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Seasonal fluctuation of the broad mite *Polyphagotarsonemus latus* (Acari: Tarsonemidae) and its predatory mites on some pepper cultivars in Egypt

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ABSTRACT
The mean number of *Polyphagotarsonemus latus* (Banks) adult and immature populations on six pepper cultivars viz. Godyon, Khyrate, Qaha, Impala, Mandy and Hora was examined during the growing season from September 2008 to April 2009. The densities of *P. latus* populations infesting pepper cultivars are higher in autumn (September and October) and spring (March) months of the studied period. The average density of *P. latus* adults, in descending order of pepper cultivars, was 1.55, 1.51, 1.28, 1.11, 0.94 and 0.64 mites/leaf on Mandy, Godyon, Khyrate, Hora, Qaha and Impala cultivars, respectively. The average population density of *P. latus* immature stages, in descending order, on pepper cultivars was 10.08, 9.80, 9.79, 9.30, 8.95 and 7.57 for Khyrate, Hora, Qaha, Mandy, Godyon and Impala, respectively. A significantly positive relation between temperature and seasonal fluctuation of *P. latus* populations was noticed on all tested pepper cultivars**.** The relationship between fluctuation of *P. latus* populations and relative humidity was significantly positive on all tested pepper cultivars except the hot pepper Impala cultivar which showed positive insignificant relation.
The present study revealed that two species of predaceous mites *Euseius* (*Amblyseius*) sp. and *Typhlodromus* sp. were collected together with *P. latus* during the studied period. Predaceous mites were markedly increased during January, February and first half of March, 2009 and rarely observed during the remaining period. A negative relation was observed between temperature, relative humidity or *P. latus* density and seasonal fluctuation of predatory mites on all tested pepper cultivars**.**

1. INTRODUCTION
Tarsonemidae is a large family of worldwide distribution. Many tarsonemid species are fungivores, algivores and herbivores and others are predators of other mites, parasites of insects and possibly symbionts of insects (Zhang, 2003). The broad mite, *Polyphagotarsonemus latus* (Banks), is an important, pest of diverse crops in tropical and subtropical regions (Palevsky *et al*., 2001).

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Seasonal fluctuation of *P. latus* infesting pepper plants was accessible as early as Dhooria and Bindra (1977) in India. Effect of environmental factors as temperature and relative humidity on the incidence of *P. latus* infesting pepper was never studied in Egypt but extensively studied in different countries of the world (Manjunatha *et al*., 2001; Srinivasulu *et al.,* 2002; Jovicich *et al.,* 2004; Rahman and Khan, 2006; Bhede *et al.,* 2008; Patil and Nandihalli, 2009). Other plants including potato (Fernandez and Ramos, 1995; Namvar and Arbabi, 2007), tea (Liu *et al*., 1996; Wang *et al*., 2010), lemon (Tsolakis *et al*., 1998; Tonet *et al*., 2000), sesame (Ahuja, 2000; Dhooria, 2005), okra (Jyotika and Bhullar, 2003) and jute (Prasad *et al.*, 2006; Somchoudhury *et al.,* 2008) were also investigated.

The study of seasonal fluctuation of predaceous mites associated with *P. latus* is necessary to explain the variation in its population and the role they play in minimizing the rate of pest infestation. In Egypt, seasonal fluctuation of predatory mites of *P. latus* or other mite pests was rarely carried out. Predaceous mites were mainly confined in biological control studies of *Tetranychus urticae* infesting strawberry (Heikal *et al*., 2000; Heikal and Ibrahim, 2001) and cucumber (Heikal and Fawzy, 2003; El-Naggar et al., 2008) by its predatory mites, *Phytoseiulus macropilis*. *P. persimilis* or *Neoseiulus californicus*.

Predatory mites associated with *P. latus* were often surveyed in several plant hosts including jute (Zaman and Karimullah, 1987), aubergines (Misra *et al*., 1990), bean and lime (Pena and Osborne, 1996), chilli (Srinivasulu *et al*., 2002; Smitha and Giraddi, 2006; Patil and Nandihalli, 2009), okra (Jyotika and Bhullar, 2003) and sweet orange cultivars (Umeh *et al*., 2007). The relationship between *P. latus* density and its predatory mites on seasonal basis was occasionally investigated (Srinivasulu *et al*., 2002; Jyotika and Bhullar, 2003; Umeh *et al*., 2007; Patil and Nandihalli, 2009).

Since *P. latus* infesting different crops in Egypt has been recently raised to the pest status, the present work is intended to study the density of life cycle stages infesting six cultivars of pepper on seasonal basis. The study also included the correlation between *P. latus* abundance, climatic factors and predatory mites.

