivation.

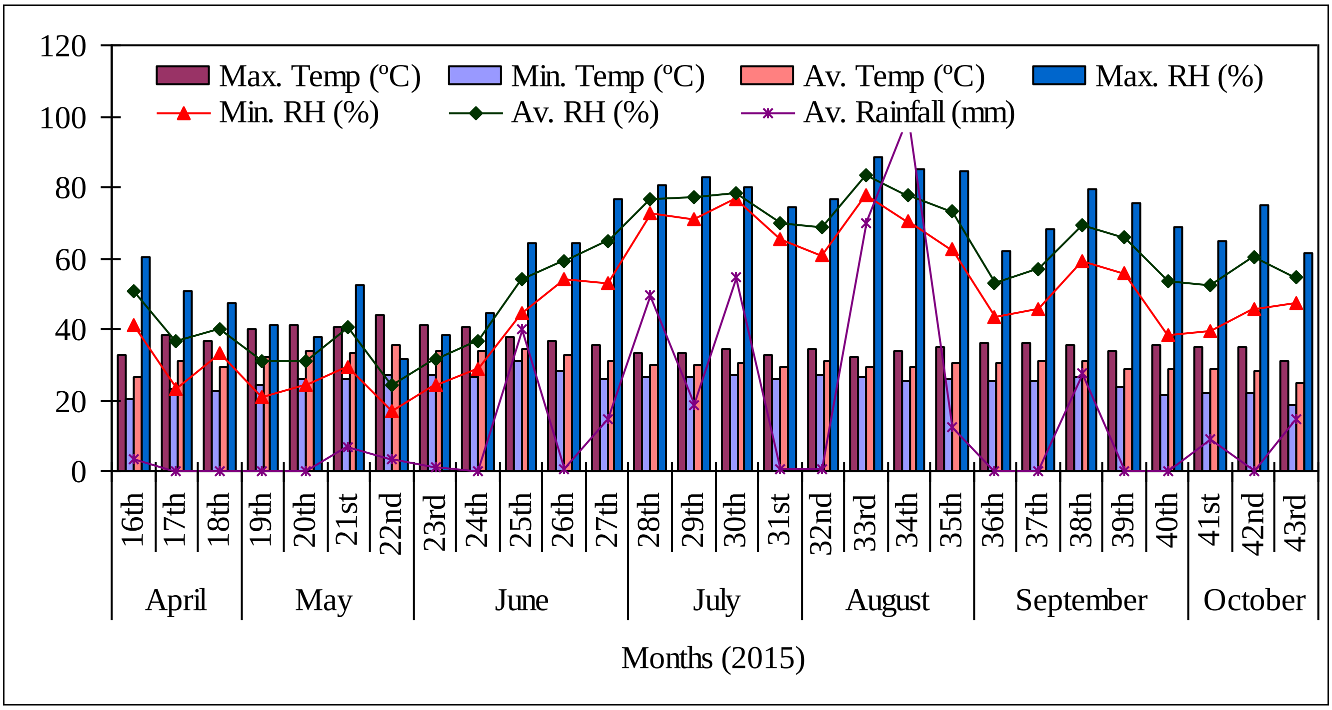

Fig 1: Meteorological data of Aligarh, India (2015). (Av. = Average; Temp. = Temperature; RH = Relative humidity; Max. = Maximum, Min. = Minimum, mm = millimeter).

