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Article

The effect of some abiotic factors on morphometrical parameters of the female stage of the *Rhizoglyphus robini* (Astigmata: Acaridae) in the saffron field

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ABSTRACT
Saffron (*Crocus sativus*: Iridaceae) is a fall-blooming perennial plant and its dried stigma is the priciest spice and a key non-oil export for Iran's economy. The bulb mite, *Rhizoglyphus robini*, is a polyandrous and multivoltine species and its damage to saffron corms directly and indirectly causes lower yields of saffron crops. Environmental conditions and abiotic factors, such as temperature, humidity, density, and diet affect the morphological traits of living organisms and subsequently affect biological abilities. In this study, changes in temperature, soil moisture, density (nymphs + adults), time, and corm weight on the morphological traits of the saffron bulb mite, including body length and width, and leg sizes of adult females were investigated in a saffron field in the Dargaz County of Iran during 2022. The results of variance analysis of the morphometrical parameters of the mite species, including body length, body width, and four pairs of legs in different months were significant. Based on simple and multiple linear regression models as well as non-linear regression, the effect of temperature and density (nymphs + adults) was reversed and the effect of soil moisture and corm weight was direct on morphometrical parameters of this species. Based on our results, soil moisture has a strong relation with female body size traits (body length, width, and leg lengths). This indicates that irrigation cycle management might be an important factor in bulb mite management in saffron agroecosystems.

KEYWORDS: Body size, bulb mites, morphological characteristics, multiple linear regression, northeast Iran.

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INTRODUCTION

Saffron (*Crocus sativus* L.), as an autumn flowering plant (foliage grows during autumn and winter) of the family Iridaceae, does not need much water to grow, and it can survive on the little rainfall that occurs in semiarid regions, and as the amount and timing of rainfall during the vegetative growth of the plant species, as well as the interactions between temperature and humidity, are crucial for its flowering success (Rashed-Mohassel 2020). It is a fall-blooming perennial plant whose dried stigma is the priciest spice and a key non-oil export for Iran's economy (Ghorbani 2007). All saffron-growing cities of Iran are infested with the bulb mite, *Rhizoglyphus robini* Claparède, 1868, but the

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contamination level varies based on the beginning of the cultivating period and control methods in different regions (Bazoobandi *et al.* 2020).

The bulb mites, *R. robini*, and *R. echinopus* (Fumouze & Robin, 1868) are two important cosmopolitan species. The first mentioned species was first reported from Saffron fields in Gonabad and Qaen City (South Khorasan Province, east of Iran) (Rahimi and Kamali 1993). These species damage a variety of crops, including *Allium*, *Lilium*, and *Hyacinthus* species, and many other vegetables, cereals, and ornamentals in storages, greenhouses, and fields (Diaz *et al.* 2000). *Rhizoglyphus robini* is a polyandrous (individual females mate with multiple males) and multivoltine species and its damage to saffron corms directly and indirectly causes lower yields of saffron crops in Iran (Smallegange *et al.* 2012; Rahimi *et al*. 2018; Rahimi and Nateq Golestan 2020). Bulb mites attack the scars and sometimes healthy parts of the saffron corms. Moreover, while feeding and tunneling inside the corm, it begins to multiply and create dark spots in the corm. Over time, the holes within the corm will progressively enlarge, allowing infectious agents to readily enter through the scarred areas, thereby expediting the deterioration process of the corm. Infected plants exhibit leaves that are thinner and shorter than those of healthy plants and foliage of infected plants tends to yellow more quickly than is typical (Bazoobandi *et al*. 2020) (Fig. 1).

Figure 1. *Rhizoglyphus robini* damage on saffron corms (Original image: scale bar: 10 mm). The arrows show mites in white.

Phenotypic plasticity is known as the capability of an organism to modify its phenotype in response to diverse environments. Temperature-size rule (TSR) is a ubiquitous example of phenotypic plasticity in ectotherms that expresses faster development at high temperatures resulting in a smaller body. In contrast, the development will be slower at low temperatures resulting in larger body sizes. Bergmann's rule (inter-specific latitudinal clines: larger-bodied species at higher, colder latitudes) and James' rule (intra-specific latitudinal clines: larger individuals at higher, colder latitudes) are two other rules for emergent body size patterns (Vangansbeke *et al*. 2019; Verberk *et al*. 2021). Body size is a key ecological trait of organisms. It influences ecological processes at various levels, such as individual reproduction, population dynamics, disease spread, food web organization, and ecosystem functions. Therefore, studying body size variation helps to understand both basic and applied aspects of ecology (Tseng *et al*. 2018).