2. MATERIALS AND METHODS

The population fluctuation of the abundance (number of mites/apical leaf) of broad mite *P. latus* on six pepper cultivars namely Godyon, Khyrate, Qaha, Impala, Mandy and Hora was examined in relation to abiotic factors viz. temperature and relative humidity under plastic house conditions. The study was conducted at a farm of protected cultivations belonging to the Agricultural Research Center, Ministry of Agriculture and Land Reclamation, Dokki area, Giza Governorate, Egypt during the growing season that extended from September 7, 2008 to April 25, 2009.

The plastic house (60 × 9 m) was divided into 18 equal plots. Seedlings of the above six pepper cultivars were transplanted into the plastic house on August 28, 2008. The trail plots were arranged in a randomized complete block design with three replicates for each cultivar. All the experimental plots received the standard cultivation practices of that area including organic and mineral fertilization, drip irrigation and mechanical control was applied to remove weeds.

For measuring population fluctuation of *P. latus*, samples of 30 apical leaves from each replicate were randomly picked at weekly intervals from the time of seedling until the end of experiment. Each sample was kept in a tightly closed paper bag and transferred to the laboratory in the same day for inspection under a stereomicroscope. Number of immature (eggs, larvae and nymphs) and adult stages of *P. latus* were counted and recorded for each cultivar. A thermo-hydrograph instrument was placed inside the plastic house to examine air temperature (maximum and minimum temperatures) and relative humidity continuously. Daily means of weather factors during the week of sampling were used in calculating the simple correlation coefficient (r) and the explained variance (E.V. %) values between the broad mite population and the weather factors either separately or collectively. Statistical analysis (ANOVA and simple correlation) of the present data were carried out using the SAS program and *f* test (Snedecor and Cochran, 1967; SAS Institute, 1988).

For light microscopical examination, *P. latus* stages and its predatory mites were cleared by placing them in lactic acid for about one day. Each specimen was then placed in a drop of

Hoyer's medium (distilled water 50 ml, gum Arabic 30 g, chloral hydrate 200 g, glycerin 20 ml) and covered with a cover slip. Slides were placed in an incubator adjusted at 42°C for another one day to remove air bubbles. Slides were examined by light microscope and identified according to Zaher (1986).

3. RESULTS

3.1. Seasonal fluctuation of *P. latus* adults:

The mean number of *P. latus* adults on six pepper cultivars viz. Godyon, Khyrate, Qaha, Impala, Mandy and Hora was examined during the growing season from September 2008 to April 2009 (Table 1). Broad mite infestation started in the second week of September 2008, reached its peak (3.92-8.8 mites/leaf) within one month i.e. October 2008 and gradually reduced to <0.6 mites/leaf during the remaining period (November 2008-April 2009) in all cultivars except March 2009 which exhibited a mild peak (0.05-1.57 mites/leaf) (Table 1).

Table 1: Seasonal fluctuation of *Polyphagotarsonemus latus* adults/leaf (apical leaves) of pepper cultivars during 2008-2009 season.

