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Population Dynamics of Alfalfa Aphids and Their Natural Enemies, Isfahan, Iran

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ABSTRACT

Population dynamics of three main alfalfa aphids, namely: pea aphid, *Acyrthosiphon pisum* (Harris), spotted alfalfa aphid, *Therioaphis trifolii* forma *maculata* (Buckton), black alfalfa aphid, *Aphis craccivora* Koch, and their most abundant predators and parasitoids in three sites and in two subsequent years in Isfahan, Iran, were investigated. The results revealed that frequency and temporal occurrence of alfalfa aphids and their natural enemies in different regions were varied, but aphid natural enemy populations were more or less coincident with aphid populations. Populations of aphids were mainly affected by alfalfa harvesting, ambient temperature, and coccinellid predators. Hemipterous predators in contrast with coccinellids, had little effect on aphid populations. Parasitoids seem to be effective on low populations of alfalfa aphids. Air humidity and rainfall had no effect on populations of alfalfa aphids.

Keywords: *Acyrthosiphon pisum*, Alfalfa aphids, *Aphis craccivora*, Natural enemies, Population dynamics, *Therioaphis trifolii*.

INTRODUCTION

Alfalfa, *Medicago sativa* L. is the most widely used forage plant (Walton, 1983). It is sometimes referred to as the "Queen of Forages". It has the highest feeding value among all commonly grown hay crops producing more protein per hectare than any other crop for livestock. Alfalfa is well adapted to a wide range of climatic and soil conditions and thus it is distributed worldwide (Hanson and Barnes, 1988). More than half a million hectares of alfalfa are grown in Iran from which 26 thousand hectares belong to Isfahan Province (Anon., 2006).

In some cases, aphids are reported to be the major pests of alfalfa (Summers, 1976; Grigorov, 1982; Rasoulian, 1985). Pea aphid, *Acyrthosiphon pisum* (Harris); Blue alfalfa aphid, *Acyrthosiphon kondoi* Shinji; Spotted alfalfa aphid, *Therioaphis trifolii* forma *maculata* (Buckton) as well as black alfalfa aphid, *Aphis craccivora* Koch are reported as major aphids invading alfalfa fields in different parts of the world (Grimm, 1972; Summers, 1976; Grigorov, 1982; Holtkamp, and Bishop, 1983; Nakashima and Akashi, 2005). These aphid species are also reported from different regions in Iran (Monajemi and Esmaili, 1981; Rasoulian, 1985; Rakhshani *et al*., 2006) as major pests of alfalfa. Alfalfa aphids are associated with a large assemblage of insect predators such as coccinellids, syrphids, chrysopids, and hemipterous predators as well as hymenopterous parasitoids.

Population structure and dynamics of insects has been the subject of much ecological research. This is the level of

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ecological organization that is the focus of evolutionary ecology, ecological genetics, biogeography, development of sampling methods, pest management, as well as the recovery of endangered species. These disciplines all have contributed enormously to our understanding of population level phenomena (Schowalter, 2000). The degrees of temporal and spatial associations between the target pest and each natural enemy species are likely to influence the ability of a natural enemy to suppress the pest population (Nakashima and Akashi, 2005). Therefore study on population dynamics of alfalfa aphids and their natural enemies can lead to a better understanding of their interrelationships and also to a better control of the pest through biological agents.

Population dynamics of alfalfa aphids and their natural enemies have been surveyed by some researchers in different regions of Iran as well as in other countries (Abdulmadzhid, 1973; Aeschlimann, 1981; Gonzalez *et al*., 1979; Grigorov, 1982; Grimm, 1972; Harper, 1978; Monajemi and Esmaili, 1981; Nakashima and Akashi, 2005; Neuenschwander *et al*., 1975; Rakhshani *et al*., 2006; Rasoulian, 1985; Summers, 1976, Takahashi and Naito, 1984; Wheeler, 1974; 1977). However, population fluctuations of whole alfalfa aphids and their natural enemies, especially in Isfahan province of Iran, are not clearly understood as yet. In this study, population dynamics of three main alfalfa aphids and their main natural enemies, including coccinellid predators, hemipterous predators and aphid parasitoids are investigated.

MATERIALS AND METHODS

Alfalfa fields in three climatically different regions of Isfahan, Iran were sampled for assessing population dynamics of aphids (*A. pisum*, *T. trifolii* and *A. craccivora*) and their natural enemies during 2004-2005. The area of each sampled alfalfa field was at least three hectares. The study sites were: 1) Isfahan University of Technology Experiment Station (Lavark region), 40 km west of Isfahan, in which samples were taken weekly, 2) Borkhar region, 30 km north of Isfahan, and 3) Ziar region, 50 km south-east of Isfahan, in which samples were taken every 2 weeks. On each sampling date, 20 sweeps were randomly taken using a 38 cm-diameter sweep-net at six random locations within the alfalfa field to assess aphid natural enemies. Also 20 alfalfa stems were sampled at six random locations within each alfalfa field to assess the aphid populations. Samples were placed in plastic bags, labeled and transferred to the laboratory for a separation and counting of aphids and their natural enemies. During the aphids' separation and counting the mummified aphids and predatory larvae were collected and reared in the laboratory until their adult insects emerged. Following counting, samples were sent to specialists for identification. According to Chen and Hopper (1997), parasitism was assayed as number of mummified aphids per total number of aphids at the time of collection.

The effect of sample date on aphid and their natural enemy species abundance in each site and in each of the two experimental years were tested using analysis of variance (ANOVA). Two series of linear regressions of the abundance of aphid natural enemy species as well as weather data (average temperature, humidity and total rainfall) versus abundance of aphids in each site and year were conducted to evaluate the parameters of the relationships among them (SAS Institute, 1998). One of the two mentioned linear regressions was conducted for the data among different cuts (mean of each cut) of alfalfa in each year for each region and another linear regression conducted for the data within each alfalfa cut (*i.e.* Seedling to blooming) for Lavark region in which the sampling procedure was weekly. Data for the linear regression were natural log transformed.

