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Influence of drought and temperature on population density of two species of spider mites and their predator, *Scolothrips longicornis* (Thysanoptera, Thripidae) in almond orchards

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Abstract. High temperatures and low-humidity are the favorable conditions for spider mites, *Tetranychus urticae* Koch and *Schizotetranychus smirnovi* Wainstein, to cause serious threat to quality and quantity of almond. This study was undertaken to understand population changes of the spider mites during the normal and dry years and to predict the possibility of the pest outbreak in order to develop a successful integrated management strategy. Population fluctuations of *S. smirnovi* and *T. urticae* were studied on almond (Mamaei variety), from April to October of 2007-2009, in Saman orchards, Chaharmahal and Bakhtiari province, Iran. Meteorological data of three nearest synoptic stations including Saman, Zaman khan and Shahre-kord were collected from the Chaharmahal and Bakhtiari meteorological organization. The Standardized Precipitation Index (SPI) was used to detect meteorological droughts based on the monthly rainfall input data of three synoptic stations. The results showed the year 2008 as an extremely dry year, while revealing 2007 and 2009 as normal years. Comparison of spider mite population density in this year (SPI < -2) with the normal years, 2007 (SPI = -0.53) and 2009 (SPI= 0.41), showed a significant increase in the population density of *S. smirnovi*, (14.65 and 2.95 times) and *T. urticae* (7.28 and 2.87 times) compared to 2007 and 2009, respectively. Spearman's correlation analysis showed significant negative correlation of mean precipitation with population density of, *S. smirnovi*, (r = -0.65, p=0.022), *T. urticae* (r = -0.73, p=0.0001), and the predatory thrips, *Scolothrips longicornis* Priesner, (r = -0.67, p=0.0001) during three studied years. In the drought year, the phytophagous mite's population increased in response to high temperatures and low humidity. In a such year, the almond trees can be more vulnerable to mite damages and control is necessary.

Keywords: Spider mite, Drought index, Climate condition, Almond, Population fluctuations

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Introduction

Insects and mites are poikilothermic organisms; the temperature of their body depends on the temperature of the environment (Kocmánková *et al.,* 2010). Thus, temperature is probably the most important environmental factor affecting their population dynamics (Kocmánková *et al.*, 2010). Spider mites are one of the most destructive pests of agricultural crops, which their population dynamic and damage are highly dependant on the climate condition. Temperature, precipitation, humidity and host plant are the most important factors that affect distribution and seasonal activity of the spider mites under field conditions (Ullah *et al.*, 2012; Bayu *et al.*, 2017; Islam *et al.,* 2017; Shimazaki *et al.,* 2019). Moreover, the population growth parameters of spider mites such as developmental rate, survival, reproduction, and longevity vary with the mentioned factors (Riahi *et al.* 2013, El-Halawany & Abdel-wahed, 2013). High temperatures and low humidity provide the suitable condition for spider mites development and outbreak in agro-ecosystems (Leite *et al.,* 2003). Almond is infested by different mites' pest species (Kamali *et al.,* 2016; Zalome *et al.*, 2019) and among them, *Tetranychus urticae* Koch and *Schizotetranychus smirnovi* Wainstein cause serious threat to the crop,

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particularly during the summer, and reduce the quality and quantity of the nuts (Saeidi, 2013; Saeidi & Nemati, 2020). During the favorable conditions, mite population rapidly increased, plant leaves were covered with webbing and the quantity and quality of the fruits were significantly reduced (Saeidi & Nemati, 2017). Investigation on the almond spider mite's natural enemies in southwest of Iran indicated *Scolothrips longicornis* Priesner as the most efficient natural enemy feeding on *T. urticae* and *S. smirnovi* (Heidarian *et al*., 2020; Saeidi & Nemati, 2020).

This study was undertaken to detect the influence of meteorological droughts and other climate parameters on the population dynamics and infestation of spider mites on almond trees. The information provided by this study will give insight to the understanding of the population changes of spider mites during normal and dry years, and is useful to predict the possibility of pest outbreak and develop a successful integrated management strategy.