EFFECT OF ABIOTIC FACTORS ON MORPHOMETRY OF *R. ROBINI*

The temperature size rule in the bulb mites was examined by Plesnar-Bielak *et al*. (2013) in laboratory conditions. Mites of this species were reared for 18 generations by feeding on yeast, in humidity above 90%, and two different temperature lines, control (24 °C) and elevated (28 °C). As a result of their investigation, this mite possessed reaction norms for body size, and the developmental time was in line with the TSR predictions, as mites developed faster and reached smaller sizes at increased temperatures. Moreover, body size reduction response to temperature was greater for females (19% decrease) than for males (7%) (Plesnar-Bielak *et al*. 2013). The response of adult body size in both sexes of *Tetranychus ludeni* Zacher, 1913 (Acari: Tetranychidae) to different temperatures was examined under laboratory conditions; adult body size decreased significantly with an increase in temperature from 20 °C, being largest at 20 °C and smallest at 30 °C (Ristyadi *et al*. 2021). Another study revealed significant differences in adult females' body size parameters of two *Abacarus* spp. (Acari: Eriophyidae) in April, September and December of 2001 in Poland (Laska *et al*. 2017). According to those results, females of *Abacarus* sp. (host: *Bromopsis inermis* Leyss.) and *A. lolli* Skoracka (host: *Lolium perenne* L.) were larger in December rather than in April and September.

Food diet effect on body and legs I lengths of bulb mites fed with the poor diet was approximately 60% of those of mites fed with the rich food, while *sci* setae were merely around 30% of the length (Gerson *et al*. 1991). The correlation between body size and fitness characteristics was investigated via two dietary regimes: starvation and *ad libitum* feeding, applied to both virgin and mated *Tetranychus urticae* Koch spider mites. It was observed that the body size of female mites, unlike their male counterparts, augmented with increased food availability, and a positive correlation was established between female fecundity and body size (Li and Zhang 2018)

Nutritional and abiotic factors not only affect the body size of mites but also influence their biological activities, such as weight, growth, and reproduction. Most of these types of research have been performed on predatory mites, especially of the family Phytoseiidae (Walzer and Schausberger 2013; Goleva *et al.* 2015; Pozzebon *et al*. 2015).

No pesticides (except for two herbicides) are registered or recommended at any level for saffron cultivation, according to Iran's authorities (Ministry of Agriculture Jihad and Plant Protection Organization) (Mahdavi *et al.* 2021). Finding an alternative control method is crucial, given Iran's large saffron exports and pesticide-free products. Knowledge of the ecological responses of pests to environmental factors can improve and accelerate pest management programs.

This study was conducted to evaluate the ecological features of *R. robini* as the most important pest of the saffron agroecosystem, from 2022 to 2023 in northeast Iran. The effects of time, soil moisture, corm weight, temperature, and mite density (nymphs + adults) were determined in the body size variation (body length, width, and leg lengths) of the bulb mite in the saffron field and it was found which environmental factor had a more influence on size variation of this mite species.

MATERIAL AND METHODS

Experimental location

The experiment took place in a five-year-old saffron field (5,000 m^2, 37° 32' 43.8" N, 58° 55' 46.8" E) in Dargaz County, Razavi Khorasan Province, Iran, from May 5, 2022 to May 5, 2023.

Sampling and extraction

Samplings were carried out periodically every two months on the 5^{th} of November, January, March, May, July, and September. Five points with cross patterns were selected and marked in the saffron field. For each marked point, 200 to 300 grams of saffron corms were removed from the soil from the ground by a shovel. Corms samples were transported to the laboratory in black bags. Aboveground plant organs were removed and the weight and number of each corm on the 200 grams of samples were calculated and recorded. During the removal of the reticulate fibrous tunics and the cutting of infected tissues, many mites were separated by shaking. To collect all of them, the tunics were separated and the infected tissues were opened in a 1-liter beaker. The extraction method was based on the washing method with water-based detergent (2% soap and 1% bleach) (Walter and Krantz 2009). Accordingly, the tunics and corm pieces were added to the same 1-liter beaker that was used for the separation. Then, 500 ml of washing solution (2% soap and 1% bleach) was added to the beaker and shaken for one hour at 100 rpm. To separate mites and other sediments, a modification of Monfreda *et al*. (2007) was used. In this method, mites were collected by pouring the suspension onto a series of stainless steel sieves assembled in the following order (top to bottom): 850 µm, 500 µm, 300 µm, and 212 µm mesh size. The surface of the last sieve (212 µm) was washed with ethanol 70% into a 200 ml beaker. The outcome solution (30 ml ethanol plus mites and other sediments) was shaken at 100 rpm, and one ml of solution was picked by a micropipette while shaking the solution and transferred to a 5 cm Petri dish observed under the stereo-microscope.

