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Article

A population growth model of *Tetranychus urticae* Koch (Acari: Tetranychidae)

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ABSTRACT

Two-spotted spider mite, *Tetranychus urticae* Koch is a serious pest of different crops over the world. Different strategies are used to regulate the population of this mite. To this end, as a first step, a population growth model has been developed for describing the dynamics of *T. urticae* population growth. In this regard, the population abundance of *T. urticae* was estimated weekly from 29 June to 29 September 2016 at two bean fields, each field was planted with Goli and Akhtar cultivars, separately. During each sampling period in each field, 30 plants were randomly chosen and a leaf was selected as a sample unit from the middle of a plant, then a simple population growth model was constructed for *T. urticae* on two bean cultivars. The result showed that *T. urticae* had a distinct seasonal pattern of abundance but differed between two cultivars. A logistic growth model was developed based on relationship between the cumulative density of *T. urticae* and time (day) and demonstrated high prediction capability for *T. urticae* population on Goli ($R^2 = 0.99$) and Akhtar ($R^2 = 0.99$) cultivars. According to the logistic equation, carrying capacity was recorded 463.9 ± 9.73 (mite/leaf) and 59.67 ± 8.72 (mite/leaf) on Goli and Akhtar cultivars, respectively. Furthermore, it has been shown that the logistic growth model can be used to make population predictions. The model parameters estimated for two different cultivars, providing a new mathematical tool for ecologists to predict two-spotted spider mite outbreaks, and ultimately to develop effective two-spotted spider mite control strategies.

KEY WORDS: Bean cultivars; carrying capacity; logistic equation; population dynamics; two-spotted spider mite.

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INTRODUCTION

The two-spotted spider mite, *Tetranychus urticae* Koch (Acari: Tetranychidae) is a cosmopolitan agricultural pest, feeding on more than 1100 plant species, of which more than 150 have economic importance (Bolland *et al.* 1998; Migeon *et al.* 2011; Cazaux *et al.* 2014; Van Leeuwen *et al.* 2015). Spider mites colonize on plants shortly after crops plantation. They start damaging as the crops start to grow. But in the summer season, spider mite numbers start to decline during plant maturation (Badii *et al.* 2004). Under favorable conditions, spider mites can build up very large populations which cause important economic losses. The number of spider mites can increase by 40% per day. This exponential population growth usually ends abruptly due to overexploitation of the host plant (Krips *et al.* 1998).

Several studies declared that environmental factors such as temperature (Düzgüneş and Çobanoğlu 1983; English-Loeb 1990; Dhar *et al.* 2000; Karami-Jamour and Shishehbor 2012; Riahi

et al. 2013), host plant cultivar (Adango *et al.* 2006; Ahmadi *et al.* 2007; Kavousi *et al.* 2009; Sedaratian *et al.* 2011; Modarres Najafabadi *et al.* 2012; Kabiri *et al.* 2012; Saei Dehghan *et al.* 2009; Khanamani *et al.* 2013; Maleknia *et al.* 2016; Uddin *et al.* 2015), profoundly affect population growth rate of *T. urticae*. But, there is no attempt to measure differences in carrying capacity or density dependence.

Forecasting of spider mite abundance is difficult due to overlapping the generations and variation in age structure of the populations which is rarely stable (Wilson 1994). When density is measured, commonly the logistic curve is used for describing population growth in ecology. Specifically, these models are widely used to describe insect populations and their life cycles in cases where the population increases monotonically to some equilibrium value called the ‘carrying capacity’ (Matis *et al.* 2003, 2006, 2009, 2010; Matis and Kiffe 2004; Matis and Kiffe 2012). The rate of growth and the tendency for growth (carrying capacity) are two internal factors that affect long-term dynamics of populations and logistic model is described by the parameters including r_m (intrinsic rate of increase) and K (carrying capacity) (Turchin 2003).

In this study, bean plant and the spider mites were used as a modal system. The objective of the current study was to develop a simple and robust analytical model for *T. urticae* population growth under field conditions.