Inspection date	Pepper Cultivars						Max.Temp. (°C)	Min.Temp. (°C)	Relative Humidity (%)
	Godyon	Khyrate	Qaha	Impala	Mandy	Hora			
Sept. 7	0.00	0.00	0.00	0.00	0.00	0.00	34.38	23.75	62.83
13	5.13	0.07	0.53	0.73	8.07	0.33	34.38	23.75	59.75
20	0.53	0.27	3.20	0.80	11.93	3.73	33.57	23.86	55.00
27	0.27	0.67	0.20	1.07	2.00	0.27	34.00	24.00	49.29
Sept. 2008	1.48	0.25	0.98	0.65	5.50	1.08	34.08	23.84	56.72
Oct. 5	6.53	8.87	5.47	1.53	1.40	1.60	32.38	21.13	54.13
11	10.47	11.33	4.13	8.27	5.73	9.40	29.17	20.17	58.83
18	5.80	5.40	5.73	3.87	6.47	5.60	28.29	19.57	59.14
25	8.27	9.60	5.93	2.00	9.13	7.33	26.29	19.29	66.86
Oct. 2008	7.77	8.80	5.32	3.92	5.68	5.98	29.03	20.04	59.74
Nov. 1	5.60	4.73	3.00	0.87	5.67	4.53	24.86	16.71	65.43
8	0.73	0.93	1.80	0.33	1.13	0.60	26.86	17.14	59.86
15	0.87	0.07	0.13	0.40	0.07	1.33	24.43	15.86	64.43
22	0.27	0.07	0.27	0.13	0.00	0.33	24.29	15.43	60.29
29	0.07	0.13	0.13	0.07	0.13	0.07	24.71	14.86	47.29
Nov. 2008	0.48	0.30	0.58	0.23	0.33	0.58	25.07	15.82	57.96
Dec. 6	0.07	0.53	0.00	0.07	0.00	0.00	26.71	14.14	52.29
13	0.00	0.00	0.13	0.07	0.00	0.00	21.14	13.43	57.29
20	0.00	0.00	0.00	0.00	0.00	0.07	23.57	12.29	58.86
27	0.00	0.00	0.00	0.00	0.00	0.07	17.57	12.14	60.86
Dec. 2008	0.02	0.13	0.03	0.03	0.00	0.03	22.25	13.00	57.32
Jan. 3	0.07	0.13	0.00	0.00	0.07	0.07	16.86	10.00	66.43
10	0.00	0.20	0.00	0.00	0.13	0.07	19.00	9.71	57.86
17	0.00	0.20	0.00	0.00	0.13	0.07	21.43	11.00	53.57
24	0.13	0.00	0.00	0.00	0.00	0.07	20.14	12.57	54.00
31	0.13	0.00	0.00	0.00	0.00	0.10	20.29	12.86	42.57
Jan. 2009	0.07	0.10	0.00	0.00	0.07	0.08	20.21	11.54	52.00
Feb. 7	0.00	0.00	0.00	0.00	0.00	0.00	22.71	11.57	50.14
14	0.00	0.07	0.00	0.00	0.00	0.00	22.86	13.43	41.71
21	0.00	0.00	0.00	0.00	0.00	0.00	19.43	11.86	46.71
28	0.00	0.00	0.00	0.00	0.00	0.00	19.29	11.14	46.71
Feb. 2009	0.00	0.02	0.00	0.00	0.00	0.00	21.07	12.00	46.32
Mar. 7	0.00	0.00	0.00	0.00	0.00	0.00	24.43	14.43	39.71
14	5.13	0.07	0.53	0.73	0.33	0.33	21.71	12.00	48.86
21	0.87	0.07	0.13	0.40	0.07	1.33	20.57	11.00	54.00
28	0.27	0.07	0.27	0.13	0.00	0.33	22.57	12.29	47.14
Mar. 2009	1.57	0.05	0.23	0.32	0.10	0.50	22.32	12.43	47.43
Apr. 4	0.07	0.13	0.13	0.07	0.13	0.07	24.86	13.57	53.29
11	0.00	0.00	0.13	0.07	0.00	0.00	26.14	16.00	51.14
18	0.00	0.00	0.00	0.00	0.00	0.00	29.14	16.57	45.00
25	0.00	0.07	0.00	0.00	0.00	0.00	28.71	16.57	47.86
Apr. 2009	0.02	0.05	0.07	0.03	0.03	0.02	27.21	15.68	49.32
Mean ± SE	1.51± 0.001	1.28± 0.001	0.94± 0.015	0.64± 0.010	1.55± 0.004	1.11± 0.003	24.90	15.41	54.09
(min-max)	(0.00-10.47)	(0.00-11.33)	(0.00-5.93)	(0.00-8.27)	(0.00-11.93)	(0.00-9.40)			

The highest value of mite abundance in Godyon (10.47 mites/leaf), Khyrate (11.33 mites/leaf), Impala (8.27 mites/leaf) and Hora cultivars (9.40 mites/leaf) were observed on

October 11, 2008. That of Mandy (11.93 mites/leaf) and Qaha cultivars (5.93 mites/leaf) were observed on September 20, 2008 and October 25, 2008, respectively (Table 1).

Generally, the density of *P. latus* adults infesting pepper cultivars is almost higher in autumn (September and October) and spring (March) months of the studied period. The average density of *P. latus* adults, in descending order of pepper cultivars, was 1.55, 1.51, 1.28, 1.11, 0.94 and 0.64 mites/leaf on Mandy, Godyon, Khyrate, Hora, Qaha and Impala cultivars, respectively.

3.2. Interaction between weather factors and seasonal fluctuation of adults:

A significantly positive relation was observed between seasonal fluctuation of *P. latus* adults with maximum or minimum temperature in all tested pepper cultivars except insignificant relation in Hora cultivar with maximum temperature (Table 2). The correlation coefficient (r) and explained variance (E.V. %) of maximum temperature showed their highest values (0.59 and 34.95%) in Mandy and their lowest ones (0.34 and 11.74%) in Hora cultivars, respectively (Table 2). In case of minimum temperature, the highest r- and E.V. % values were observed in Mandy (0.74 and 54.05%), while the lowest ones were observed in Impala cultivars (0.47 and 22.14%), respectively.

The relationship between fluctuation of *P. latus* adults and relative humidity was significantly positive in all tested pepper cultivars except the hot pepper Impala which showed insignificant relation recording 0.27 and 0.1215 in its r-value and probability, respectively (Table 2). Hora cultivar showed the highest r-value (0.46). The E.V. % in case of relative humidity ranged between 7.56 in Impala to 21.19 in Hora cultivar cultivars (Table 2).

Table 2: Interaction between weather factors and population fluctuation of *Polyphagotarsonemus latus* adults infesting six pepper cultivars.