Materials and methods

Location and environmental condition of the studied area

All experiments were conducted in the infested almond orchards of Saman, Chaharmahal and Bakhtiari province, Iran. The studied area is located in south-west of Iran in the central part of Zagros Mountains and is one of the famous almond plantation areas in Iran. According to the Köppen classification, the region has snow climate with dry and warm summer (Kottek *et al*., 2006). The weather is cold in winter, cool in spring and fall, and warm in summer. Rainfall season generally commences from the second decade of November and ends in the last decade of May with an annual average rainfall of 340 mm. January and February are the coldest, whereas June and July are the warmest months in this region.

Identification of mite species

For the identification of mite species, microscopic slides were mounted in Hoyer medium with different morphological types found in the samples and investigated under an optical microscope with phase contrast at Agricultural and Natural Resources Research and Education Center, Chaharmahal and Bakhtiari, Iran. To ensure the mite species, at each sampling date, 10 specimens (5 males and 5 females) from each replicate were mounted as permanent micro-slides and identified in the laboratory according to Wainstein (1958) and Meyer (1974).

Population sampling

Population fluctuations of *S. smirnovi* and *T. urticae* were studied on almond (Mamaei variety), from April to October during three successive years 2007-2009. Two commercial orchards of almond (Mamaei variety), with the distance of 10 km, were selected and no acaricides were sprayed in them during the study period. The orchards were almost uniform in term of almond variety, soil texture and nutrition management. Trees were approximately 15 years old, 4-5 m high, and planted at 4×5 m distances between and along the rows.

Assessments were made weekly from April to October of each year. For the first sampling, 20 trees in each orchard were randomly selected and 15 leaves were randomly taken from the middle portion (at different sides) of each tree. Then, the leaves were kept in polyethylene bags maintained in a cool box, and subjected to laboratory observation. All life stages (egg, nymph and adult) of spider mites were counted on the abaxial leaf surface of the almond under a stereomicroscope at 10X magnification. Also, the number of predatory thrips was recorded on both leaf surfaces. To calculate the sample sizes of the second unit (leaves) in subsequent sampling intervals, the random sampling method was used, considering 20 trees in each sampling (Krebs, 1989).

$$N = \left(\frac{Z\alpha/_2}{D}\right)^2 \left(\frac{\sigma^2}{\mu^2}\right)$$

Where, *N:* sample size, *D:* constant error (D=0.2), σ^2 and μ are, population variance and mean in the previous sampling, respectively.

Meteorology data

Meteorological data of the three synoptic stations nearest to the studied orchards including Saman, Zaman khan, and Shahre-kord were collected from the Chaharmahal and Bakhtiari meteorological office. The geographical location and climate condition of the studied synoptic station are given in Appendix 1. The Standardized Precipitation Index (SPI) was used to detect meteorological droughts based on the monthly rainfall input data of three synoptic stations. Among various indices that have been used for detecting and characterizing meteorological droughts, SPI is the most commonly used indicator worldwide (Parsons *et al*., 2019). The SPI indicator, was developed by McKee *et al.* (1993) and described in detail by Edwards and McKee (1997).

Statistical analysis

The data obtained from the seasonal activity of spider mites on almond was analyzed using the Statistical Package for Social Science (SPSS), version 22 for windows. As drought index, the standardized precipitation index (SPI) for a 12-months time scale was used. SPI is simply defined as the difference of precipitation from the mean from a specified time period divided by standard deviation where the mean and standard deviation are determined from past records (McKee *et al.*, 1993). Calculation of the SPI was carried out using the following equation.

$$SPI = x - \mu/\sigma$$

Where, x = Precipitation for the station, μ = Mean precipitation, and σ = Standard deviation. Positive SPI values indicate that the rainfall is greater than median rainfall and negative values indicate less than median rainfall. The Standardized Precipitation Index (SPI) values and drought categories are given in Table 1.

Results

Dry and wet years

Comparison of SPI (standard rainfall index) during the study period (2007 to 2009) showed different drought categories in the studied stations of Chaharmahal and Bakhtiari province. The most drought-affected year was 2008 (with SPI value of < -2), whereas precipitation was almost normal in 2007 and 2009 with SPI values of -0.53 and 0.41, respectively (Table 2).