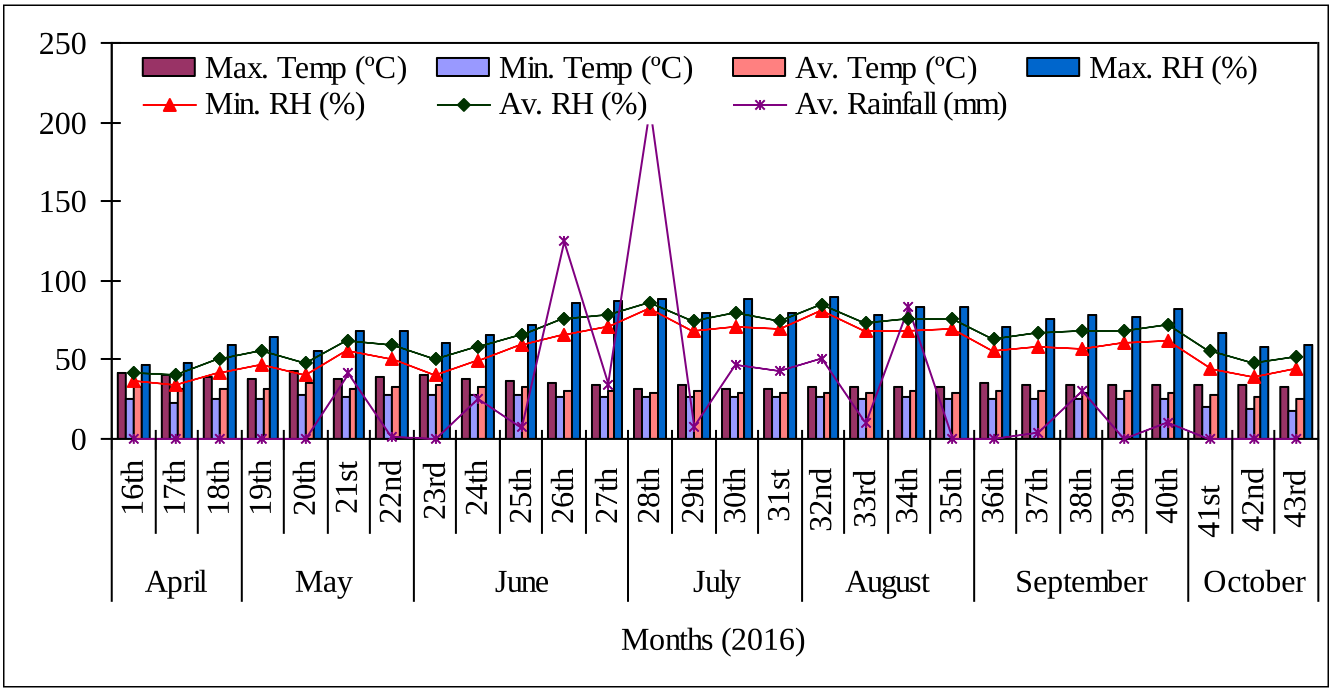

Fig 2: Meteorological data of Aligarh, India (2016). (Av. = Average; Temp. = Temperature; RH = Relative humidity; Max. = Maximum, Min. = Minimum, mm = millimeter).