Preparation of microscope slides and measurtments

Thirty females were picked from each sample solution with a thin brush and transferred into lactic acid for two weeks at room temperature. The specimens were prepared on microscope slides in dorsal position with Heinze PVA (polyvinyl alcohol) medium and heated in an oven at 50 °C for two weeks (modified method of Evans 1992). For keeping the spherical shape of the body, we used a dense form of medium. Mite specimens were identified according to Fan and Zhang (2004) and Bu and Li (1998). Morphological characters were measured via a camera lucida of an Olympus BH-2 microscope. All measurements were done based on Fan and Zhang (2004). The body length was measured from the anterior margins to the posterior margins of the idiosoma and the body width was taken at the maximum width of the idiosoma between legs II and III, and legs were measured from the bases of trochanters to the tips of claws (Fig. 2). All the measurements are given in micrometers (µm).

Figure 2. Female body length, width and legs length diagram of *R. robini* based on Fan and Zhang (2004) (Original image: scale bar: 150 µm).

Soil moisture and temperatures

The air temperature information was obtained from the Iran Meteorological Organization (https://nivar.irimo.ir). The percentage of soil moisture content was determined using the oven-dry technique based on Okoh *et al*. (1999); Approximately five grams of soil from each sample were weighed and then placed in an oven. The temperature of the oven was consistently maintained at 105 °C for 24 hours. the samples were allowed to cool in a desiccator before their weight was measured again. This process was carried out repeatedly until the weight of the samples remained unchanged.

Data analysis

Analysis of variance was performed for all data. A comparison of the means was done based on Tukey's test at a 5% level. Also, simple and multiple linear and non-linear regression models were fitted with independent variables of temperature, soil moisture, density (nymphs + adults), time and corm weight, and dependent morphometrical data of the saffron bulb mite using SPSS version 16 software (SPSS 2007).

RESULTS

The results of variance analysis of the morphometrical parameters of the saffron bulb mite including body length, body width, and four pairs of legs in different months of the year were significant ($F_{5,54}$ = 18.269**, $F_{5,54}$ = 4.163**, $F_{5,54}$ = 22.532**, $F_{5,54}$ = 10.963**, $F_{5,54}$ = 8.554**, $F_{5,54}$ = 12.020**, respectively). Based on Tukey's test results, the highest body length was observed in May (804 ± 16.778) and July (784.5 ± 16.496) and the lowest in November (555 ± 8.519). The highest body width was observed in May (446 ± 13.292) and July (410 ± 12.828), and the lowest in November (334.5 ± 3.860) and March (334 ± 6.908) (Table 1). The highest first leg length was observed in July (171 ± 3.643) and May (161 ± 2.684) and the lowest in November (107 ± 1.911). The highest second leg length was observed in July (171 ± 3.57) and May (162 ± 2.852) and the lowest in November (96.8 ± 2.647). The lowest third leg length was observed in November (67.5 ± 1.567) and the highest had no significant differences. The highest fourth leg length was observed in July (133.5 ± 1.567) and the lowest in November (66.5 ± 1.664) (Table 2). The length of the first (107 ± 3.43) and second (96.8 ± 4.75) legs of saffron bulb mite in November was equal to and greater than the third (67.5 ± 2.81) and fourth (66.5 ± 2.99) legs (P-value < 0.05) and this trend was observed in other months of the year.

Table 1. Comparison of average length and width of body (µm) of the saffron bulb mite in different months of the year.

Month	N	Body length					Month	Body width		
		1	2	3	4	5		1	2	3
November	30	555					**November**	334.50		
September	30		642				**March**	344		
January	30			717			**September**		396.5	
March	30			752	752		**January**		398	
July	30				784.5	784.5	**July**		410	410
May	30					804	**May**			446
P-value		1	1	0.344	0.429	0.874		0.992	0.961	0.234

A simple linear regression analysis was performed to examine the effect of temperature on the morphometrical parameters of the bulb mite for each semi-year, separately. The results showed that all the traits were significantly correlated with temperature and the regression parameters for each trait were presented in Table 3 and Figure 3. The effect of temperature on these variables was reversed, which means that the length and width of the body and leg length have been decreased with increasing temperature. The slope of the regression model of body length and width and length of legs in the first and second semi-year was significant (P-value < 0.05). In the first semi-year, the slope of the model of body and width length was higher than in the second semi-year. As a result, the severity of the decrease in body size with the increasing temperature in the spring and summer seasons was greater than those in autumn and winter (Fig. 3A, B). The slope of the model of leg lengths in the first six months was significantly different from that of the second six months. In the legs, the slope of the model was higher in the second six months (Fig. 3 C–F).

Table 2. Comparison of average leg length (μm) of the saffron bulb mite in different months of the year.