Schizotetranychus smirnovi Wainstein

The mite overwintered as eggs around the buds of almond shoots. Observations showed that in 2008, overwintering eggs hatched in the fourth week of March, when the mean temperature increased to 15°C, and along with the increasing temperature, the mite population continuously increased and reached maximum density (82.70 mites/leaf) in 22nd of June. The second (99.5 mites/lea) and third (11.8 mites/leaf) peaks of the mite population were observed on July second and the last week of September, respectively (Fig. 2). In 2007 and 2009, overwintering eggs hatched in the third (mean temperature= 12.5°C) and fourth (mean temperature= 13.3°C) weeks of April but, because of the rainy days, they could not settle on the leaves untill June 6 and May 15, respectively. During 2009, three peaks (August 1st, September 1st and October 3rd weeks) were observed in the population of *S. smirnovi*, whereas in 2007, two peaks (July 3rd and September 2nd weeks) were observed (Figs 1 & 3). According to figures 1 to 3, as the temperature dropped to less than 15°C in October, mites' population growth declined, and females gradually moved to 2-3 year old shoots and laid overwintering eggs around the buds untill the end of October.

Tetranychus urticae Koch

The mite overwintered as mated females under the bark, in the soil, and in the plant debris. In the spring, when the temperature increased to 15°C, the mite started feeding and increasing its population on the weeds before attacking almond trees. The population of *T. urticae* appeared on almond foliage from the 2nd to the 3rd week of June in the studied years which was 30 to 45 days later compared to *S. smirnovi*. In 2008, the 1st peak of the two-spotted sider mite (TSSM) population was observed in the 1st week of July, whereas it was observed in the 3rd week of July and 1st week of August during 2007 and 2009, respectively. The population of TSSM peaked for the 2nd time in August 22, September 15 and September 8, in 2007, 2008 and 2009, respectively.

Table 1. The Standardized Precipitation Index (SPI) values and drought categories (Source: National Climatic Data Center, U.S. Department of Commerce, 2012).

	SPI values	Category
1	2.00 and above	Extremely wet
2	1.50 to 1.99	Very wet
3	1.00 to 1.49	Moderately wet
4	−0.99 to 0.99	Near Normal
5	−1.00 to −1.49	Moderately dry
6	−1.50 to −1.99	Severely dry
7	−2.00 and less	Extremely dry

Scolothrips longicornis Priesner

During the studied years, the population density of both phytophagous mites and predatory thrips fluctuated simultaneously. According to the results, the population density of predatory thrips, *S. longicornis*, peaked to maximum values, when population of *S. smirnovi* and *T. urticae* reached the highest level. Moreover,the population density of both mites rapidly declined to the lowest values with the increase of the predatory population (Figs 1-3). In all studied years, correlations of the population density of *S. smirnovi* (r= 0.75, p=0.002), and *T. urticae* (r = 0.71, p=0.001) with the predatory thrips, *S. longicornis* were significantly positive.