RESULTS

In all the three main study sites, the major aphid species was *T. trifolii* followed by *A. pisum* on the basis of population densities. *Aphis craccivora* was found in lower densities (Table 1). Sampling date had a significant effect on aphids and their natural enemies' abundance in each of the three regions in both experimental years (Table 2). Population fluctuations of more abundant aphid natural enemies including adult coccinellids (*Hippodamia variegata*, *Coccinella septempunctata*, *C. undecimpunctata* and assemblage of other coccinellids including *Adalia bipunctata* L., *Exochomus nigromaculatus* Goez, *Hippodamia tredecimpunctata* L., *Oenopia conglobata* L., *Propylea quatourdecimpunctata* L., and *Scymnus* spp.) and also their larvae, hemipterous adults and nymphs (*Nabis* spp., *Deraeocoris* spp., *Orius* spp. and *Geocoris* spp.) and aphid parasitoids (*Aphidius ervi* Haliday, *Praon exsoletum* (Nees), *Trioxys complanatus* Quilis) and assemblage of other aphid parasitoids including *Aphidius colemani* Viereck, *A. eadyi* Stary, *A. matricariae* Haliday, *A. smithi* Sharma and Subba Rao, *Diaeretiella rapae* (McIntosh), *Lysiphlebus fabarum* (Marshall) and *Praon volucre* (Haliday)) are given. Larvae of syrphids and chrysopids were scarce in all the regions during this survey. The results of population fluctuations of alfalfa aphids and their selected predators and parasitoids in the three sites of study are as follows:

T. trifolii

This species was the most abundant alfalfa aphid in all of our three study sites (Table 1). Its population somewhat increased in June but peaks mainly occurred in August and September (Figure 1B).

A. pisum

For this species it was observed that population mainly increased in late April and May as well as in September-October but an occurrence of their maximum number varied in the three study sites. In Borkhar and Ziar regions a maximum number of the aphid was observed in late April and May but in Lavark region the maximum number occurred in October and November (Figure 1B).

A. craccivora

Population of this aphid was much lower than those of the other two species in all the three regions for the two subsequent years (Table 1) with its densities never exceeding 12 aphids per 20 plant stems. Maximum number of this aphid was mainly observed in October and November (Figure 1B).

H. variegata

This predator was the most abundant coccinellid predator in all three study sites (Table 1) and was mainly observed in high populations in May-July as well as in September-November. Occurrences of population peaks were different in the three study sites for the two subsequent years (Figure 1C).

C. septempunctata

This species was observed in a much lower population density than *H. variegata* (Table 1). Its population mainly reached its peak in autumn (Figure 1C) and was coincident with aphid populations.

C. undecimpunctata

Population fluctuations in this aphid predator were similar to *those for C. septempunctata* (Figure 1C).

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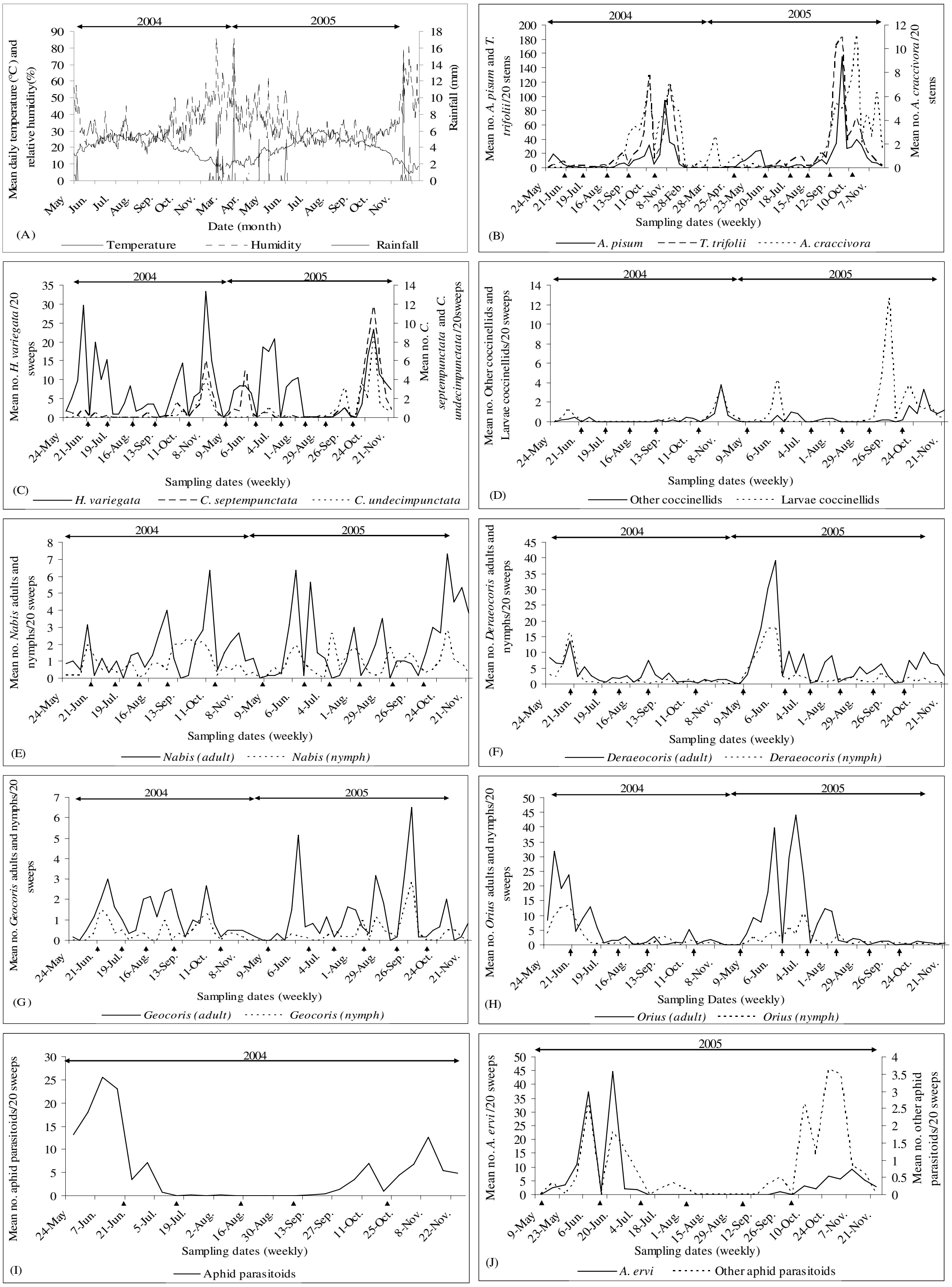

Figure 1. Weather data (A) and population fluctuations of alfalfa aphids (B) and their natural enemies (C-J) in two subsequent years in Lavark region in Isfahan, Iran. Symbol ▲ shows harvesting date of alfalfa.