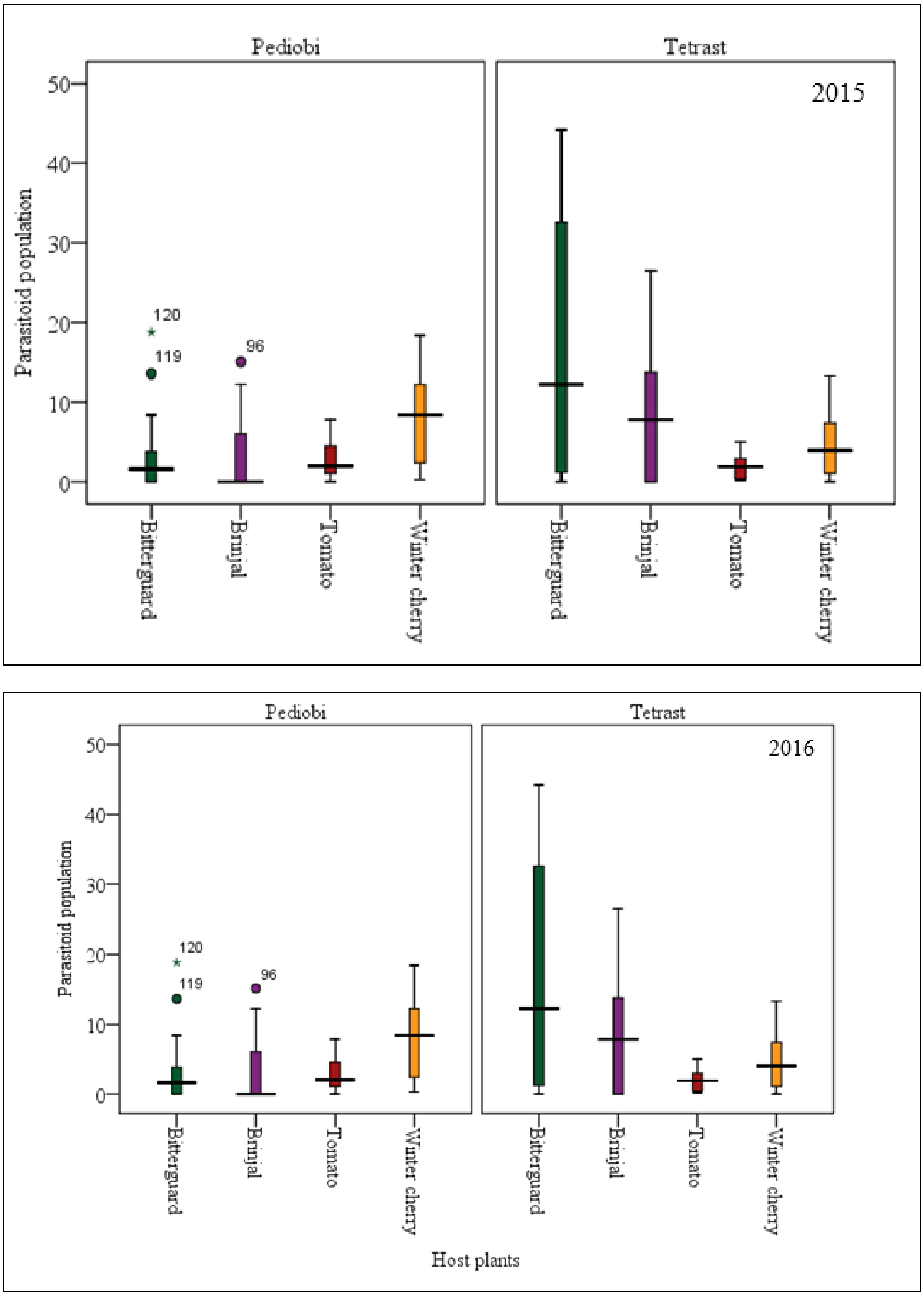

Fig 3: Average population of parasitoid (i.e. Pediobi = *Pediobius foveolatus* and Tetrast = *Tetrastichus* spp.) of *Henosepilachna spp.* on various crops for two consecutive years i.e. 2015 and 2016. Comparisons were made using Mann Whitney U test for independent samples. The limits of a box denote the upper and lower quartiles, the horizontal bar is the median, and the 1.5 IQR criterion has been used to classify outliers.

Table 1: Seasonal incidence of parasitoids of *Henosepilachna spp.*on various hosts (2015).

Months	Std. weeks	Percent parasitization by *Tetrastichus spp.*				Percent parasitization by *Pediobius foveolatus*			
		Brinjal	Bitterguard	Tomato	Winter cherry	Brinjal	Bitterguard	Tomato	Winter cherry
April	16th	11.80	0.00	0.70	NCS	0.00	0.00	0.00	NCS
	17th	12.70	0.00	1.50	NCS	0.00	0.00	0.00	NCS
	18th	14.60	1.40	2.25	NCS	4.20	0.00	2.00	NCS
May	19th	15.80	2.60	3.40	NCS	7.80	0.00	2.00	NCS
	20th	11.80	5.20	5.00	NCS	10.20	1.60	2.80	NCS
	21st	23.60	9.80	2.50	NCS	8.20	1.80	4.50	NCS
	22nd	8.10	18.40	0.20	NCS	12.10	2.60	7.80	NCS
June	23rd	4.30	25.20	0.20	NCS	10.40	4.80	6.30	NCS
	24th	0.00	13.00	NCS	NCS	0.00	7.80	1.10	NCS