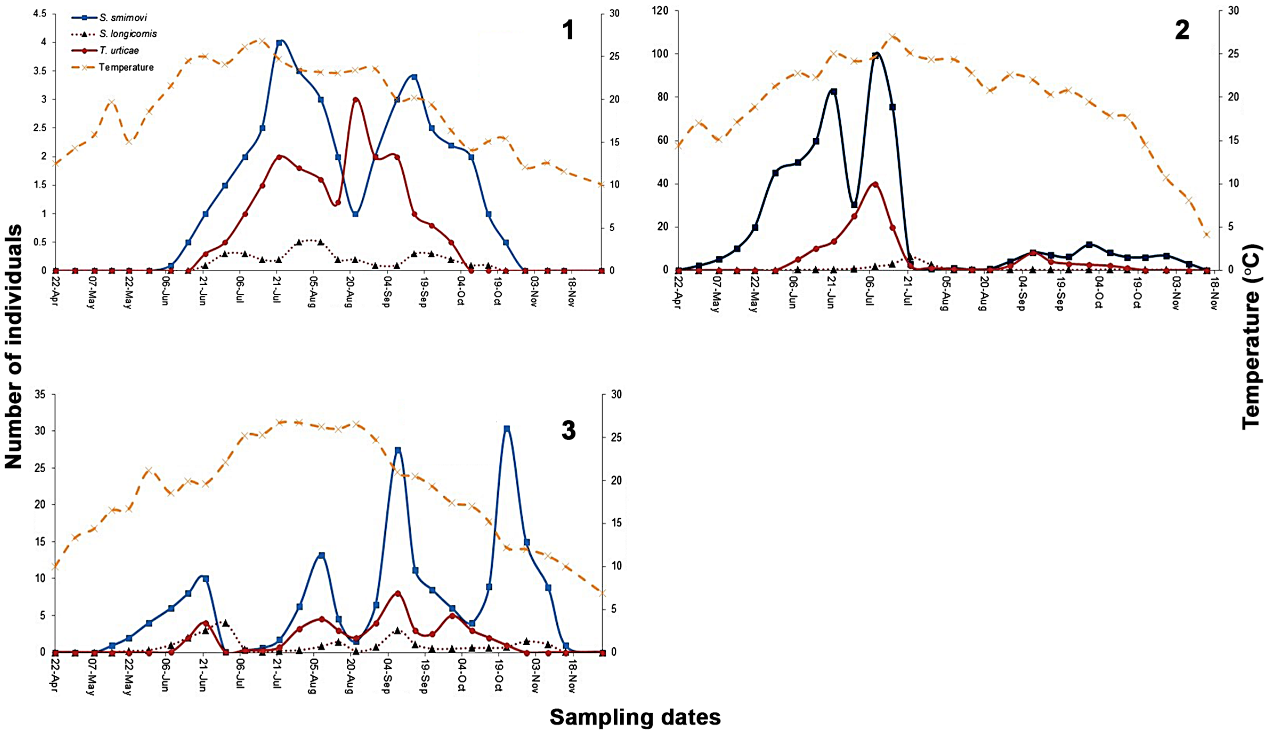
Impact of drought and temperature on the outbreak of spider mites on almond

Population fluctuations of the almond spider mite, *S. smirnovi*, and two-spotted spider mite, *T. urticae*, on almond trees were compared during 2007-2009 (Figs 4 & 5). According to the figures, the feeding and seasonal activity of both species started on almond 3-4 weeks earlier in 2008 (severely dry year) compared to normal years 2007 and 2009 (Figs 4 & 5). Moreover, the population density of the mites at different sampling times was higher in 2008 than other studied years. The mean numbers of *S. smirnovi* on each leaf were calculated as 37.7, 552.4 and 186.7 for 2007, 2008 and 2009, respectively. The same trend was observed for *T. urticae*, with the population density of 19.2, 139.9 and 48.7 mites/leaf in 2007, 2008 and 2009, respectively (Fig. 5).

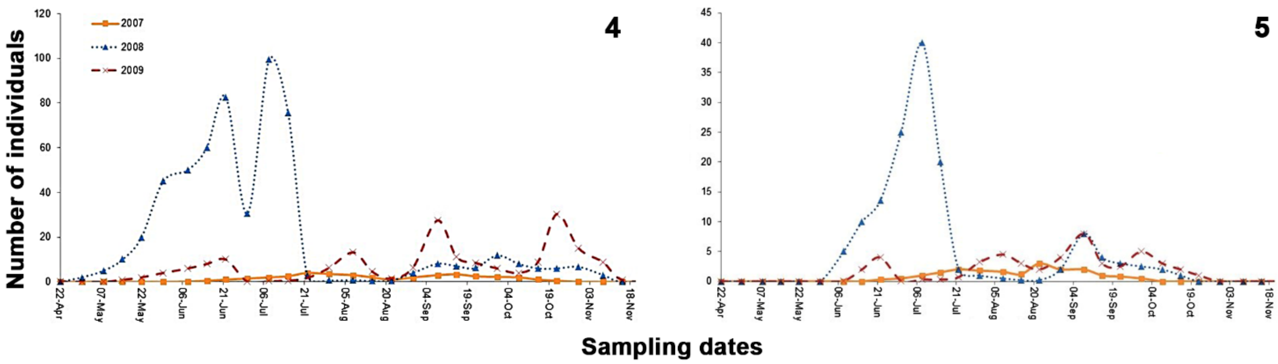
The results showed that spring and summer rains drastically reduced the spider mites' populations. Under the favorable conditions (temperature > 17°C and no rainy days) of May 2008 (Appendix 1), the newly hatched overwintering eggs of *S. smirnovi* were settled on the almond leaves and the mite population rapidly increased (Figs 2 & 4). However, the continuation of rainy days during May 2007 and 2009 (Appendix 1) did not allow the increase and settlement of the *S. smirnovi* population on the almond leaves (Figs 1, 3 & 4). Also, summer precipitation plays an important role on the population density of the studied species. For example, rainfall on June 19 to 23, 2009 (in total amount of 11.6 mm), and 8 to 10 September 2008 (8.3 mm) in Saman station caused a sharp decline in the population density of the spider mite species (Figs 2 to 5). Spearman's correlation analysis showed significant negative relation of mean precipitation with population density of the mite, *S. smirnovi*, (r = -0.65, p=0.022), *T. urticae* (r = -0.73, p=0.0001) and predatory thrips, *S. longicornis*, (r = -0.67, p=0.0001) during three studied years.