Pepper Cultivars	Maximum Temperature			Minimum Temperature			Relative Humidity		
	(r)	(p)	E.V.%	(r)	(p)	E.V.%	(r)	(p)	E.V.%
Godyon	0.403	0.020	16.250	0.516	0.002	26.610	0.414	0.017	17.120
Khyrate	0.367	0.035	13.500	0.477	0.005	22.790	0.385	0.027	14.820
Qaha	0.472	0.006	22.240	0.599	0.000	35.860	0.422	0.015	17.790
Impala	0.373	0.033	13.880	0.471	0.006	22.140	0.275	0.122	7.560
Mandy	0.591	0.000	34.950	0.735	0.000	54.050	0.418	0.016	17.480
Hora	0.343	0.051	11.740	0.494	0.004	24.420	0.460	0.007	21.190

(r) = Correlation coefficient, (p)= Probability, E.V.%= Explained variance.

3.3. Seasonal fluctuation of *P. latus* immature stages:

The mean number of *P. latus* immature stages collectively infesting different cultivars were firstly noticed on September 13, 2008 (0.27-6.87 immatures/leaf), markedly increased in October 2008 (35.3-56.22 immatures/leaf), then gradually decreased to <16.82 immatures/leaf during the remaining period (November 2008- April 2009) (Table 3).

The highest abundance of *P. latus* immatures in Godyon (83.47 immatures/leaf), Khyrate (106.27 immatures/leaf), Qaha (104.33 immatures/leaf), and Impala cultivars (116.63 immatures/leaf) were observed on October 11, 2008. The highest abundance in Hora (73.93 immatures/leaf) and Mandy cultivars (53.93 immatures/leaf) were observed in October 18 and 25, 2008, respectively. The average population density of *P. latus* immature stages, in descending order, on pepper cultivars were 10.08, 9.80, 9.79, 9.30, 8.95 and 7.57 for Khyrate, Hora, Qaha, Mandy, Godyon and Impala, respectively (Table 3).

Table 3: Seasonal fluctuation of *Polyphagotarsonemus latus* immature (eggs, larvae and nymphs)/leaf (apical leaves) of pepper cultivars during 2008-2009 season.

Inspection date	Pepper Cultivars						Max.Temp. (°C)	Min.Temp. (°C)	Relative Humidity (%)
	Godyon	Khyrate	Qaha	Impala	Mandy	Hora			
Sept. 7	0.00	0.00	0.00	0.00	0.00	0.00	34.38	23.75	62.83
13	3.60	0.00	0.67	0.87	6.87	0.27	34.38	23.75	59.75
20	0.33	0.33	5.53	0.53	28.47	3.13	33.57	23.86	55.00
27	3.93	3.80	2.07	37.70	16.40	0.47	34.00	24.00	49.29
Sept. 2008	1.97	1.03	2.07	9.78	12.93	0.97	34.08	23.84	56.72
Oct. 5	33.20	23.07	21.20	15.87	9.40	21.13	32.38	21.13	54.13
11	83.47	106.27	104.33	116.63	40.33	69.00	29.17	20.17	58.83
18	53.00	56.80	50.20	41.60	37.53	73.93	28.29	19.57	59.14
25	29.07	26.13	49.13	18.87	53.93	42.07	26.29	19.29	66.86
Oct. 2008	49.68	53.07	56.22	48.24	35.30	51.53	29.03	20.04	59.74
Nov. 1	40.53	56.80	34.27	11.60	45.40	65.67	24.86	16.71	65.43
8	24.47	42.67	29.07	5.07	53.60	26.00	26.86	17.14	59.86
15	6.60	10.07	15.87	1.40	11.87	7.87	24.43	15.86	64.43
22	5.13	1.47	4.60	1.93	0.40	5.07	24.29	15.43	60.29
29	2.87	0.73	2.60	0.73	1.40	5.87	24.71	14.86	47.29
Nov. 2008	9.77	13.73	13.03	2.28	16.82	11.20	25.07	15.82	57.96
Dec. 6	2.27	0.20	2.47	0.27	1.13	1.07	26.71	14.14	52.29
13	0.53	7.87	1.80	0.40	0.13	0.47	21.14	13.43	57.29
20	0.80	0.60	0.87	0.20	0.13	0.20	23.57	12.29	58.86
27	0.53	0.47	0.20	0.40	0.93	0.80	17.57	12.14	60.86
Dec. 2008	1.03	2.28	1.33	0.32	0.58	0.63	22.25	13.00	57.32
Jan. 3	0.93	0.40	0.40	0.20	0.33	0.13	16.86	10.00	66.43
10	0.73	0.40	0.33	0.20	0.33	0.13	19.00	9.71	57.86
17	0.73	0.40	0.33	0.20	0.33	0.13	21.43	11.00	53.57
24	0.13	0.00	0.00	0.00	0.00	0.20	20.14	12.57	54.00
31	0.20	0.00	0.00	0.00	0.00	0.20	20.29	12.86	42.57
Jan. 2009	0.45	0.20	0.17	0.10	0.17	0.17	20.21	11.54	52.00
Feb. 7	0.00	0.07	0.00	0.00	0.00	0.00	22.71	11.57	50.14
14	0.00	0.00	0.00	0.00	0.00	0.00	22.86	13.43	41.71
21	0.13	0.00	0.00	0.00	0.07	0.00	19.43	11.86	46.71
28	0.07	0.00	0.00	0.00	0.00	0.00	19.29	11.14	46.71
Feb. 2009	0.05	0.02	0.00	0.00	0.02	0.00	21.07	12.00	46.32
Mar. 7	0.07	0.00	0.00	0.00	0.07	0.00	24.43	14.43	39.71
14	0.87	0.00	0.13	0.40	0.33	0.13	21.71	12.00	48.86
21	3.40	0.27	0.87	0.73	4.33	1.00	20.57	11.00	54.00
28	3.67	0.60	3.13	1.07	1.27	7.00	22.57	12.29	47.14
Mar. 2009	2.00	0.22	1.03	0.55	1.50	2.03	22.32	12.43	47.43
Apr. 4	2.40	3.20	2.47	0.47	1.07	1.13	24.86	13.57	53.29
11	0.53	0.20	0.20	0.00	0.20	0.27	26.14	16.00	51.14
18	0.07	0.00	0.00	0.00	0.07	0.00	29.14	16.57	45.00
25	0.00	0.00	0.00	0.00	0.00	0.00	28.71	16.57	47.86
Apr. 2009	0.75	0.85	0.67	0.12	0.33	0.35	27.21	15.68	49.32
Mean ± SE	8.95± 0.04	10.08± 0.06	9.79± 0.07	7.57± 0.05	9.30± 0.04	9.80± 0.05	24.90	15.41	54.09
(min-max)	(0.00-83.47)	(0.00-106.27)	(0.00-104.33)	(0.00-116.63)	(0.00-53.93)	(0.00-73.93)			