	25th	0.00	6.40	NCS	NCS	0.00	8.40	NCS	NCS
	26th	0.00	0.00	NCS	NCS	0.00	2.20	NCS	NCS
	27th	0.00	0.00	NCS	NCS	0.00	0.00	NCS	NCS
July	28th	0.00	0.00	NCS	NCS	0.00	0.00	NCS	NCS
	29th	0.00	0.00	NCS	NCS	0.00	0.00	NCS	NCS
	30th	7.48	12.20	NCS	NCS	0.00	0.00	NCS	NCS
	31st	12.40	25.40	NCS	1.10	0.00	0.00	NCS	NCS
August	32nd	11.20	44.20	NCS	4.20	0.00	13.60	NCS	NCS
	33rd	12.90	42.60	NCS	13.30	0.00	18.80	NCS	NCS
	34th	22.30	40.40	NCS	9.80	0.00	7.40	NCS	NCS
	35th	26.50	42.20	NCS	6.10	0.00	3.80	NCS	2.40
September	36th	22.60	40.80	NCS	8.70	12.20	2.60	NCS	12.20
	37th	21.20	43.20	NCS	7.40	15.10	2.80	NCS	15.10
	38th	0.00	32.60	NCS	4.00	4.20	1.60	NCS	18.40
	39th	0.00	12.20	NCS	2.60	1.50	1.20	NCS	11.80
	40th	0.00	1.20	NCS	2.30	0.00	0.00	NCS	8.40
October	41st	0.00	NCS	NCS	0.00	0.00	NCS	NCS	3.60
	42nd	0.00	NCS	NCS	0.00	0.00	NCS	NCS	1.20
	43th	0.00	NCS	NCS	0.00	0.00	NCS	NCS	0.30
DF =		27, 35	25, 35	7, 35	13, 35	27, 35	25, 35	8, 35	8, 35
F =		5.82	9.25	6.28	8.29	8.28	15.2	6.2	5.18
P =		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
LSD =		1.25	2.32	0.26	1.18	0.34	0.15	0.55	1.10

Table 2: Pearson's correlation between the population of parasitoids of *Henosepilachna* spp. and abiotic factors

		Abiotic factors					
Stages	**Host plants**	**Av. Temp (°C)**	**P value**	**Av. RH (%)**	**P value**	**Av. Rainfall (mm)**	**P value**
2015							
Tetrastichus spp.	Brinjal	0.099	0.62	-0.061	0.76	0.077	0.07
	Bitterguard	0.085	0.66	0.296	0.13	0.254	0.19
	Tomato	0.093	0.83	-0.769	0.026*	-0.32	0.44
	Winter cherry	0.350	0.29	0.510	0.11	0.66	0.027*
Pediobius foveolatus	Brinjal	0.044	0.04*	.-.671	0.001**	.-0.443	0.039*
	Bitterguard	0.028	0.902	0.210	0.349	0.368	.092*
	Tomato	0.646	0.117	-0.58	0.173	0.562	0.19
	Winter cherry	0.667	.050*	0.151	0.698	0.107	0.784
Av. = Average; Temp. = Temperature; RH = Relative humidity; mm = milimeter							
** Significant at 0.01 level; * Significant at 0.05 level; ns- Not significant							

Table 3: Seasonal incidence of parasitoids of *Henosepilachna spp.*on various hosts (2016).

Months	**Std. weeks**	**Percent parasitization by *Tetrastichus spp.***				**Percent parasitization by *Pediobius foveolatus***			
		Brinjal	**Bitterguard**	**Tomato**	**Winter cherry**	**Brinjal**	**Bitterguard**	**Tomato**	**Winter cherry**
April	16th	2.20	0.00	0.00	NCS	0.00	0.00	0.00	NCS
	17th	5.30	0.00	0.10	NCS	0.00	0.00	0.00	NCS
	18th	12.90	0.00	0.50	NCS	9.10	0.00	1.20	NCS
May	19th	17.01	0.00	0.80	NCS	13.00	2.40	1.50	NCS
	20th	42.20	0.00	1.50	NCS	13.70	3.80	1.80	NCS
	21st	21.20	25.80	2.00	NCS	15.40	6.40	3.10	NCS
	22nd	5.30	32.00	0.50	NCS	18.70	7.20	1.20	NCS
June	23rd	0.00	34.80	0.10	NCS	15.40	10.80	0.40	NCS
	24th	0.00	18.20	NCS	NCS	0.00	9.60	0.00	NCS
	25th	0.00	2.20	NCS	NCS	0.00	1.80	NCS	NCS
	26th	0.00	0.00	NCS	NCS	0.00	0.20	NCS	NCS
	27th	0.00	0.00	NCS	NCS	0.00	0.00	NCS	NCS
July	28th	0.00	0.00	NCS	NCS	0.00	0.00	NCS	NCS
	29th	0.00	4.60	NCS	NCS	0.00	0.00	NCS	NCS
	30th	12.10	11.80	NCS	NCS	0.00	9.40	NCS	NCS
	31st	23.20	28.20	NCS	7.20	0.00	18.60	NCS	0.00
August	32nd	42.30	42.60	NCS	14.30	0.00	23.20	NCS	0.00
	33rd	39.70	47.80	NCS	13.80	0.00	21.80	NCS	0.00
	34th	35.10	52.20	NCS	11.90	17.60	9.60	NCS	0.00
	35th	38.30	49.60	NCS	21.50	19.00	3.80	NCS	6.20
September	36th	37.20	45.20	NCS	26.40	25.40	2.20	NCS	16.40
	37th	41.10	0.00	NCS	21.10	23.80	0.00	NCS	18.50
	38th	27.60	0.00	NCS	13.80	0.00	0.00	NCS	22.70
	39th	21.20	NCS	NCS	1.50	0.00	NCS	NCS	24.50
	40th	0.00	NCS	NCS	0.30	0.00	NCS	NCS	8.20