Table 2. Standard precipitation index and drought severity category of studied stations during 2007-2009.

	Saman			**Zaman khan**			**Shahre-kord**		
Year	Precipitation (mm)	SPI Index	Drought Severity	Precipitation (mm)	SPI Index	Drought Severity	Precipitation (mm)	SPI Index	Drought Severity
2007	312.4	-0.53	Near normal	287.5	-0.75	Near normal	303.9	-0.61	Near normal
2008	129.8	-2.43	Extremely dry	117.2	-2.83	Extremely dry	140.9	-2.62	Extremely dry
2009	443.4	0.41	Near normal	396.3	0.17	Near normal	439.8	0.56	Near normal



Figs 1–3. Population fluctuations of the almond spider mite, *Shizotetranychus smirnovi* Wainst. and *Tetranychus urticae* Koch, and their predator *Scolothrips longicornis* under field conditions in Saman region, Chaharmahal and Bakhtiari province, **1.** Year 2007. **2.** Year 2008, and **3.** Year 2009. (One-fourth of the mites population is shown in the figure).



Figs 4–5. Population fluctuations of the mites under field conditions in Saman region, Chaharmahal and Bakhtiari province during 2007-2009. **4.** Almond spider mite, *Shizotetranychus smirnovi* Wainstein, **5.** Two-spotted spider mite, *Tetranychus urticae* Koch.

Discussion

Climate change and extreme weather events have major impacts on agricultural crops and their relative pests. In this paper, the effects of rising temperature and severity of drought on the population fluctuation of two important spider mites of almond trees, *S. smirnovi* and *T. urticae*, in Chaharmahal and Bakhtiari province, Iran, was addressed. According to Saeidi (2013), these two mites cause serious threat to almond, particularly during the summer, and reduce the quality and quantity of the nuts. The results indicated the year 2008 as the most drought-affected year during the studied period with SPI values of < -2 at the studied stations. Comparison of the spider mite's population density in this year with the normal years 2007 (SPI = -0.53) and 2009 (SPI= 0.41) showed significant increase in the population density of *S. smirnovi* (14.65 and 2.95 times) and *T. urticae* (7.28 and 2.87 times) than their population in 2007 and 2009, respectively. According to Saeidi and Nemati (2017) increasing temperature and drought stress during the growing season and extensive use of pesticides against other important pests of almond have led to the outbreak of spider mites in almond orchards during the recent years. According to the results, drought has a positive impact on the outbreak of spider mites on almond. In other words, variations in the occurrence and population density of the spider mites were related to variations in SPI. Other researchers believe that temperature, precipitation, and humidity significantly affect the distribution and seasonal activity of the spider mites under field conditions (Ullah *et al.*, 2012; Bayu *et al.*, 2017; Islam *et al.*, 2017; Shimazaki *et al.*, 2019).