3.4. Interaction between weather factors and seasonal fluctuation of immature stages:

There is a significantly positive relation between maximum temperature and seasonal fluctuation of *P. latus* immatures in Godyon, Impala and Mandy cultivars and insignificantly positive relation in Khyrate, Qaha and Hora cultivars (Table 4). The highest and lowest r-values and E.V. % were observed in Mandy and Hora cultivars, respectively (Table 4). In case of minimum temperature, there is a significantly positive relation with the seasonal fluctuation of immatures on all tested pepper cultivars (Table 4). The highest and lowest r-values (0.57 and 0.4) and E.V. % (32.16% and 16.1%) were observed in Mandy and Khyrate cultivars, respectively.

The relationship between fluctuation of *P. latus* immatures and relative humidity was significantly positive in all tested pepper cultivars except the hot pepper Impala which showed insignificant relation recording the lowest r-value (0.21) and E.V. % (4.42%) (Table 4). Mandy cultivar recorded the highest r-value (0.53) and E.V. % (27.60%) (Table 4).

Table 4: Interaction between weather factors and population fluctuation of *Polyphagotarsonemus latus* immatures infesting six pepper cultivars.

Pepper Cultivars	Maximum Temperature			Minimum Temperature			Relative Humidity		
	(r)	(p)	E.V.%	(r)	(p)	E.V.%	(r)	(p)	E.V.%
Godyon	0.35	0.048	11.99	0.45	0.008	20.510	0.41	0.019	16.560
Khyrate	0.29	0.100	8.50	0.40	0.021	16.100	0.41	0.018	16.830
Qaha	0.31	0.075	9.88	0.44	0.011	19.060	0.43	0.013	18.440
Impala	0.36	0.037	13.27	0.46	0.008	20.750	0.21	0.240	4.420
Mandy	0.41	0.016	17.22	0.57	0.001	32.160	0.53	0.002	27.600
Hora	0.28	0.110	8.05	0.41	0.017	17.040	0.46	0.007	21.030

(r) = Correlation coefficient, (p) = Probability, E.V. % = Explained variance.

3.5. Seasonal fluctuation of *P. latus* predatory mites on different pepper cultivars:

The predaceous mites *Euseius* (*Amblyseius*) sp. and *Typhlodromus* sp. were the main predators associated with *P. latus*. The weekly and monthly mean number of adults of the two predaceous mites collectively on pepper plant is reported in Table (5).

Table 5: Seasonal fluctuation of predatory mites of *Polyphagotarsonemus latus*/leaf (apical leaves) of pepper cultivars during 2008-2009 season.