Table 1. Mean number of alfalfa aphids and mummified aphids (per 20 stems) and aphid natural enemies (per 20 sweeps) in three regions and two years in Isfahan (Iran).

		Lavark region				Borkhar region				Ziar region			
	Taxa	2004	(%)	2005	(%)	2004	(%)	2005	(%)	2004	(%)	2005	(%)
APHIDS	*T. trifolii*	21.96a*	61%	28.33a	60.3%	26.33a	65.2%	48.38a	80%	39.21a	73%	74.77a	97.9%
	A. pisum	12.20b	33.9%	17.49b	37.2%	13.78b	34.1%	11.83b	19.6%	13.83b	25.7%	0.76b	1.6%
	A. craccivora	1.83c	5.1%	2.15c	2.4%	0.29c	0.7%	0.29c	0.5%	0.69c	1.3%	0.24b	0.5%
	LSD:	1.38	-	1.35	-	1.82	-	2.24	-	2.06	-	1.95	-
COCCINELLIDS	*H. variegata*	8.01a	85.8%	6.87a	71.7%	13.03a	88.1%	24.08a	85.5%	12.56a	87.2%	15.21a	68.4%
	C. septempunctata	0.64b	6.9%	1.33b	13.9%	0.44b	3%	1.51b,c	5.4%	0.47b	3.3%	0.43c	1.9%
	C. undecimpunctata	0.36b	3.9%	0.92c	9.6%	0.93b	6.3%	2.24b	7.9%	0.72b	5%	5.79b	26%
	Other Coccinellids	0.33b	3.5%	0.46d	4.8%	0.39b	2.6%	0.35c	1.2%	0.65b	4.5%	0.81c	3.6%
	LSD:	0.36	-	0.40	-	0.71	-	1.18	-	0.63	-	0.98	-
HEMIPTERA	*Orius* spp.	7.48a	47.3%	9.40b	38.5%	4.03b	30.5%	9.78b	29.5%	7.75a	53.8%	19.36a	54.3%
	Deraeocoris spp.	4.53b	28.6%	10.14a	41.6%	6.25a	47.2%	19.82a	59.8%	3.18b	22.1%	13.54b	38%
	Nabis spp.	2.37c	15%	3.19c	13.1%	2.44c	18.4%	2.75c	8.3%	2.76b	19.2%	2.51c	7%
	Geocoris spp.	1.45d	9.2%	1.67d	6.8%	0.51d	3.9%	0.79d	2.4%	0.72c	5%	0.24d	0.7%
	LSD:	0.59	-	0.64	-	0.58	-	1.28	-	0.69	-	1.37	-
PARASITOIDS	*Aphidius ervi*	-	-	5.11a	86.6%	-	-	0.26c	13.1%	-	-	1.14c	10.7%
	Praon exsoletum	-	-	0.30b	5.15	-	-	0.54b	27.3%	-	-	2.68b	25.1%
	T. complanatus	-	-	0.12b	2%	-	-	0.90a	45.5%	-	-	6.45a	60.4%
	Other Aphidiinae	-	-	0.37b	6.3%	-	-	0.28c	14.1%	-	-	0.40c	3.7%
	LSD:	-	-	0.30	-	-	-	0.21	-	-	-	0.67	-
MUMMY	*T. trifolii* (mummified)	0.12b	32.4%	0.03b	13.6%	0.24a	50%	0.33a	80.5%	0.38a	67.9%	0.68a	90.7%
	A. pisum (mummified)	0.25a	67.6%	0.19a	86.4%	0.24a	50%	0.08b	19.5%	0.18b	32.1%	0.07b	9.3%
	LSD:	0.09	-	0.06	-	0.12	-	0.12	-	0.12	-	0.15	-

*Means with different letters (a, b, c, and d) in each column indicate significant difference ($P<0.05$) among insects in each group (e. g. APHIDS).
For Lavark region: N=162, For Borkhar and Ziar regions: N=72

Other Coccinellids

Other coccinellids were found in very low populations (Table 1) and were mainly observed in early and late periods of alfalfa growing season (Figure 1D).

Larvae of Coccinellids

Occurrence of coccinellid larvae were coincident with coccinellid adults and mainly observed in higher populations in autumn as compared with the early period of alfalfa growing season (Figure 1D).

Nabis spp.

Populations of *Nabis* spp. in Lavark region reached the peaks in October but in Borkhar and Ziar regions peaked in June (Figure 1E).

Deraeocoris spp.

Population densities of *Deraeocoris* spp. were different in the two experimental years and for the three study sites (Table 1). Their population peaks were similar to those in *Nabis* spp. and different in the three study sites (Figure 1F).

Geocoris spp.

Populations of *Geocoris* spp. were lower than those of the other hemipterous predators (Table 1) not exceeding seven adults/20 sweeps. Their population peak occurrences were different and mainly observed in June and September (Figure1G).

Orius spp.

High population densities of *Orius* spp. were varied and observed from May to late September depending on region and experimental year (Figure 1H).

Aphid Parasitoids

Aphid parasitoids were mainly observed in May-June and in September-October coincidence with occurrence of alfalfa aphids. Population density of these parasitoids was almost zero in July and August when air temperature increased and lowered aphid populations (Figures 1I, 1J). In Lavark region *A. ervi* was the most abundant aphid parasitoid but in Ziar region *T. complanatus* densities were more than those in other aphid parasitoids (Table 1). In all the three study sites, population peaks of *T. complanatus* and *P. exsoletum* (parasitoids of *T. trifolii*) were observed in late August and September (Figure 1J). In Borkhar and Ziar regions maximum number of *A. pisum* was observed in late April and May while in Lavark region it was observed in October and November. Peak population of its parasitoid (*A. ervi*) in all the regions occurred only in May and June (Figure1J). Populations of mummified aphids were low in all the regions and for both years (Table 1). Percent parasitism was low for all the three regions, not exceeding 16% (Figure 2).