MATERIALS AND METHODS

Study area

The field experiments were conducted in Varamin vicinity of Tehran, Iran from 29 June to 29 September 2016. Two cultivars, Goli and Akhtar were planted in each of two fields (~ 1 hectare). No pesticides were applied in two fields.

Sampling

From each field, 30 plants were selected at random and sampled at weekly intervals to record the total number of mite population per leaf. Sampling unit was one leaf taken from the mid-height of a plant. Leaves were placed individually in plastic bags and stored at 4 °C in refrigerator. The number of *T. urticae* (eggs, immature stages, and adults) was determined on each leaf using stereo-microscope (OLYMPUS, SZH-ILLB) in laboratory. The two-spotted spider mite population fluctuations in two fields were plotted.

Model development

The relationship between cumulative mean number of total population of *T. urticae* in each sampling date obtained in the two fields were fitted to the logistic growth function (Meyer *et al.* 1999).

$$N_t = \frac{k}{1 + e^{(-\alpha(\beta-T))}}$$

where T is time (days), N_t is the mite population size at time t (mite/leaf), α is growth rate parameter that specifies the width or steepness of sigmoidal curve, β specifies the time when the curve reaches $\frac{1}{2}k$, or midpoint of the growth trajectory and k is the carrying capacity (mite/leaf). Nonlinear regression (proc nlin; SAS Institute 2013) was used to fit the logistic growth model to data and estimate values of mean \pm SE and assess goodness of fit, using R^2 .

RESULTS

Summer fluctuation of *T. urticae* population on two cultivars are shown in Figure 1 for each sampling

field. The result of the present study revealed *T. urticae* appeared firstly on Goli cultivar on July 4. The first and second peaks of *T. urticae* population on Goli cultivar were recorded 86.44 mite/leaf on July 18 and 33.84 mite/leaf on August 28, respectively, whereas the first and second peaks on Akhtar cultivar occurred 6.2 mite/leaf on July 11 and 7.54 mite/leaf on September 2, respectively. Thereafter, the population of *T. urticae* declined and disappeared at the end of September. On Goli cultivar, *T. urticae* exhibited a distinct seasonal pattern of abundance with a period of early summer increase and late summer decline but on Akhtar cultivar was *vice versa* (Fig. 1).