Inspection date	Pepper Cultivars						Max.Temp. (°C)	Min.Temp. (°C)	Relative Humidity (%)
	Godyon	Khyrate	Qaha	Impala	Mandy	Hora			
Sept. 7	0.00	0.00	0.00	0.00	0.00	0.00	34.38	23.75	62.83
13	0.00	0.00	0.00	0.00	0.00	0.00	34.38	23.75	59.75
20	0.00	0.00	0.00	0.00	0.00	0.00	33.57	23.86	55.00
27	0.00	0.00	0.00	0.00	0.00	0.00	34.00	24.00	49.29
Sept. 2008	0.00	0.00	0.00	0.00	0.00	0.00	34.08	23.84	56.72
Oct. 5	0.00	0.00	0.00	0.00	0.00	0.00	32.38	21.13	54.13
11	0.00	0.00	0.00	0.00	0.00	0.00	29.17	20.17	58.83
18	0.00	0.00	0.00	0.00	0.00	0.00	28.29	19.57	59.14
25	0.00	0.07	0.00	0.00	0.00	0.00	26.29	19.29	66.86
Oct. 2008	0.00	0.02	0.00	0.00	0.00	0.00	29.03	20.04	59.74
Nov. 1	0.13	0.07	0.00	0.00	0.07	0.00	24.86	16.71	65.43
8	0.00	0.07	0.00	0.00	0.00	0.07	26.86	17.14	59.86
15	0.07	0.00	0.00	0.00	0.00	0.07	24.43	15.86	64.43
22	0.00	0.00	0.00	0.00	0.00	0.00	24.29	15.43	60.29
29	0.13	0.00	0.00	0.00	0.00	0.00	24.71	14.86	47.29
Nov. 2008	0.05	0.02	0.00	0.00	0.00	0.03	25.07	15.82	57.96
Dec. 6	0.13	0.00	0.00	0.07	0.20	0.07	26.71	14.14	52.29
13	0.00	0.13	0.07	0.07	0.00	0.00	21.14	13.43	57.29
20	0.20	0.20	0.27	0.00	0.00	0.07	23.57	12.29	58.86
27	0.20	0.20	0.27	0.00	0.00	0.07	17.57	12.14	60.86
Dec. 2008	0.13	0.13	0.15	0.03	0.05	0.05	22.25	13.00	57.32
Jan. 3	0.80	0.07	0.13	0.33	0.67	0.07	16.86	10.00	66.43
10	0.73	0.13	0.13	0.33	0.80	0.13	19.00	9.71	57.86
17	0.73	0.13	0.13	0.33	0.80	0.13	21.43	11.00	53.57
24	0.47	0.27	0.67	0.20	0.13	0.60	20.14	12.57	54.00
31	0.47	0.33	0.67	0.20	0.20	0.60	20.29	12.86	42.57
Jan. 2009	0.60	0.22	0.40	0.27	0.48	0.37	20.21	11.54	52.00
Feb. 7	0.27	0.13	0.20	0.13	0.07	0.07	22.71	11.57	50.14
14	0.20	0.33	0.20	0.20	0.13	0.07	22.86	13.43	41.71
21	0.53	0.13	0.40	0.20	0.53	0.60	19.43	11.86	46.71
28	0.47	0.13	0.40	0.20	0.53	0.60	19.29	11.14	46.71
Feb. 2009	0.37	0.18	0.30	0.18	0.32	0.33	21.07	12.00	46.32
Mar. 7	0.40	0.20	0.47	0.20	0.60	0.47	24.43	14.43	39.71
14	0.47	0.13	0.40	0.20	0.53	0.60	21.71	12.00	48.86
21	0.13	0.00	0.00	0.00	0.00	0.00	20.57	11.00	54.00
28	0.00	0.00	0.00	0.00	0.00	0.00	22.57	12.29	47.14
Mar. 2009	0.25	0.08	0.22	0.10	0.28	0.27	22.32	12.43	47.43
Apr. 4	0.13	0.07	0.00	0.00	0.07	0.00	24.86	13.57	53.29
11	0.07	0.00	0.00	0.00	0.00	0.07	26.14	16.00	51.14
18	0.00	0.00	0.00	0.00	0.00	0.00	29.14	16.57	45.00
25	0.00	0.00	0.00	0.00	0.00	0.00	28.71	16.57	47.86
Apr. 2009	0.05	0.02	0.00	0.00	0.02	0.02	27.21	15.68	49.32
Mean ± SE	0.20± 0.01	0.085± 0.02	0.13± 0.02	0.081± 0.04	0.16± 0.02	0.13± 0.01	24.90	15.41	54.09
(min-max)	(0.00-0.80)	(0.00-0.33)	(0.00-0.67)	(0.00-0.33)	(0.00-0.80)	(0.00-0.60)			

Predaceous mites on six pepper cultivars were generally few during October and December, 2008 (0.02-0.15 predators/leaf), markedly increased during January, February and first half of March, 2009 (0.25-0.6 predators/leaf) and rarely observed during the second half of March and April, 2009. Collection dates of January, 2009 recorded the highest mean numbers of predatory mites per leaf being 0.8 in Godyon and Mandy, 0.33 in Khyrate and Impala, 0.67 in Qaha and 0.60 in Hora cultivars (Table 5). In descending order, the overall density of predaceous mites was 0.20, 0.16, 0.13, 0.13, 0.085 and 0.081 in Godyon, Mandy, Hora, Qaha, Khyrate and Impala, respectively (Table 5).