Month	N	Leg I			Month	Leg II			
		1	2	3		1	2	3	4
November	30	107			**November**	96.8			
September	30		153		**March**		137		
March	30		154		**September**		142		
January	30		157		**January**		152	152	
May	30		161	161	**May**			162	162
July	30			171	**July**				171
P-value		1	0.262	0.075		1	0.202	0.558	0.694
Month		**Leg III**			**Month**	**Leg IV**			
	N	**1**	**2**	**3**		**1**	**2**	**3**	**4**
November	30	67.5			**November**	66.5			
May	30		95.1		**March**		98.7		
January	30		104	104	**January**		104	104	
September	30		104	104	**May**			114	
March	30		106	106	**September**			117	
July	30			117	**July**				133
P-value		1	0.132	0.056		1	0.907	0.122	1

Table 3. Linear regression model of temperature effect on morphological traits of saffron bulb mite.

Traits	0-6 month				6-12 month			
	Model Summary		Parameter estimates		Model Summary		Parameter estimates	
	R^2	F	intercept	Temp.	R^2	F	intercept	Temp.
Body length	0.999	931.75^{**}	1089	−14.02 ± 0.23	0.999	20510^{**}	810.39	−10.55 ± 0.074
Body width	0.799	30.67^{*}	595.84	−8.07 ± 1.53	0.976	159.91^{**}	418.73	−3.05 ± 0.241
Leg I	0.999	3192^{**}	200	−1.473 ± 0.026	0.987	294.69^{**}	183.67	−3.06 ± 0.178
Leg II	0.998	1930^{**}	219.76	−2.435 ± 0.055	0.983	231.29^{**}	176.36	−3.25 ± 0.214
Leg III	0.815	17.64^{*}	123.26	−0.646 ± 0.15	0.985	257.65^{**}	120.64	−2.17 ± 0.136
Leg IV	0.953	81.22^{**}	146.10	−1.031 ± 0.114	0.993	599.70^{**}	122.76	−2.31 ± 0.094

The effect of mite density (nymphs + adults), soil moistures, saffron bulb weight, and semi-year on the morphological traits of the mite body was fitted with a multiple linear regression model (P-value < 0.05). Based on this, the density (nymphs + adults) factor had an inverse effect on morphological traits, and soil moisture, corm weight and semi-year factors had a direct effect. The most direct and inverse effects were observed in soil moisture (Beta = 1.13) and mite density (nymphs + adluts) (Beta = −1.311), respectively (Table 4). Corm weight factor was not significant in this model for Leg II–IV and was removed. Also, the semi-year factor for Leg III was not fitted with this model and was removed (P-value < 0.05).

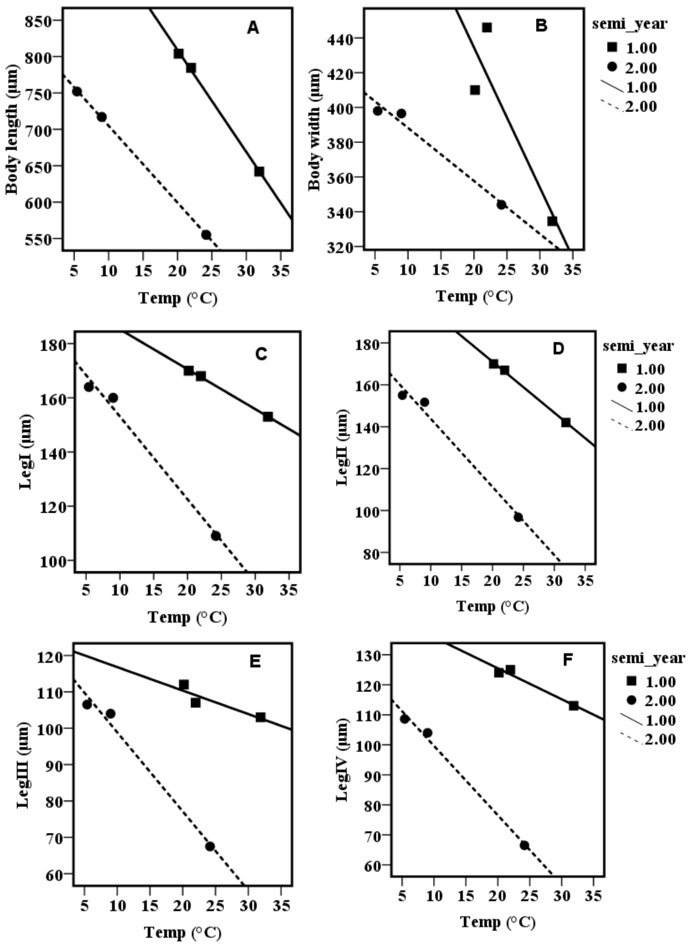

Figure 3. Linear graph of the temperature effect on morphological traits in the saffron bulb mite.