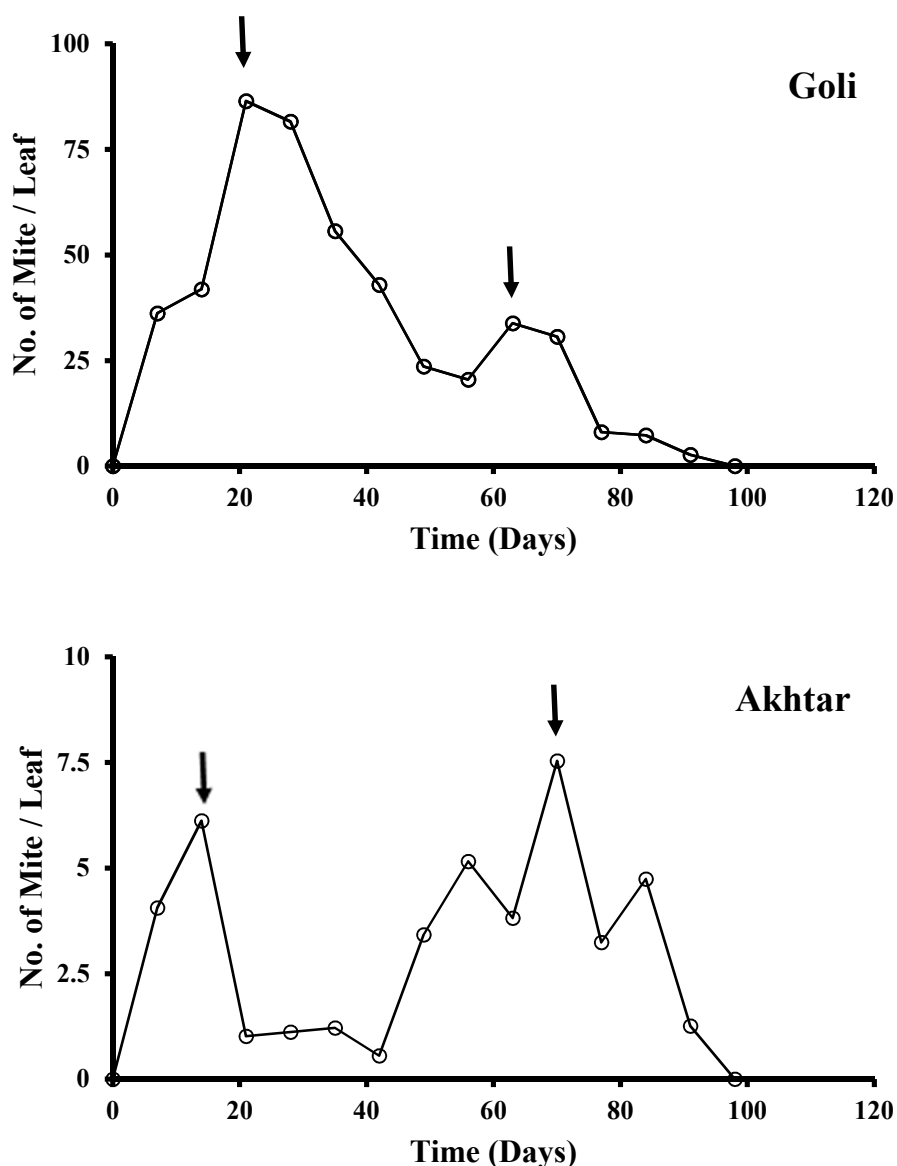


Figure 1. Population fluctuation of total population of *T. urticae* on two bean fields in 2016.

In this study, the simplest form of the logistic equation was used and indicated a sigmoidal population growth for *T. urticae* on both varieties (Fig. 2). This equation produces the S-shaped curve and these three parameters α , β and k are needed to fully specify the curve. The growth rate parameter α specifies the “width” or “steepness” of the sigmoidal curve (Table 1). It is often helpful to replace α with a variable that specifies the time required for the trajectory to grow from 10% to 90% of the

limit k , a period which is called the characteristic duration, or Δt . Through simple algebra, the characteristic duration is related to α by $\Delta t = \frac{\ln(81)}{\alpha}$ that 52.88 and 114.44 days were recorded for Goli and Akhtar varieties, respectively. The parameter Δt is usually more useful than α for the analysis time-series data because the units are easier to perceive. The parameter β , shows the time when the curve reaches $\frac{1}{2}k$, or the midpoint of the growth trajectory, that 29.32 and 66.51 days for Goli and Akhtar cultivars, respectively (Table 1). The parameter k , is the asymptotic limit that the growth curve approaches, i.e., carrying capacity that is different on two cultivar (Table 1, Fig. 2).

Table 1. Parameter estimates (\pm SE) of population growth curves for two spotted spider mite on two varieties of bean using logistic model.

Variety	Parameters (\pm SE)			R^2
	k	α	β	
Goli	463.9 \pm 9.73	0.0831 \pm 0.008	29.32 \pm 1.19	0.997
Akhtar	59.67 \pm 8.72	0.0384 \pm 0.006	66.51 \pm 8.92	0.996