The current study indicated that the occurrence and seasonal activity of both spider mites and their natural enemies differed among the studied years. In 2008, the infestation of almond with spider mite, *S. smirnovi,* occurred one month earlier than in 2007 and 2009. Bentz *et al.* (2010) reported that drought stress influences growth, mating selection, and reproduction of insect and mite pests, which possibly affects the trends of pest population, migration and diffusion, habitat selection, and other ecological characteristics. The finding indicated that the lack of rainy days during May 2008 allowed *S. smirnovi* individuals to settle on the almond leaves and increase their population rapidly under favorable conditions (temperature > 17°C and precipitation= 0). High temperature and low-humidity were reported as suitable conditions for spider mites development and outbreak in agro-ecosystems (Leite *et al.,* 2003). The present study showed that increasing temperatures during the drought-affected year (2008) increased the population of spider mites, *S. smirnovi* and *T. urticae*, on almond trees. Moreover, in this year the population of the mites increased faster than the normal years 2007 and 2009. Lee *et al.* (2021) believe that an increase in temperature towards optima usually accelerates the immature developmental stages and increases the chances of insects survival. Different researchers reported a dome-shaped relation between temperature and spider mites performances, in which the population growth parameters of the spider mites such as developmental rate, survival, reproduction, and longevity increased by increasing the temperature up to optimum temperature (Riahi *et al.,* 2013 ; El-Halawany & Abdel-wahed, 2013; Saeidi & Nemati, 2017).

Based on the results, the spider mites population increased rapidly during the months of June and July. The relation between population density of *S. smirnovi* and *T. urticae*, and mean temperature were significantly positive. Kumral and Kovanci (2005) reported that *T. urticae* population was positively correlated with mean temperature, while negatively to mean humidity. Moreover, Singh and Singh (1993), Mandal *et al.* (2006) and Kumar *et al.* (2015) recorded the highest density of two-spotted spider mite, *T. urticae,* on okra plants during the summer season. Extreme climatic events such as those observed in 2008 (drought stress and high temperature) may have direct and indirect impacts on the outbreak of spider mites on almond trees. They directly influence the population growth parameters of the spider mites such as developmental rate, survival, reproduction, and longevity. They may also have indirect impacts on spider mite populations through plant-pest relationships and other trophic interactions. Severe water stress would decrease tree resistance to pest attacks (Herms & Mattson, 1992; Lieutier, 2004) and may affect the growth and population dynamics of natural enemies (Arango-Velez *et al*., 2014). Our findings provide practical information on the population fluctuations of spider mites (*S. smirnovi* and *T. urticae)* on almond trees under extreme climatic events, which may be useful to predict the possibility of pest outbreak and help farmers develop a successful integrated pest management (IPM) program.

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Appendix 1. The geographical location and climate condition of the studied synoptic stations, Chaharmahal va Baktiari, Iran, during 2007-2009.

Station	Geographical location	Parameter	year	January	February	March	April	May	Jun	July	August	September	October	November	December	Annual
Saman	32.44 N	Temperature	2007	-5.7	2.2	5.3	11	17.5	24.1	25.7	24.1	19.9	14.2	9.9	1.6	13.2
	50.87 E	Temperature	2008	-5.1	1.9	11.3	14.1	18.4	24	25.9	23.6	21.1	15.6	6.2	3	14.3
	2075 m	Temperature	2009	0.3	4.2	8.4	9.8	18	20.7	26.9	26.5	20	14.3	7.5	1.2	12.1
		Precipitation	2007	29.4	48.6	76.4	70.5	17.2	0.1	0.6	0	0	0.3	8.1	65.4	316.6
		Precipitation	2008	28.1	15	0	13.4	3.4	0	0.1	0	8.3	16.9	42	8.1	135.3
		Precipitation	2009	38.4	76.3	29.4	102.4	8.3	11.6	0	0	6.3	7	117.2	61.9	458.8
Shahrekord	32 17 N	Temperature	2007	-7.3	2.5	5.2	10.7	16.3	21.5	24.6	22.1	18.1	13.1	8.4	1.1	11.4
	50 51 E	Temperature	2008	-5.2	1.3	9.5	12.5	16.4	21.3	23.8	25.1	18.9	13.7	6.2	2.5	12.2
	2048 m	Temperature	2009	-0.1	3.8	7.3	9.2	16.0	19.0	24.1	23.4	17.8	12.9	7.5	-0.1	11.7
		Precipitation	2007	32.4	48.1	74.3	66.3	11.3	3.0	0.0	0.0	0.0	1.2	9.3	58.0	303.9
		Precipitation	2008	28.3	22.0	0.1	11.3	3.0	0.0	0.0	0.0	3.4	21.8	46.8	4.2	140.9
		Precipitation	2009	24.8	88.6	22.7	103.3	9.7	2.3	0.0	0.0	7.3	2.6	103.5	75.0	439.8
Zamankhan	32.50 N	Temperature	2007	-5.4	3.1	5.9	11.2	17.7	24.9	25.8	24.1	18.4	13.2	10.5	0.9	12.5
	50.90 E	Temperature	2008	-4.8	2.8	11.9	14.3	18.6	24.8	26.0	23.6	19.6	14.6	6.8	2.3	13.6
	1883 m	Temperature	2009	0.6	5.1	9	10	18.2	21.5	27.0	26.5	18.5	13.3	8.1	0.5	11.4
		Precipitation	2007	24.0	34.2	70.0	74.2	21.6	1.5	0.0	0.0	0.0	0.0	4.5	57.5	287.5
		Precipitation	2008	21.3	14.3	0.0	15.2	3.0	0.0	0.0	0.0	3.1	17.0	37.1	6.2	117.2
		Precipitation	2009	18.0	77.6	35.0	87.4	8.0	10.0	0.0	0.0	7.5	7.7	110.1	35.0	396.3