3.6. Interaction between weather factors and seasonal fluctuation of predatory mites:

A significantly negative relation between maximum temperature and seasonal fluctuation of *P. latus* predatory mites was observed in all pepper cultivars except Hora which showed insignificantly negative relation (Table 6). The highest (-0.686) and lowest (-0.390) r-values as well as the highest (47.01%) and lowest (15.17%) E.V. % were observed in Godyon and Hora cultivars, respectively (Table 6). In case of minimum temperature, the seasonal fluctuation of predatory mites showed significantly negative relation in Godyon, Impala and Mandy cultivars and insignificantly negative relation in Khyrate, Qaha and Hora cultivars (Table 6). The highest (-0.705) and lowest (-0.289) r-values were observed in Godyon and Khyrate cultivars, respectively. The latter cultivars revealed E.V. % of 49.64% and 8.35%, respectively (Table 6).

The relationship between seasonal fluctuation of predatory mites and relative humidity was insignificantly negative in all tested pepper cultivars except Qaha and Hora cultivars which showed significantly negative relation (Table 6). The E.V. % ranged between 2.86% in Godyon and 27.2% in Hora cultivars (Table 6).

Table 6: Interaction between weather factors and population fluctuation of predator mites associated with *Polyphagotarsonemus latus* infesting six pepper cultivars.

Pepper Cultivars	Maximum Temperature			Minimum Temperature			Relative Humidity		
	(r)	(p)	E.V.%	(r)	(p)	E.V.%	(r)	(p)	E.V.%
Godyon	-0.686	0.000	47.010	-0.705	0.000	49.640	-0.169	0.419	2.860
Khyrate	-0.406	0.044	16.510	-0.289	0.161	8.350	-0.387	0.056	15.010
Qaha	-0.499	0.011	24.880	-0.385	0.057	14.840	-0.486	0.014	23.670
Impala	-0.604	0.001	36.510	-0.638	0.001	40.750	-0.283	0.170	8.010
Mandy	-0.491	0.013	24.090	-0.570	0.003	32.460	-0.209	0.315	4.390
Hora	-0.390	0.054	15.170	-0.302	0.142	9.150	-0.522	0.008	27.200

(r) = Correlation coefficient, (p) = Probability, E.V. % = Explained variance.

4. DISCUSSION

The population density of *P. latus* stages was higher during the first three months (September, October and November) than other months during 2008-2009 season. The second occurrence was recorded in mid-March, 2009. The obtained data are almost similar to those mentioned in pepper (Mote, 1976; Lingeri *et al.,* 1998; Srinivasulu *et al*., 2002; Rabindra *et al.*, 2006), potato (Dhooria and Bindra, 1977; Namvar and Arbabi, 2007), okra (Jyotika and Bhullar, 2003), sesame (Dhooria, 2005) and the fence plant *Jatropha curcas* (Kavitha *et al*., 2007). Yadav *et al.* (2008), (2009) reported that the highest abundance of *P. latus* infesting jute in the 3rd week of August, i.e. closely nearer to September month in the present study. Accordingly, we may conclude that *P. latus* favors warm and humid conditions of

autumn or late summer rather than low temperature and heavy rains of winter months. During summer months, higher incidence of mite population infesting lime (Pena, 1989), potato (Fernandez and Ramos, 1995) and jute (Zaman and Karimullah, 1987; Sarma and Borah, 2009) was also observed.

Screening of mite density per leaves may be helpful to obtain good yield and reflect the degree of susceptibility in each of the six pepper cultivars in the present study. The overall mean of *P. latus* population (adults and immatures collectively) in descending order were 11.36, 10.91, 10.85, 10.73, 10.46 and 8.21 mites/leaf in Khyrate, Hora, Mandy, Qaha, Godyon and Impala, respectively. This indicates that Khyrate and other cultivars are more susceptible to *P. latus* than the hot pepper Impala cultivar. This may be due to the phytochemical components or anatomical characters of different pepper cultivars. Among pepper cultivars in India, Khalid *et al*. (2001) detected that *P. latus* population varied from 1.81-12.03 mites/leaf during 1990-1991 and 1.78-12.93 mites/leaf during 1991-1992.

Statistical analysis of the obtained results showed positive and significant relationship between population density of *P. latus* and each of maximum and minimum temperature. In case of relative humidity, the same relation was detected for all tested cultivars except the hot pepper Impala cultivar which showed insignificant relation. In case of immature stages, there was positive and insignificant relation between maximum temperature and their population fluctuation on Khyrate, Qaha and Hora cultivars and positive and significant relation on Godyon, Impala and Mandy cultivars. Minimum temperature showed positive and significant relation with population fluctuation of *P. latus* immatures on all tested pepper cultivars. Relative humidity showed positive and significant relation in all tested pepper cultivars except the hot pepper Impala cultivar which showed insignificant relation. The overall E.V. % for the three tested factors in tested cultivars of pepper collectively was 42.16 in case of adults and 34.18 in case of immatures. Li and Li (1986) mentioned that the increase of population density was influenced by temperature, rainfall, initial population and the growth condition of food plants. Results of the present study are almost similar to those obtained in potato (Sontakke *et al*., 1989), aubergines (Misra *et al*., 1990) and jute (Somchoudhury *et al*., 2008). However, the present results are not in the same direction to those obtained by Ahuja (2000), who found that maximum temperature showed negative and significant correlation and minimum temperature showed negative and none significant correlation with mite population infesting sesame and Leite *et al*. (2008) who found higher population density of mites on *Pfaffia glomerata* plants in the period of low relative humidity. This may be due to different leaf morphological features between these plants and pepper plant.