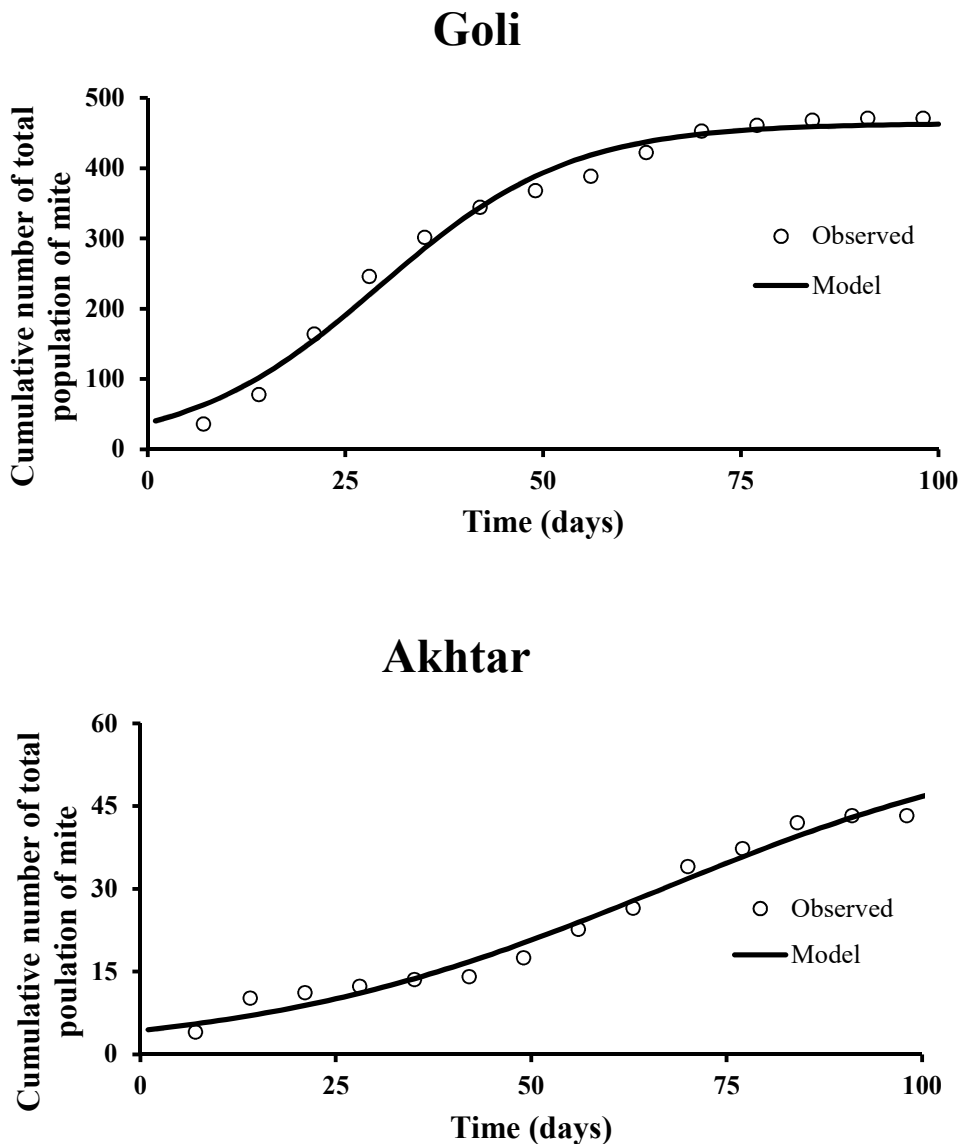


Figure 2. Growth of total population of *T. urticae* on two bean fitted to logistic curve.

DISCUSSION

In this study, the population of *T. urticae* peaked twice in both cultivars and the first peak occurred in mid July and the second was observed at the end of August and at the beginning of September. This result is in agreement with Ho and Chen (1992) and Kumral and Kovanci (2005) who reported two peak emergence pattern of *T. urticae* on eggplants in Turkey and Taiwan. Also, there are insects that show a two or three peak of population fluctuation (Whitfield 1984, Lashomb *et al.* 1984; Tauber *et al.* 1994).