Table 4. Multiple linear regression model between the effect of environmental factors on morphological traits of the saffron bulb mite.

Traits	Model summary		Parameter estimates									
	R^2	F	intercept	Density	Beta	Soil Rh	Beta	semi-year	Beta	Corm weight	Beta
Body length	0.920	20.187**	188.087	−0.362	−1.311	15.864	1.13	−119.012	−0.688	55.218	0.625
Body width	0.992	230.9**	102.286	−0.093	−1.074	5.212	1.19	−25.327	−0.47	24.01	0.871
Leg I	0.980	87.34**	122.603	−0.088	−1.356	3.278	0.991	−25.088	−0.616	5.030	0.241
Leg II	0.925	32.88**	185.064	−0.082	−1.08	4.397	1.14	−42.229	−0.889	-	-
Leg III	0.941	72.42**	107.353	−0.063	−1.272	1.166	0.463	-	-	-	-
Leg IV	0.965	74.259**	148.596	−0.061	−0.922	2.022	0.603	−30.05	−0.727	-	-

The effect of time (day) on length, width, and width-to-length ratio was fitted using a quadratic linear regression model (P-value < 0.05). With the increase of time, the body length decreased and it reached its lowest value (595.84) at the vertex point on the 217th day Solar Hijri (SH) will be the first of Aban (Iranian month) or 23 October, and then the body length increased with the increase of days. The body width decreased with increased time and it reached the lowest value (345.57) at the vertex point on the 206th day SH will be 20 Mehr (Iranian month) or 12 October. As time (day) increases, the width-to-length ratio increased and reached the maximum width-to-length ratio (0.582) at the vertex point on the 231st day SH will be 15 Aban or 6 November, and it was its most spherical shape and then, with the increase of day, the body was more elongated (Table 5, Fig. 4; vertex points were marked with red points).

Table 5. Non-linear regression of time effect on morphological traits of the saffron bulb mite.

Parameters	F	R^2	Time	$Time^2$	Intercept
Body length	36.88^{**}	0.891	−4.340 ± 0.506	0.01 ± 0.001	1066.61 ± 46.12
Body width	14.65^{**}	0.765	−1.23 ± 0.235	0.003 ± 0.001	471.32 ± 21.38
Width/Length ratio	9.11^{**}	0.670	0.002 ± 0.42E-3	−3.67E-6 ± 0.1E-5	0.386 ± 0.38

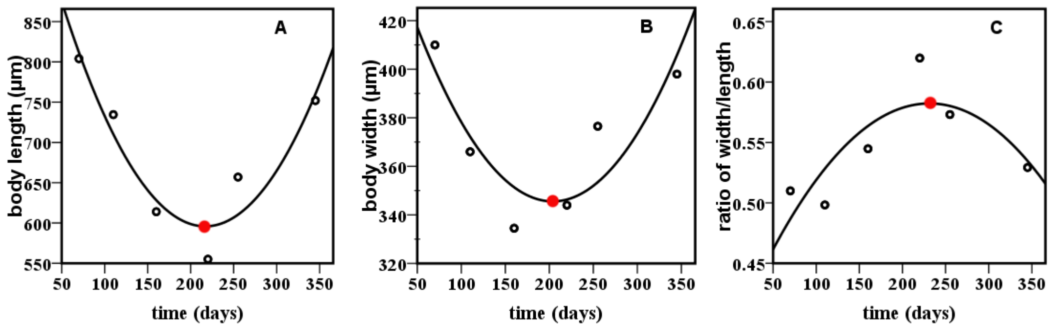

Figure 4. Non-linear graph of time effect on morphometrical parameters of the saffron bulb mite.

In this study, the effect of abiotic factors including temperature, soil moisture, mite density (nymphs + adults), time, and saffron corm weight on the body morphology traits of *R. robini*, including body length and width as well as leg length, was significant (P-value < 0.05).

The comparison of the mites' morphological traits in different months of the year showed that the lowest sizes are in the autumn season and November, which is the time when the reproductive activity of the saffron bulb begins. It seems that with the beginning of the physiological activity of the saffron bulb, the activity of *R. robini* also increases, and simultaneously with the increase in density (nymphs + adults) (Tabel 4), the body size of the mite also decreases (Tabel 1). On the other hand, the largest morphological sizes of the bulb mite were observed in late spring and early summer in May and July, which is the end of the saffron plant vegetative activity and entering true dormancy.