Parameters of the linear regression of mean number of aphid natural enemy species as well as weather data versus mean number of aphids in each alfalfa cut during each experimental year in the three regions are given in Table 3. Few significant relationships were observed between abundance of aphid natural enemies and weather data versus aphid's abundance in Lavark and Ziar regions and none for Borkhar region (Table 3). The above mentioned parameters at each alfalfa harvesting stage (period between two harvestings) for Lavark region are separately given in Table 4. Linear regressions revealed that coccinellid populations were in high correlations with aphid populations in five out of six alfalfa cuts during 2004 and in 6th alfalfa cut during 2005 (Table 4). Also in the

Table 2. Parameters of the effects of sample date on alfalfa aphids and their natural enemies in 3 regions and 2 years in Isfahan, Iran.

	Lavark region					
	2004			2005		
Taxa	F	df	P	F	df	P
Aphids	126.8	26	<.0001	269.2	26	<.0001
Coccinellids	65.15	26	<.0001	52.57	26	<.0001
Hemiptera	57.96	26	<.0001	114.6	26	<.0001
Parasitoids	-	-	-	99.64	26	<.0001
Mummified aphids	5.61	26	<.0001	3.60	26	<.0001
	Borkhar region					
	2004			2005		
Taxa	F	df	P	F	df	P
Aphids	198.9	11	<.0001	243.9	11	<.0001
Coccinellids	140.2	11	<.0001	123.2	11	<.0001
Hemiptera	42.21	11	<.0001	99.4	11	<.0001
Parasitoids	-	-	-	21.75	11	<.0001
Mummified aphids	16.23	11	<.0001	7.22	11	<.0001
	Ziar region					
	2004			2005		
Taxa	F	df	P	F	df	P
Aphids	233.4	11	<.0001	669.9	11	<.0001
Coccinellids	229.1	11	<.0001	147.9	11	<.0001
Hemiptera	86.31	11	<.0001	139.9	11	<.0001
Parasitoids	-	-	-	92.49	11	<.0001
Mummified aphids	8.7	11	<.0001	7.21	11	<.0001

5th cut of alfalfa a high R-square (0.84) but P= 0.06 correlation was observed between aphids and coccinellids. A significant linear relationship was observed between aphids and coccinellids larvae in 6th cut of alfalfa in both years 2004 and 2005 (Table 4). A high correlation was also observed between aphids and *Nabis* spp. in the 5th cut of alfalfa in 2004 and in the 1st and 4th cuts in 2005 (Table 4). For *Deraeocoris* spp. and aphids we did not find any high correlation for year 2004 but the correlation was high in the 1st and 4th cuts of alfalfa (Table 4). For *Geocoris* spp. and aphids we observed only one significant correlation in the 3rd cuts of alfalfa in 2004 (Table 4). For *Orius* spp. this correlation was high in the first and 3rd cuts of alfalfa in 2005 (Table 4). Correlation between aphids and their parasitoids was high in the 5th and 6th cut of alfalfa in 2004 and also in the 1st and 6th cuts in 2005 (Table 4). Correlation between number of aphids and temperature was high and positive in the 3rd cut of alfalfa while negative in the 5th cut in 2004. This correlation was highly positive in the 1st cut of alfalfa in 2005 (Table 4).

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Table 3. Parameters of the linear regression of mean number of aphid natural enemy species and also weather data versus mean number of aphids in each cut of alfalfa during each year in 3 regions in Isfahan, Iran. (data were natural log transformed).

	Lavark region					
	2004			2005		
	y=a+bx	R-squar	P	y=a+bx	R-squar	P
Coccinellids	y= 1.714+0.153x	0.1103	0.5201	y= 2.275-0.100x	0.0127	0.8317
Coccinellids larvae	y= -0.219+0.151x	0.4283	0.1585	**y= -1.294+0.578x**	**0.8913**	**0.0046**
Nabis spp.	y= 0.672+0.171x	0.4423	0.1495	y= 1.314+0.013x	0.0032	0.9147
Deraeocoris spp.	y= 1.945-0.147x	0.0760	0.5970	y= 2.593-0.125x	0.0297	0.7439
Geocoris spp.	y= 1.264-0.140x	0.2333	0.3318	y= 0.372+0.186x	0.2890	0.2713
Orius spp.	y= 2.415-0.267x	0.1060	0.5289	y= 4.488-0.776x	0.5298	0.1010
Aphid parasitoids	y= 0.431+0.300x	0.1195	0.5021	y= 2.130-0.237x	0.0425	0.6952
Temperature	**y= 3.644-0.181x***	**0.7122**	**0.0346**	y= 3.570-0.135x	0.3114	0.2498
Humidity	**y= 3.047+0.145x**	**0.7062**	**0.0362**	y= 3.243+0.059x	0.1246	0.4925
Rainfall	y= 1.144+0.600x	0.4592	0.1391	y=- 0.238+0.355x	0.0795	0.5884
	Borkhar region					
	2004			2005		
	y=a+bx	R-squar	P	y=a+bx	R-squar	P
Coccinellids	y= 1.312+0.393x	0.2707	0.4797	y= 1.234+0.507x	0.7089	0.1580
Coccinellids larvae	y= 0.195+0.138x	0.0543	0.7670	y= -0.817+0.579x	0.8588	0.0733
Nabis spp.	y= 1.394-0.013x	0.0028	0.9469	y= 0.767+0.185x	0.7482	0.1350
Deraeocoris spp.	y= 2.968-0.326x	0.2921	0.4595	y= 0.285+0.667x	0.8289	0.0896
Geocoris spp.	y= 0.618-0.047x	0.0651	0.7449	y= 1.420-0.254x	0.8400	0.0835
Orius spp.	y= 1.676-0.0153x	0.0032	0.9438	y= 1.009+0.362x	0.4361	0.3396
Aphid parasitoids	y= -0.178+0.412x	0.2165	0.5347	y= -0.057+0.212x	0.3354	0.4209
Temperature	y= 3.340+0.011x	0.0141	0.8811	y= 3.426-0.034x	0.2327	0.5176
Humidity	y= 3.517-0.058x	0.4116	0.3584	y= 3.354+0.003x	0.0195	0.8602
Rainfall	y= 0.059+0.066x	0.0232	0.8477	y= -0.056+0.33x	0.3877	0.3773
	Ziar region					
	2004			2005		
	y=a+bx	R-squar	P	y=a+bx	R-squar	P
Coccinellids	y= 1.742+0.320x	0.2512	0.4988	y= 2.478+0.072x	0.0116	0.8389
Coccinellids larvae	**y= -1.930+0.881x**	**0.9874**	**0.0063**	y= -0.007+0.206x	0.2518	0.3105
Nabis spp.	y= 1.831-0.163x	0.0841	0.7100	y= 1.112-0.014x	0.0013	0.9469
Deraeocoris spp.	**y= -0.849+0.633x**	**0.9286**	**0.0363**	y= 2.194-0.119x	0.0207	0.7857
Geocoris spp.	y= 0.634-0.031x	0.0040	0.9364	y= 0.168+0.002x	0.0002	0.9779
Orius spp.	y= -0.207+0.675x	0.6957	0.1659	y= 3.211-0.175x	0.0584	0.6446
Aphid parasitoids	**y= -1.671+0.905x**	**0.9869**	**0.0066**	y= 0.705+0.330x	0.1426	0.4605
Temperature	y= 3.103+0.030x	0.0264	0.8376	y= 3.073+0.036x	0.0610	0.6371
Humidity	y= 3.488-0.015x	0.0442	0.7899	y= 3.597-0.011x	0.0060	0.8837
Rainfall	y= -0.008+0.016x	0.0400	0.7999	y= -0.232+0.153x	0.0888	0.5661