تأثیر خشکی و دما بر تراکم جمعیت دو گونه کنه تارتن و شکارگر آنها *Scolothrips longicornis* (Thysanoptera, Thripidae) در باغ‌های بادام

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تاریخچه مقاله

دریافت: ۱٤۰۱/۰۷/۰۹ | **پذیرش:** ۱٤۰۱/۰۹/۰۵ | **دبیر تخصصی:** علیرضا صبوری

چکیده

دمای بالا و رطوبت کم، شرایط مساعدی جهت حمله کنه‌های تارتن، *Tetranychus urticae* Koch و *Schizotetranychus smirnovi* Wainstein به درختان بادام و کاهش کیفیت و کمیت محصول ایجاد می‌کند. مطالعه حاضر با هدف بررسی تغییرات جمعیت کنه‌های تارتن در طول سال‌های عادی و خشک و پیش‌بینی احتمال شیوع آنها به منظور بکارگیری موفق برنامه‌های مدیریت تلفیقی، انجام شد. نوسانات جمعیت *S. smirnovi* و *T. urticae* روی درختان بادام (رقم مامایی) در باغ‌های سامان استان چهارمحال و بختیاری از فروردین تا مهرماه ۸۸–۱۳۸۶ مورد بررسی قرار گرفت. داده‌های هواشناسی سه ایستگاه سینوپتیک سامان، زمان خان و شهرکرد از اداره کل هواشناسی استان چهارمحال و بختیاری جمع‌آوری شد. شاخص بارش استاندارد شده (SPI) برای شناسایی خشکسالی های هواشناسی بر اساس داده های ورودی ماهانه بارندگی سه ایستگاه سینوپتیک استفاده شد. نتایج سال ۱۳۸۷ را سال بسیار خشک و سال های ۱۳۸۶ و ۱۳۸۸ را سال های عادی نشان داد. مقایسه تراکم جمعیت کنه‌های تارتن در سال خشک ۱۳۸۷ (SPI <-2)با سال های نرمال ۱۳۸۶ (SPI = -0.53) و ۱۳۸۸ (SPI=0.41) افزایش معنی داری در تراکم جمعیت *S. smirnovi* (۱۴/۶۵و ۲/۹۵ برابر) و *T. urticae* (۷/۲۸ و ۲/۸۷ برابر) را در مقایسه با سال‌های ۱۳۸۶ و ۱۳۸۸ نشان داد. تجزیه و تحلیل همبستگی اسپیرمن نشان داد که میانگین بارش با تراکم جمعیت *S. smirnovi* (r=-0.65, p=0.022) ، جمعیت *T. urticae* (r=-0.73, p=0.0001) و تریپس شکارگر، *Scolothrips longicornis* Priesner (r=-0.67, p=0.0001) همبستگی منفی معناداری دارد. در سال خشک، جمعیت کنه‌های گیاهخوار در واکنش به دماهای بالا و رطوبت کم افزایش یافت. در چنین سالی تولید بادام می تواند در برابر کنه آسیب پذیرتر باشد و کنترل آفت لازم است.

کلمات کلیدی: کنه تارتن، خشکسالی، شرایط اقلیمی، بادام، نوسان جمعیت

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