This study demonstrates the versatility of the model to describe *T. urticae* populations on Goli and Akhtar cultivars and the effect of plant on carrying capacity. The variation in growth rate and density dependence within a population can be resulted from two sources, 1. Genetic variation among individuals, and 2. Variation in the environment where the population live. For example, in insects both growth rate (Agrawal *et al.* 2004; Helms *et al.* 2004) and carrying capacity (Underwood *et al.* 2000) differed among host plant genotypes. The logistic growth models have often served to characterize the overall patterns of insect population increase in time and space (Renshaw 1991). In some cases, insect ecologists have used these models to estimate parameters that may be used in identifying cultivars' resistance (Kindlmann and Dixon 2010; Underwood 2007). This study indicated that population growth of *T. urticae* has become sigmoidal. In fact, researchers have recorded examples of such S-shaped growth in animal populations (Marchetti *et al.* 1996). At the beginning, often the measured population of a species grows exponentially. However, natural systems cannot sustain exponential growth indefinitely and, negative feedback mechanisms from the environment slow the growth, producing the S-shaped curve. Thus, for a single growth process, a single sigmoidal curve is often a useful model (Meyer *et al.* 1999). In this study, the model gave excellent fit (coefficient of determination $R^2 = 0.99$) on two varieties. The carrying capacity (k) in low time duration reached the more value on Goli than Akhtar. Therefore, the variation in population dynamic parameters between two cultivars has the potential to have an effect on *T. urticae* population size in the field.

The analysis of growth is an important component of many biological studies. The classic Verhulst–Pearl logistic equation has a long and distinguished history dating back to 1838 (Renshaw 1991). Andrewartha (1961) suggests that such curves may be generally true of any local population whose numbers are determined by the stock of some non-expendable resource e.g. food. It is widely used to describe insect populations and their life cycles in cases where the population increases monotonically to some equilibrium value called the carrying capacity. This powerful technique can predict insect counts and therefore to prepare effective control strategies on different types of crops (Matis and Al-Muhammed 2010).

This study shows that the logistic model may be used to describe the size of *T. urticae* population. The model parameters estimated for two cultivars, providing a new mathematical tool for ecologists to predict two spotted spider mite outbreaks, and hopefully to develop effective control strategies of *T. urticae*. We expect that the logistic model will become widely used in practice.

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REFERENCES

Adango, E., Onzo, A., Hanna, R., Atachi, P. & James, B. (2006) Comparative demography of the spider mite, *Tetranychus ludeni*, on two host plants in West Africa. *Journal of Insect Science*,