This increase in body size can be due to the bulb mite entering harsh living conditions (summer without humidity and high temperature), which is according to the study Verberk *et al*. (2021). Our results confirmed the TSR predictions in bulb mites in saffron field conditions, and this opinion is consistent with the findings of Plesnar-Bielak *et al*. (2013) who stated temperature (24 and 28 °C) influenced the body size of both male and female *R. robini* and decreased once temperature increased. Also, our results followed Ristyadi *et al*. (2021) findings, that stated adult body size of *Tetranychus ludeni* Zacher (Acari: Tetranychidae) decreased significantly with an increase in temperature from 20 °C, being largest at 20 °C and smallest at 30 °C. Furthermore, our findings are in concordance with those reported by Laska *et al*. (2017) who stated females of *Abacarus* sp. (host: *Bromopsis inermis*) and *A. lolli* (host: *Lolium perenne*) had increased body size in winter in comparison to spring and late summer.

The shortest and longest sizes of the legs were observed in November and July, respectively. These times coincide with the highest (flowering) and lowest (dormancy) activity of the saffron plant, respectively. It seems that due to the high food quality of saffron corms in November, the mobility of the mite is as low as possible and also, the low food quality of saffron corms in July, the mobility increases as much as possible, which causes changes in the size of the legs. Also, based on this it seems that this pest has the most dispersion in July and the most aggregation in November.

In all months, the lengths of the legs I and II were observed to be equal to and longer than the third and fourth legs. This result is consistent with the study of Fan and Zhang (2004) and it seems that the first two legs have become stronger and longer due to the crawling and penetrating movement of the mite in the saffron corm. The morphological size of the bulb mite body decreased from May to September. This happened with the dormancy of the saffron plant, which seems to be due to the decrease in soil moisture and the saffron bulb, as well as the increase in air temperature.

Also, one of the most striking outcomes is the response of size traits to soil moisture change, which was more effective than time, temperature, and saffron corm weight. Based on Gerson *et al*. (1985), wheat fields had fewer mites in the summer than in the fall and spring. They suggested that high temperatures and dry soil might account for the observed patterns of abundance.

The morphological characteristics of the body increased from autumn (November) to winter (March) (Tabel 1), which can be due to the increase in soil moisture and the increase in the quality of saffron bulbs (vegetative activity), which is consistent with the studies of Gerson *et al*. (1991). They studied how food quality affected the body and leg lengths of mites and found that mites that ate low-quality food had only about 60% of the size of mites that ate high-quality food. Based on Li and Zhang (2018) body size of *Tetranychus urticae* (Acari: Tetranychidae) female mites, unlike their male counterparts, augmented with increased food availability, and a positive correlation was established between female fecundity and body size.

Also, this opinion was confirmed by a multiple linear regression model. According to this model, with the increase of soil moisture and saffron bulb weight, body size indices showed that soil moisture (Beta = 1.13) had a greater effect than corm weight (Beta = 0.625) (Table 4).

The inverse effect of ambient temperature on the morphological traits of the saffron bulb mite in the first (spring and summer) and second (winter and winter) six months of the year was separately significant and fitted as a linear regression (Table 3). The slope of the regression line of body length and width in the first six months of the year (-14.02 ± 0.23) was higher than the second six months (-10.55 ± 0.074), which shows the further decrease in body length and width in the first six months. This greater effect of temperature in reducing body size indices in the first six months of the year can be due to the decrease in moisture of the soil in summer (lack of rain and irrigation) and dormancy of saffron bulbs.

CONCLUSION

Understanding the interaction of bulb mites with environmental factors can help us to plan better pest management and reduce pesticide-free production, especially for saffron, which is a strategic product of Iran. Based on our results, soil moisture has a strong relation with female body size traits (body length, width, and leg lengths). This indicates that irrigation cycle management might be an important factor in bulb mite management in saffron agroecosystems. Also, in summer, the effect of increasing temperature which reduces the body size of the mite can be an important factor in controlling this pest, and on this basis, the cultivation of this product cannot be recommended in climates with mild summer. On the other hand, the period from July to May is the right time for the pest control strategy in the field, because this pest has the largest size of legs and has probably the most mobility.

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REFERENCES

Bazoobandi, M., Rahimi, H. & Karimi-Shahri, M.R. (2020) Saffron crop protection. *In*: Koocheki, A. & Khajeh-Hosseini, M. (Eds.), *Saffron: Science, technology and health*. Woodhead Publishing, pp. 169–185.

Bu, G.S. & Li, L.S. (1998) Taxonomic notes on and key to known species of the genus *Rhizoglyphus* (Acari: Acaridae) from China. *Systematic and Applied Acarology*, 3(1): 179–182.