*Bolded data show high R-squar (>0.70) and $P<0.05$

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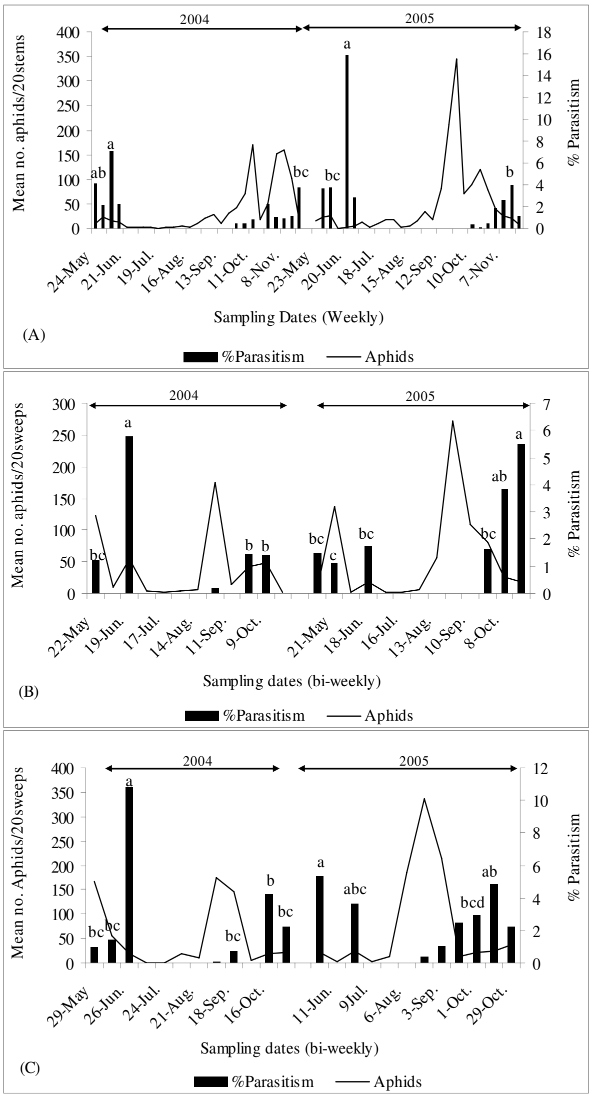

Figure 2. Mean number of total aphids and percent parasitism in Lavark (A), Borkhar (B) and Ziar (C) regions in two years. percent parasitism with no similar letters in each region and year show significant differentce (P<0.05) among them. LSD for Lavark 2004, 2005, Borkhar 2004, 2005 and Ziar 2004,2005 were 3.28, 3.81, 1.33, 2.62, 3.63 and 2.29 respectively.

Correlation between humidity and number of aphids was high only in the 4th cut of alfalfa in 2004 (Table 4). No high correlation was found between rainfall and aphid populations in either years 2004 and 2005 (Table 4). The results of a *t*-test comparison of mean number of insects before and after harvesting of the crop alfalfa, for Lavark region, are presented in Table 5. A significant difference was observed (P< 0.05) between the number of aphids, coccinellids and hemipterous predators before and after alfalfa harvests but it was not significant (P< 0.05) for coccinellids larvae and for parasitoids (Table 5).

DISCUSSION

In this study it was observed that frequency and temporal occurrence of alfalfa aphids and their natural enemies was varied in different regions for the two subsequent years. Similar to the present results, differences for population peaks of *A. pisum* have also been reported from other parts of Iran as well as from other countries. For example in Karaj, Iran, occurrence of maximum number of the aphid is reported in June (Monajemi and Esmaili, 1981; Rasoulian, 1985), and also in Hokkaido, Japan, it is reported in June (Nakashima and Akashi, 2005). This is while Takahashi and Naito (1984) reported populations of *A. pisum* in Tochigi, Japan peaked in June and July and again in November but Bueno *et al*. (1996) showed that population peak for *A. pisum* in Albany, California occurred in October. Comparable to our finings, population peak for *T. trifolii* in Karaj, Iran, is reported in August (Rasoulian, 1985) and in Sophia, Bulgaria, it is reported in late August and early September (Chan, 1982). Takalloozadeh (2003) observed maximum number of *A. craciivora* in Kerman, Iran, in February till mid-May.

There are reports concurrent with our findings concerning population fluctuations of coccinellids that prey on alfalfa aphids (Summers, 1976; Wheeler, 1977; Nakashima and Akashi, 2005). Summers (1976) observed that populations of coccinellids in an alfalfa field in Berkeley, California were high in May and September. Similar trends for coccinellid predators of alfalfa aphids were observed by Wheeler (1977) in Ithaca, New York.