6(49): 1–9

- Agrawal, A.A., Underwood, N., & Stinchcombe, J. (2004) Intraspecific variation in the strength of density dependence in aphid populations. *Ecological Entomology*, 29: 521–526.
- Ahmadi, M., Fathipour, Y. & Kamali, K. (2007) Population growth parameters of *Tetranychus urticae* (Acari: Tetranychidae) on different bean varieties. *Journal of Entomological Society of Iran*, 26(2): 1–10.
- Andrewartha, H.G. (1961) *Introduction to the study of animal populations*. University of Chicago Press, Chicago, IL, 281 pp.
- Badii, M.H., Hernandez-Ortiz, E., Flores, A.E. & Landeros, J.N. (2004) Prey stage preference and functional response of *Euseius hibisci* to *Tetranychus urticae* (Acari: Phytoseiidae, Tetranychidae). *Experimental & Applied Acarology*, 34: 263–273.
- Bolland, H. R., Gutierrez, J. & Flechtmann, C.H.W. (1998) *World catalogue of the spider mite family (Acari: Tetranychidae)*. Brill Academic Publishers. Leiden, 392 pp.
- Cazaux, M., Navarro, M., Bruinsma, K.A., Zhurov, V., Negrave, T., Van Leeuwen, T., Grbic, V. & Grbic, M. (2014) Application of two-spotted spider mite *Tetranychus urticae* for plant-pest interaction studies. *Journal of Visualized Experiment*, 89:e51738.
- Dhar, T., Dey, P.K. & Sarkar, P.K. (2000) Influence of abiotic factors on population build-up of red spider mite, *Tetranychus urticae* on okra vis a vis evaluation of some new pesticides for their control. *Pestology*, 24(9): 34–37.
- Düzgüneş, Z. & Çobanoğlu, S. (1983) The life history and tables *Tetranychus urticae* Koch and *Tetranychus cinnabarinus* (Boisduval) (Acarina: Tetranychidae) under the various temperatures and humidities. *Plant Protection Bulletin*, 23(4):171–187.
- English-Loeb, G.M. (1990) Plant drought stress and outbreaks of spider mites: A field test. *Ecology*, 71: 1401–1411.
- Helms, S.E., Connelly, S. J. & Hunter, M.D. (2004) Effects of variation among plant species on the interaction between a herbivore and its parasitoid. *Ecological Entomology*, 29: 44–51.
- Ho, C. & Chen, W.A. (1992) Species survey of spider mites and seasonal occurrence of *Thrips palmi*, *Chlorita biguttula* and *Tetranychus cinnabarinus* on eggplant. *Chinese Journal of Entomology*, 14(4): 259–268.
- Kabiri, H., Saboori, A. & Allahyari, H. (2012) Impact of different cotton (*Gossypium* spp.) cultivars, as host plant, on development and fertility life-table parameters of *Tetranychus urticae* (Acari: Tetranychidae). *International Journal of Acarology*, 38(1): 46–50.
- Karami-Jamour, T. & Shishehbor, P. (2012) Development and life table parameters of *Tetranychus turkestanii* (Acarina: Tetranychidae) at different constant temperatures. *Acarologia*, 52(2): 113–122.
- Kavousi, A., Chi, H., Talebi, K., Bandani, A., Ashouri, A. & Naveh, V.H. (2009) Demographic traits of *Tetranychus urticae* (Acari: Tetranychidae) on leaf discs and whole leaves. *Journal of Economic Entomology*, 102: 595–601.
- Khanamani, M., Fathipour, Y. & Hajiqanbar, H. (2013) Population growth response of *Tetranychus urticae* to eggplant quality: application of female age-specific and age-stage, two-sex life tables. *International Journal of Acarology*, 39: 638–648.
- Kindlmann, P. & Dixon, A.F. (2010) Modelling population dynamics of aphids and their natural enemies. In: Kindlmann P., Dixon A. & Michaud, J. (Eds.) *Aphid Biodiversity under Environmental Change*. Springer, New York, NY, USA, pp. 1–20.
- Krips, O.E., Witul, A., Willems, P.E.L. & Dicke, M. (1998) Intrinsic rate of population increase of the spider mite *Tetranychus urticae* on the ornamental crop gerbera: intraspecific variation in host plant and herbivore. *Entomologia Experimentalis et Applicata*, 89: 159–168.
- Kumral, N. A. & Kovanci, B. (2005) Seasonal population dynamics of the two-spotted spider mite, *Tetranychus urticae* Koch (Acari: Tetranychidae) under acaricide constraint on eggplant in Bursa province (Turkey). *Acarologia*, 45(4): 295–301.