Diaz, A., Okabe, K., Eckenrode, C.J., Villani, M.G. & Oconnor, B.M. (2000) Biology, ecology, and management of the bulb mites of the genus *Rhizoglyphus* (Acari: Acaridae). *Experimental and Applied Acarology*, 24: 85–113. DOI: 10.1023/a:1006304300657

Evans, G.O. (1992) *Principles of acarology*. CAB international, Wallingford, Oxon, UK, 563 pp.

Fan, Q.-H. & Zhang, Z.-Q. (2004) *Revision of* Rhizoglyphus *Claparède. Acari: Acaridae of Australasia and Oceania*. Systematic & Applied Acarology Society, London, 375 pp.

Gerson, U., Yathom, S., Capua, S. & Thorens, D. (1985) *Rhizoglyphus robini* Claparede (Acari: Astigmata: Acaridae) as a soil mite. *Acarologia*, 26(4): 371–380.

Gerson, U., Cohen, E. & Capua, S. (1991) Bulb mite, *Rhizoglyphus robini* (Astigmata: Acaridae) as an experimental animal. *Experimental & Applied Acarology*, 12(1–2): 103–110. DOI: 10.1007/BF01204403

Ghorbani, M. (2007) The economics of saffron in Iran. *Acta Horticulturae*, 739: 321–331. DOI: 10.17660/ActaHortic.2007.739.42

Goleva, I., Rubio Cadena, E.C., Ranabhat, N.B., Beckereit, C. & Zebitz, C.P.W. (2015) Dietary effects on body weight of predatory mites (Acari, Phytoseiidae). *Experimental and Applied Acarology*, 66(4): 541–53. DOI: 10.1007/s10493-015-9920-5

Laska, A., Rector, B.G., Kuczyński, L. & Skoracka, A. (2017) Is body size important? Seasonal changes in morphology in two grass-feeding *Abacarus* mites. *Experimental and Applied Acarology*, 72(4): 317–328.

Li, G.Y. & Zhang, Z.-Q. (2018) Does size matter? Fecundity and longevity of spider mites (*Tetranychus urticae*) in relation to mating and food availability. *Systematic and Applied Acarology*, 23(9): 1796–1808.

Mahdavi, V., Eslami, Z., Golmohammadi, G., Tajdar-oranj, B., Behbahan, A.K. & Khaneghah, A.M. (2021) Simultaneous determination of multiple pesticide residues in Iranian saffron: A probabilistic health risk assessment. *Journal of Food Composition and Analysis*, 100: 103915. DOI: 10.1016/j.jfca.2021.103915

Monfreda, R., Nuzzaci, G. & de Lillo, E. (2007) Detection, extraction, and collection of eriophyoid mites. *Zootaxa*, 1662(1): 35–43. DOI: 10.11646/zootaxa.1662.1.4

Okoh, I.A., Badejo, M.A., Nathaniel, I.T. & Tian, J.G. (1999) Studies on the bacteria, fungi and springtails (Collembola) of an agroforestry arboretum in Nigeria. *Pedobiologia*, 43: 18–27.

Pozzebon, A., Loeb, G.M. & Duso, C. (2015) Role of supplemental foods and habitat structural complexity in persistence and coexistence of generalist predatory mites. *Scientific Reports*, 5(1):14997. DOI: 10.1038/srep14997

Plesnar-Bielak, A., Jawor, A. & Kramarz, P.E. (2013) Complex response in size-related traits of bulb mites (*Rhizoglyphus robini*) under elevated thermal conditions – an experimental evolution approach. *Journal of Experimental Biology*, 216(24): 4542–4548. DOI: 10.1242/jeb.090951

Rahimi, H. & Kamali, K. (1993) Laboratory studies on biology of bulb mite *Rhizoglyphus robini* (Acari; Acaridae) and its damages on saffron corn in Gonbad and Ghayen. *The Scientific Journal of Agriculture*, 16(1–2): 53–65. (In Persian with English abstract).

Rahimi, H. & Nateq Golestan, M. (2020) Preliminary study on non-chemical management factors for bulb mite *Rhizoglyphus robini* (Acari: Acaridae) control in the saffron crop. *Journal of Crop Protection*, 9(2): 251–259.

Rahimi, H., Nateq Golestan, M. & Kakhki, A. (2018) Exploring the impact of non-chemical methods on the control of bulb mite (*Rhizoglyphus robini* Claparède) and yield of saffron (*Crocus sativus* L.). *New Zealand Plant Protection*, 71: 93–101. DOI: 10.30843/nzpp.2018.71.108

Rashed-Mohassel, M.H. (2020) Evolution and botany of saffron (*Crocus sativus* L.) and allied species. *In*: Koocheki, A. & Khajeh-Hosseini, M. (Eds.), *Saffron: science, technology and health*. Woodhead Publishing Limited, United Kingdom, pp. 37–57.