In contrast to the coccinellid predators, population fluctuations of the hemipterous predators including *Nabis* spp., *Deraeocoris* spp., *Geocoris* spp., and *Orius* spp. differed more in our three study sites and for the two successive experimental years. Similar results are reported by other investigators (Rakickas and Watson, 1974; Neuenschwander *et al*., 1975; Summers, 1976; Monajemi and Esmaili, 1981; Nakashima and Akashi, 2005).

Main aphid parasitoids plus their frequency and temporal occurrence differed in our three study sites. Population fluctuations of alfalfa aphids and their associated parasitoids reported by Nakashima and Akashi (2005) in Japan, Summers (1976) in Berkeley, California, and Monajemi and Esmaili (1981) in Karaj, Iran, were similar to our findings for the species mentioned.

The results of linear regression for mean number of aphid natural enemies and weather data versus mean number of aphids in each alfalfa harvest during each year for the three regions showed little significant associations (Table 3). This is possibly due to harvesting effect which strongly influenced alfalfa aphids and their natural enemies' abundance (Figure 1, Table 5) and as a result did not allow a possible response to the natural environmental changes. Monajemi and Esmaili (1981) and Chan (1982) also emphasized the adverse effect of alfalfa harvest on populations of alfalfa aphids as well as on their natural enemies.

Linear regressions of the above mentioned data for each separate alfalfa cut (*i.e.* seedling to blooming) and for Lavark region revealed some correlations between them (Table 4). Some of the factors that may affect alfalfa aphids and their natural enemies' abundance are as follows:

Temperature

It seems that air temperature exerts a great influence on alfalfa aphids' density. Occurrence and population peaks for aphids were mainly observed in relatively cool days, but during warm days, from late June to early August, populations declined to near zero (Figure 1B). This is similar to the results obtained by some other investigators (Monajemi and Esmaili, 1981; Rasoulian, 1985; Chan, 1982; Takahashi and Naito, 1984; Nakashima and Akashi, 2005).

In Lavark region, alfalfa aphids were most frequent in the 5^{th} and 6^{th} harvests (Figure 1B). At the 5^{th} harvest of alfalfa in 2004 negative and significant correlations were observed between temperature and abundance of alfalfa aphids (Table 4). During this period a decrease of temperature from 27˚C to 18˚C resulted in an increase in number of aphids. At 6th harvest in 2004, we did not find any significant association between temperature and aphid population because this period was long and reduction in temperature drastic. In the first 3-weeks of this period aphid numbers increased but with further reduction in temperature the numbers drastically reduced during the next 2-weeks. At the first harvest of alfalfa in 2005, there were positive and significant relationships between aphids and temperature as temperature increased from 16 to 22˚C. At the 5th harvest in 2005, in contrast to increase in aphid numbers, a significant relationship between aphid number and temperature was not found because during this period fluctuations of temperature were low (21.2-23.6˚C) but suitable for aphids' increasing. In the first 3-weeks of the 6th cut of alfalfa in 2005, aphid numbers increased after which, with more reduction in temperature, aphid numbers were much reduced reaching about seven aphids/20stem on the 21st of November (Figure 1A). Generally it was observed that high temperatures (higher than 25˚C) and also low temperatures (lower than 12˚C) can cause drastic reduction in alfalfa aphid numbers. Dixon (1998) noted that in high temperatures, relative growth rate of aphids decreases and their mortality increases. Similar trends have been observed by Monajemi and Esmaili (1981) and Nakashima and Akashi (2005).

Similar to alfalfa aphids, their natural enemy densities were reduced during warm days in summer. It seems that reduction in aphid populations along with higher temperatures during this period had their negative effect on the densities of alfalfa aphid natural enemies (Monajemi and Esmaili, 1981; Nakashima and Akashi, 2005).

Humidity

Except for one case (4th cut of alfalfa, 2004) there was not any significant found relationship between humidity and aphid's abundance (Table 4).

Rainfall

No significant relationship was observed between alfalfa aphids and rainfall (Table 4). Esilva *et al*. (2007) observed that, in general, weather conditions had little effect on the variation of alfalfa aphid populations.

Alfalfa Harvesting

It was observed that after a harvesting of alfalfa crop population densities of aphids were drastically reduced (Figure1). Comparison of mean number of aphids before and after harvesting of the crop in Lavark region showed that number of aphids was significantly ($P< 0.05$) lower after harvesting than that before harvest (Table 5). According to Chan (1982) the periodic cutting of alfalfa results in a considerable change in the population dynamics of the aphids, probably due to the influence of unfavorable environmental conditions.

It was also observed that maximum numbers of aphid natural enemies mainly occurred before harvesting the crop, while after harvest the numbers drastically declined (Figure 1). A significant difference ($P< 0.05$) was also observed between the number of coccinellids, *Nabis* spp., *Deraeocoris* spp., *Geocoris* spp. and *Orius* spp. before and after harvest (Table 5). It seems that harvesting greatly influences migration or fatality of aphid natural enemies. Our findings in this respect were similar to thease obtained by Monajemi and Esmaili (1981), Chan (1982), and Rasoulian (1985). No significant difference was obtained between the number of coccinellids larvae and aphid parasitoids before and after harvesting of alfalfa. In the case of coccinellids larvae this might be due to their lack of flight ability that cause them to remain in the field even after harvest of the crop but as for aphid parasitoids it is likely

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Table 4. Parameters of the linear regression of abundance of aphid natural enemy species and also weather data versus abundance of aphids at each cut (period between two cuts of alfalfa) in Lavark region, Isfahan, Iran. (data were natural log transformed).