October	41st	0.00	NCS	NCS	0.10	0.00	NCS	NCS	1.50
	42nd	0.00	NCS	NCS	0.00	0.00	NCS	NCS	0.30
	43th	0.00	NCS	NCS	0.00	0.00	NCS	NCS	0.00
DF =		27, 35	22, 35	7, 35	12, 35	27, 35	23, 35	8, 35	12, 35
F =		6.76	8.5	5.2	9.29	6.25	15.15	5.25	4.16
P =		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
LSD =		2.14	2.72	0.20	2.00	1.81	1.15	0.25	2.20

Table 4: Pearson's correlation between the population of parasitoids of *Henosepilachna* spp. and abiotic factors

		Abiotic factors					
Stages	**Host plants**	**Av. Temp (°C)**	**P value**	**Av. RH (%)**	**P value**	**Av. Rainfall (mm)**	**P value**
2016							
Tetrastichus spp.	Brinjal	0.095	0.58	-0.054	0.69	0.067	0.06
	Bitterguard	0.079	0.59	0.389	0.35	0.456	0.56
	Tomato	0.085	0.78	-0.657	0.0123*	-0.24	0.76
Pediobius foveolatus	Brinjal	0.021	0.05*	.-.528	0.0213*	.-0.321	0.045*
	Bitterguard	0.032	0.670	0.123	0.453	0.298	0.056*
	Tomato	0.564	0.201	-0.67	0.234	0.587	0.29
Av. = Average; Temp. = Temperature; RH = Relative humidity; mm = milimeter							
** Significant at 0.01 level; * Significant at 0.05 level; ns- Not significant							

Table 5: Pearson's correlation between the population of parasitoids of *Henosepilachna* spp. and abiotic factors

		Abiotic factors					
Stages	**Host plants**	**Av. Temp (°C)**	**P value**	**Av. RH (%)**	**P value**	**Av. Rainfall (mm)**	**P value**
2016							
Tetrastichus spp.	Brinjal	0.095	0.58	-0.054	0.69	0.067	0.06
	Bitterguard	0.079	0.59	0.389	0.35	0.456	0.56
	Tomato	0.085	0.78	-0.657	0.0123*	-0.24	0.76
	Winter cherry	0.245	0.34	0.498	0.21	0.57	0.025*
Pediobius foveolatus	Brinjal	0.021	0.05*	.-.528	0.0213*	.-0.321	0.045*
	Bitterguard	0.032	0.670	0.123	0.453	0.298	.056*
	Tomato	0.564	0.201	-0.67	0.234	0.587	0.29
	Winter cherry	0.456	.040*	0.213	0.546	0.206	0.678
Av. = Average; Temp. = Temperature; RH = Relative humidity; mm = milimeter							
** Significant at 0.01 level; * Significant at 0.05 level; ns- Not significant							

5. Conclusion

From present study it can be concluded that the knowledge of the population dynamics of natural enemies of a pest species is as important as the knowledge of pest population dynamics. Sufficient number of natural enemies regulates and keeps the population of pests under control. Therefore, understanding of seasonal emergence, correct time of peak parasitization, and time of activity of natural enemies help once to utilize the natural enemies as a mean of eco-friendly control tactics of pest. Although knowledge of naturally occurring parasites, pathogens, and parasitoids of coccinellids has increased in recent years, a limited number of studies have investigated the biology and ecology of those species, which often contribute to the reduction of herbivore populations in managed and unmanaged ecosystems.

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