Ristyadi, D., He, X.Z. & Wang, Q. (2021) Response to thermal environment in *Tetranychus ludeni* (Acari: Tetranychidae). *Systematic and Applied Acarology*, 26(5): 942–953. DOI: 10.11158/saa.26.5.9

Smallegange, I.M., Thorne, N. & Charalambous, M. (2012) Fitness trade-offs and the maintenance of alternative male morphs in the bulb mite (*Rhizoglyphus robini*). *Journal of Evolutionary Biology*, 25(5): 972–980. DOI: 10.1111/j.1420-9101.2012.02490.x

Tseng, M., Kaur, K.M., Soleimani Pari, S., Sarai, K., Chan, D., Yao, C.H., Porto, P., Toor, A., Toor, H.S. & Fograscher, K. (2018) Decreases in beetle body size linked to climate change and warming temperatures. *Journal of Animal Ecology*, 87(3): 647–659. DOI: 10.1111/1365-2656.12789

Vangansbeke, D., Duarte, M.V., Gobin, B., Tirry, L., Wäckers, F. & De Clercq, P. (2019) Cold-born killers: exploiting temperature–size rule enhances predation capacity of a predatory mite. *Pest Management Science*, 76(5): 1841–1846. DOI: 10.1002/ps.5713

Verberk, W.C., Atkinson, D., Hoefnagel, K.N., Hirst, A.G., Horne, C.R. & Siepel, H. (2021) Shrinking body sizes in response to warming: explanations for the temperature–size rule with special emphasis on the role of oxygen. *Biological Reviews*, 96(1): 247–268. DOI: 10.1111/brv.12653

Walter, D.E. & Krantz, G.W. (2009) Collecting, rearing, and preparing specimens. *In*: Krantz, G.W. & Walter, D.E. (Eds.), *A manual of acarology*. 3rd edition. Texas Tech University Press, Texas, USA, pp. 83–96.

Walzer, A. & Schausberger, P. (2013) Intra- and trans-generational costs of reduced female body size caused by food limitation early in life in mites. *PLoS ONE*, 8(11): e79089. DOI: 10.1371/journal.pone.0079089

تاثیر برخی عوامل غیرزنده بر فراسنجه‌های ریخت‌سنجی جنس ماده کنهٔ بنهٔ زعفران *Rhizoglyphus robini* (Astigmata: Acaridae) در کشتزار زعفران

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چکیده

زعفران (*Crocus sativus* L.: Iridaceae) گیاهی چند ساله و پاییزی است. کلالهٔ خشک آن گران‌ترین ادویه و نقشی کلیدی در صادرات غیرنفتی ایران ایفا می‌کند. کنهٔ بنهٔ زعفران *Rhizoglyphus robini* گونه‌ای چند شوهری و چندنسلی است که آسیب آن به بنهٔ زعفران به طور مستقیم و غیرمستقیم باعث کاهش عملکرد زعفران می‌شود. شرایط و عوامل محیطی مانند دما، رطوبت، تراکم و رژیم غذایی بر ویژگی‌های ریختی موجودات زنده و به دنبال آن بر توانایی‌های زیستی تأثیر می گذارد. در مطالعه حاضر، تغییرات دما، رطوبت خاک، تراکم، زمان و وزن بنه بر روی فراسنجه‌های ریختی کنهٔ بنهٔ زعفران شامل طول و عرض بدن و اندازه پاهای مادهٔ بالغ در مزرعه زعفران در شهر درگز، ایران بررسی شد (۲۰۲۲). نتایج تجزیه واریانس فراسنجه‌های ریخت‌سنجی کنه شامل طول بدن، عرض بدن و چهار جفت پا در ماه‌های مختلف معنی‌دار بود. بر اساس مدل‌های رگرسیون خطی ساده و چندگانه و همچنین رگرسیون غیر خطی، اثر دما و تراکم معکوس و تأثیر رطوبت خاک و وزن بنه بر فراسنجه‌های ریخت‌سنجی این گونه مستقیم بود. بر اساس نتایج به دست آمده در مطالعه حاضر، رطوبت خاک بر فراسنجه‌های اندازهٔ بدن مادهٔ بالغ (طول، عرض و طول پا) نسبت به بقیه عوامل تاثیر بیشتری می‌گذارد. بر این اساس، مدیریت دورهٔ آبیاری ممکن است عامل مهمی در مدیریت کنهٔ بنه در اکوسیستم‌های زعفران باشد.

واژگان کلیدی: اندازه بدن، کنهٔ بنه، ویژگی‌های ریختی، رگرسیون خطی چندگانه، شمال شرق ایران.

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