	2004					
	1st cut (24 May-14 June)	2nd cut (21 June-12 July)	3rd cut (19 July-9 Aug.)	4th cut (16 Aug.-6 Sep.)	5th cut (13 Sep.-11 Oct.)	6th cut (18 Oct.-22 Nov.)
Coccinellids	y= -0.211+0.891x R^2=0.10, P=0.68	**y= -4.489+4.897x* R^2=0.94, P=0.03**	**y= -469+1.402x R^2=0.93, P=0.04**	**y= 0.753+0.240x R^2=0.90, P=0.05**	**y= -2.784+1.149x R^2=0.87, P=0.02**	**y= -1.307+0.905x R^2=0.63, P=0.05**
Coccinellids larvae	y= -0.979+0.494x R^2=0.26, P=0.49	y= 0 R^2= -, P= -	y= 0 R^2= -, P= -	y= 0 R^2= -, P= -	y= 0.466-0.092x R^2=0.25, P=0.39	**y= -1.221+0.456x R^2=0.75, P=0.03**
Nabis spp.	y= 1.303-0.128x R^2=0.10, P=0.93	y= 0.837+0.002x R^2=0, P=0.99	y= 0.732+0.040x R^2=0.00, P=0.94	y= 1.050+0.160x R^2=0.65, P=0.20	**y= -0.063+0.433x R^2=0.94, P=0.006**	y= -0.100+0.274x R^2=0.53, P=0.10
Deraeocoris spp.	y= 3.611-0.322x R^2=0.05, P=0.78	y= 3.486-1.386x R^2=0.35, P=0.41	y= 0.406+0.538x R^2=0.68, P=0.18	y= 0.462+0.398x R^2=0.66, P=0.20	y= 1.137-0.019x R^2=0.00, P=0.95	y= -0.080+0.217x R^2=0.47, P=0.13
Geocoris spp.	y= 0.872-0.182x R^2=0.02, P=0.85	y= 2.243-0.696x R^2=0.21, P=0.54	**y= -0.287+0.855x R^2=0.93, P=0.04**	y= 0.809+0.119x R^2=0.18, P=0.58	y= -0.034+0.251x R^2=0.26, P=0.39	y= -0.285+0.163x R^2=0.54 P=0.10
Orius spp.	y= -0.530+1.403x R^2=0.81, P=0.10	y= 3.190-0.530x R^2=0.12, P=0.65	y= 0.584+0.395x R^2=0.83, P=0.09	y= 0.112+0.245x R^2=0.29, P=0.46	y= 0.547+0.171x R^2=0.08, P=0.64	y= -0.076+0.178x R^2=0.11, P=0.53
Aphid parasitoids	y= 1.775+0.446x R^2=0.29, P=0.46	y= 3.164-1.543x R^2=0.13, P=0.64	y= 0.143+0.054x R^2=0.10, P=0.68	y= 0 R^2= -, P= -	**y= -2.105+0.805x R^2=0.91, P=0.01**	**y= -328+0.514x R^2=0.63, P=0.05**
Temperature	y= 3.161+0.003x R^2=0.00, P=0.99	y= 3.199+0.089x R^2=0.82, P=0.10	**y= 3.212+0.048x R^2=0.90, P=0.05**	y= 3.412-0.035x R^2=0.41, P=0.46	**y= 3.653-0.155x R^2=0.84, P=0.03**	y= 2.868-0.048x R^2=0.05, P=0.69
Humidity	y= 2.858+0.181x R^2=0.26, P=0.49	y= 3.666-0.236x R^2=0.16, P=0.60	y= 3.543-0.164x R^2=0.75, P=0.14	**y= 2.963+0.119x R^2=0.95, P=0.03**	y= 3.328+0.050x R^2=0.16, P=0.51	y= 3.967+0.033x R^2=0.03, P=0.74
Rainfall	y= 0 R^2= -, P= -	y= 0 R^2= -, P= -	y= 0 R^2= -, P= -	y= 0 R^2= -, P= -	y= 0.114-0.008x R^2=0.00, P=0.94	y= 3.085-0.621x R^2= 0.28, P= 0.28

To be continued…

Table 4. Continued.

	2005					
	1st cut (9 May-6 June)	2nd cut (13 June-4 July)	3rd cut (11 July-1 Aug.)	4th cut (8 Aug.-29 Aug.)	5th cut (5 Sep.-26Sep.)	6th cut (3 Oct.-21 Nov.)
Coccinellids	y= -0.380+0.883x R^2=0.58, P=0.14	y= -0.280+1.515x R^2=0.67, P=0.18	**y= -975+1.209x R^2=0.95, P=0.03**	y= 0 R^2= -, P= -	y= -1.702+0.602x R^2=0.87, P=0.06	**y= -1.307+0.900x R^2=0.63, P=0.05**
Coccinellids larvae	y= -2.823+1.180x R^2=0.60, P=0.13	y= 0 R^2= -, P= -	y= 0 R^2= -, P= -	y= 0 R^2= -, P= -	y= -2.654+0.835x R^2=0.84, P=0.08	**y= -1.221+0.456x R^2=0.75, P=0.02**
Nabis spp.	**y= -3.496+1.610x R^2=0.75, P=0.0.5**	y= 1.172+-0.040x R^2=0.00, P=0.95	y= 1.007+0.081x R^2=0.02, P=0.84	**y= 0.340+0.326x R^2=0.91, P=0.04**	y= 0.817+0.059x R^2=0.55, P=0.25	y= -0.100+0.274x R^2=0.53, P=0.10
Deraeocoris spp.	**y= -1.296+1.630x R^2=0.95, P=0.005**	y= 1.595+0.355x R^2=0.48, P=0.31	y= 0.062+0.679x R^2=0.76, P=0.13	**y= 0.718+0.361x R^2=0.97, P=0.01**	y= 1.541+0.032x R^2=0.15, P=0.60	y= -0.079+0.216x R^2=0.47, P=0.13
Geocoris spp.	y= -3.250+1.378x R^2=0.65, P=0.09	y= 0.419+0.095x R^2=0.11, P=0.67	y= 0.234+0.239x R^2=0.75, P=0.13	y= 0.327+0.311x R^2=0.33, P=0.42	y= -2.235+0.734x R^2=0.78, P=0.11	y= -0.284+0.163x R^2=0.54, P=0.09
Orius spp.	**y= -1.586+1.510x R^2=0.75, P=0.05**	y= 0.975+1.215x R^2=0.61, P=0.21	**y= 1.248+0.441x R^2=0.98, P=0.01**	y= 1.605-121x R^2=0.13, P=0.64	y= 0.211+0.136x R^2=0.56, P=0.25	y= -0.075+0.178x R^2=0.10, P=0.52
Aphid parasitoids	**y= -5.981+2.768x R^2=0.87, P=0.02**	y= 1.784+0.022x R^2=0.00, P=0.98	y= -0.166+0.163x R^2=0.83, P=0.08	y= 0 R^2= -, P= -	y= -1.012+0.285x R^2=0.61, P=0.21	**y= -0.327+0.514x R^2=0.63, P=0.05**
Temperature	**y= 2.386+0.216x R^2=0.94, P=0.005**	y= 3.173+0.087x R^2=0.52, P=0.27	y= 3.347-0.029x R^2=0.19, P=0.55	y= 3.392-0.050x R^2=0.54, P=0.26	y= 3.252+0.020x R^2=0.37, P=0.38	y= 2.868-0.048x R^2=0.04, P=0.68
Humidity	y= 3.339+0.077x R^2=0.06, P=0.70	y= 3.411+0.065x R^2=0.42, P=0.34	y= 3.194+0.068x R^2=0.27, P=0.48	y= 3.421-0.029x R^2=0.08, P=0.71	y= 3.488-0.031x R^2=0.75, P=0.13	y= 3.967-0.033x R^2=0.03, P=0.73
Rainfall	y= -1.918+0.903x R^2=0.20, P=0.45	y= 0 R^2= -, P= -	y= 0 R^2= -, P= -	y= 0 R^2= -, P= -	y= 0 R^2= -, P= -	y= 3.084-0.620x R^2=0.27, P=0.28