Accordingly, we may conclude that the temperature-humidity combination is an important regulatory factor affecting arthropod development and that the warm and humid conditions prevailing during spring and autumn months is more suitable for the increase of population densities of *P. latus*. The progressive increase in mite population in the latter months suggests the need for initiating control of *P. latus* in the nursery in July or August before the permanent planting and the peak of *P. latus* population period.

The present study revealed two species of predaceous mites namely *Amblyseius* sp. and *Typhlodromus* sp. collected together with *P. latus* during the studied period from September 7, 2008 to April 25, 2009. These results are almost similar to those obtained by Zaman and Karimullah (1987) and Misra *et al*. (1990) who observed the predatory phytoseiid mites *Amblyseius delhiensis* on jute and *Amblyseius multidentatus* on brinjal (aubergines), respectively in association with *P. latus*. Also, Pena and Osborne (1996) recorded that the two phytoseiid predator mites *Neoseiulus californicus* and *N. bakeri* (*Amblyseius bakeri*) were effective in

reducing the population density of *P. latus* on bean and lime plants in green houses and field. Nicotina and Cioffi (2000) used the predatory mite *Amblyseius stipulates* in controlling *P. latus*. Furthermore, Jyotika and Bhullar (2003) mentioned the predator mites *Amblyseius finlandius* and *A. alstoniae* in association with *P. latus* infesting okra plant. Smitha and Giraddi (2006) observed *Amblyseius ovalis* and *A. lougispinosus* associated with *P. latus* in chilli under field condition.

Predaceous mites on six pepper cultivars were generally few during the period between October and December, 2008 (0.02-0.15 predators/leaf), markedly increased during January, February and first half of March, 2009 (0.25-0.6 predators/leaf) and rarely observed during the second half of March and April, 2009. The present findings are more or less similar to those obtained by Srinivasulu *et al*. (2002), who found that the predatory mite population on *C. annuum* plant appeared from the third week of October, reached a low peak during the third week of November and a negligible level in December, started again in the first week of January and progressively increased to the highest peak in the third week of February. Studies of Srinivasulu *et al*. (2002) and the present study revealed that the peaks of predaceous mites follow that of *P. latus* by ≈1 month. Furthermore, Roy *et al*. (2005) noticed that the predator coleopteran *Stethorus punctillum* was absent in pesticide-free fields of raspberry and its arrival was delayed by a similar period of the presence of its prey mite *Tetranychus mcdanieli*. However, Jyotika and Bhullar (2003) showed that July was a peak month for the predatory mites (the Bdellidae family) of *P. latus*. Jyotika and Bhullar (2003) and Umeh *et al*. (2007) noticed that the highest density of the predatory mites was observed during both the lowest and highest density of their prey *P. latus* on okra and sweet orange cultivars, respectively.

The relationship between seasonal fluctuation of predaceous mites and associated *P. latus* population in the present study showed negative correlation in all tested pepper cultivars, i.e. increase of predaceous mite density accompanied with decrease in *P. latus* infestation rate. Similarly, Patil and Nandihalli (2009) found negative correlation between the predator mite *Amblyseius* sp. and *P. latus* population infesting chilli. However, Umeh *et al*. (2007) found positive correlation between the predator mites (the Bdellidae family) and *P. latus* on sweet orange cultivars.

Weintraub *et al.* (2003) controlled the broad mite *P. latus* on organic green house sweet pepper by the predatory mite *Neoseiulus cucumeris*. Jovicich *et al.* (2008) conducted that early broad mite infestations in pepper crops grown in greenhouses might be effectively controlled with *N. californicus* released at early seedling developmental stages in the nursery and at transplanting in the fruit production greenhouse. VanMaanen *et al.* (2010) found that population-dynamical experiments with *Amblyseius swirskii* on sweet pepper plant in greenhouses showed successful control of broad mites. Accordingly, the present study suggests that the broad mites' infestation of pepper crops could be effectively controlled with the release of predatory mites *Amblyseius sp*. and *Typhlodromus sp*. at early seedling development. The importance of the use of predatory mites in pest management lies in the fact that it is a tool for growers who intend to produce pesticide-free crops, with a minimum use of pesticides, or follow organic production standards.

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