*Bolded data show high R-squar (>0.60) and $P\leq 0.05$

Table 5. Comparison (t-test) between mean number of insects before and after harvesting alfalfa in Lavark region (data were natural log transformed).

	Befor cut ($\overline{X}$ ±SE)	After cut ($\overline{X}$ ±SE)	Difference ($\overline{X}$ ±SE)	t value	P
Aphids	3.29±0.42	1.82±0.40	-1.48±0.58	-2.54	0.02
Coccinellids	2.29±0.30	0.41±0.10	-1.88±0.31	-6.02	<.0001
Coccinellids larvae	0.72±0.34	0.30±0.24	-0.42±0.41	-1.01	0.32
Nabis spp.	1.41±0.17	0.84±0.9	-0.56±0.20	-2.84	0.01
Deraeocoris spp.	2.11±0.32	1.09±0.16	-1.01±0.36	-2.83	0.01
Geocoris spp.	1.19±0.16	0.57±0.13	-0.61±0.20	-2.95	0.008
Orius spp.	2.27±0.35	1.19±0.22	-1.08±0.42	-2.59	0.01
Aphid parasitoids	1.20±0.44	0.34±0.16	-0.85±0.47	-1.81	0.08

N=10

that an increase of odor emitted from alfalfa harvest causes their attraction to the alfalfa field. According to Hagvar and Hofsvang (1991) odors from the host food plants seem particularly important in habitat location for aphid parasitoids, attraction to volatile chemicals emitted from plants having been demonstrated in several parasitoid species.

Aphid Predators

Generally, coccinellid predators appeared to respond to aphid numbers and were more coincident with aphid populations than hemipterous predators. This could be due to more host specification of coccinellid predators than hemipterous predators on aphids. According to Nielson and Henderson (1959) and also Nakashima and Akashi (2005) *Nabis* and *Orius* predators were considered to be less affecting predators on the basis of their feeding tendencies for aphids. Hagen and van den Bosch (1968) suggested that Synchronization or coincidence with prey is one of the main factors to be taken into account in determining a predator's effectiveness.

Aphid Parasitoids

Correlation between aphids and their parasitoids were high in the 5th and 6th cuts of alfalfa in 2004 and also in the 1st and 6th cuts of alfalfa in 2005 (Table 4). Also, in this study, it was observed that *T. complanatus* and *P. exsoletum* were temporally more coincident with their host (*T. trifolii*) in contrast with *A. ervi* synchronization versus *A. pisum* (Figure 1J). One reason for this trend could be the fact that *T. complanatus* and *P. exsoletum* are specific parasitoids of *T. trifolii* (Stary, 1976; Kvallieratos *et al*., 2001; Rakhshani *et al*., 2006) but *A. ervi* is a nearly polyphagous species (Stary, 1976; Kvallieratos *et al*., 2001; Rakhshani *et al*., 2006).

Percent parasitism was low in all regions and mainly maximized in early and late growing season when aphid numbers were lower than 50/20 stems (Figure 2). Similar results were obtained by Nakashima and Akashi (2005). Despite biases in inferring to mortality from parasitism measured in this way, it appears that alfalfa aphids' mortality from parasitoids were low and it also seems that aphid parasitoids were more effective on low populations of aphids.

In addition to the factors discussed above that may affect populations of aphids and their natural enemies, there are probably other factors that may affect their populations. These factors including soil characteristics, alfalfa varieties, and microclimatic conditions in each field along with other unknown factors remain for further and more precise investigations.

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دینامیسم جمعیت شته‌های یونجه و دشمنان طبیعی آنها در اصفهان، ایران

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چکیده

در این تحقیق دینامیسم جمعیت سه گونه مهم شته‌های یونجه شامل شته سبز نخودفرنگی *Acyrthosiphon pisum* (Harris)، شته خال‌دار یونجه (Monell) *Therioaphis trifolii*، شته سیاه یونجه *Aphis craccivora* Koch و فراوانترین شکارگرها و پارازیتوئیدهای آنها در سه منطقه از اصفهان و در طی دو سال بررسی شد. نتایج نشان داد که فراوانی و زمان فعالیت شته‌ها و دشمنان طبیعی آنها در طول سال در مناطق مختلف با هم متفاوت بود ولی تغییرات جمعیت دشمنان طبیعی با جمعیت شته‌ها از نظر زمانی و فراوانی تقریباً هماهنگ بود. جمعیت شته‌ها عمدتاً تحت تأثیر برداشت یونجه، دمای محیط و کفشدوزکها قرار داشت. سنهای شکارگر تأثیر کمتری نسبت به کفشدوزکها روی جمعیت شته‌ها داشتند. زنبورهای پارازیتوئید در جمعیتهای کم شته‌ها مؤثر بودند. رطوبت محیط و بارندگی تأثیری روی جمعیت شته‌ها نداشتند.

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