- Lashomb, J. H., Ng, Y. S., Ghidui, G. & Green, E. (1984) Description of spring emergence by the Colorado potato beetle, *Leptinotarsa decemlineata* (Say) (Coleoptera: Chrysomelidae), in New Jersey. *Environmental Entomology*, 13: 907–910.
- Maleknia, B., Fathipour, Y. & Soufbaf, M. (2016) How greenhouse cucumber cultivars affect population growth and two-sex life table parameters of *Tetranychus urticae* (Acari: Tetranychidae). *International Journal of Acarology*, 42: 70–78.
- Marchetti, C., Meyer, P.S. & Ausubel, J.H. (1996) Human population dynamics revisited with the Logistic Model: How much can be modeled and predicted? *Technological Forecasting and Social Change*, 52: 1–30.
- Matis, J. H. & Al-Muhammed, M. J. (2010) Theory and application of the logistic probability density function as a population growth model. *Damascus University Journal for Basics Science*, 26(1): 9–19.
- Matis, J.H. & Kiffe, T.R. (2004) On stochastic logistic population growth models with immigration and multiple births. *Theoretical Population Biology*, 65(1), 89–104.
- Matis, J.H. & Kiffe, T.R. (2012) Stochastic population models: A compartmental perspective. Lecture Notes in Statistics, Vol. 145. Springer-Verlag, New York, 202 pp.
- Matis, J.H., Kiffe, T.R., Matis, T.I. & Stevenson, D.E. (2006) Application of population growth models based on cumulative size to pecan aphids. *Journal of Agricultural, Biological and Environmental Statistics*, 11(4): 425–449.
- Matis, J., Kiffe, T.R., Renshaw, E. & Hassan, J. (2003) A simple saddlepoint approximation for the equilibrium distribution of the stochastic logistic model of population growth. *Ecological Modelling*, 161(3): 239–248.
- Matis, J.H., Kiffe, T.R., van der Werf, W., Costamagna, A.C., Matis, T.I. & Grant, W.E. (2009) Population dynamics models based on cumulative density dependent feedback: A link to the logistic growth curve and a test for symmetry using aphid data. *Ecological Modelling*, 220(15): 1745–1751.
- Meyer, P.S., Yung, J.W. & Ausubel, J.H. (1999) A primer on logistic growth and substitution: the mathematics of the Loglet Lab software. *Technological Forecasting and Social Change*, 61(3): 247–271.
- Migeon A., Nouguié E. & Dorkeld F. (2011) Spider mites web: a comprehensive database for the Tetranychidae. *Trends in Acarology*, pp. 557–560.
- Modarres Najafabadi, S.S., Vafaei Shoushtari, R., Zamani, A.A., Arbabi, M. & Farazmand, H. (2012) Life parameters of *Tetranychus urticae* (Acari: Tetranychidae) on six common bean cultivars. *Journal of Economic Entomology*, 107: 614–622.
- Renshaw, E. (1991) *Modelling biological populations in space and time*. Cambridge University Press, New York, USA, 403 pp.
- Riahi, E., Shishehbor, P., Nemati, A.R. & Saeidi, Z. (2013) Temperature effects on development and life table parameters of *Tetranychus urticae* (Acari: Tetranychidae). *Journal of Agricultural Science & Technology*, 15: 661–672.
- Saei Dehghan, M., Allahyari, H., Saboori, A., Nowzari, J. & Hosseini Naveh, V. (2009) Fitness of *Tetranychus urticae* (Acari: Tetranychidae) on different soybean cultivars: biology and fertility life tables. *International Journal of Acarology*, 35(4): 341–347.
- SAS Institute (2013) SAS/STAT User's Manual. Version 9.4. SAS Institute Inc., Cary, North Carolina.
- Sedaratian, A., Fathipour, Y. & Moharramipour, S. (2011) Comparative life table analysis of *Tetranychus urticae* (Acari: Tetranychidae) on 14 soybean genotypes. *Insect Science*, 18: 541–553.
- Tauber, M.J., Tauber, C.A. & Nyrop, J.P. (1994) Soil moisture and postdormancy emergence of Colorado potato beetles (Coleoptera: Chrysomelidae): descriptive model and field emergence

- patterns. *Environmental Entomology*, 23: 1485–1496.
- Turchin, P. (2003) Complex population Dynamics: A Theoretical/Empirical Synthesis. Princeton University Press, New Jersey, USA, 472 pp.
- Uddin, M.N., Alam, M.Z., Mian, M.R.U. & Mustarin, K.E. (2015) Life table parameters of *Tetranychus urticae* Koch (Acari: Tetranychidae) on different bean varieties. *African Entomology*, 23(2): 418–426.
- Underwood, N. (2007) Variation in and correlation between intrinsic rate of increase and carrying capacity. *The American Naturalist*, 169(1): 136–41.
- Underwood, N., Morris, W., Gross, K. & Lockwood, J.R.I. (2000) Induced resistance to Mexican bean beetles in soybeans: variation among genotypes and lack of correlation with constitutive resistance. *Oecologia*, 122: 83–89.
- Van Leeuwen, T., Tirry, L., Yamamoto, A., Nauen, R. & Dermauw, W. (2015) The economic importance of acaricides in the control of phytophagous mites and an update on recent acaricide mode of action research. *Pesticide Biochemistry & Physiology*, 121: 12–21.
- Whitfield, G.H. (1984) Temperature threshold and degree-day accumulation required for development of postdiapause sugarbeet root maggots (Diptera: Otitidae). *Environmental Entomology*, 13: 1431–1435.
- Wilson, L.J. (1994) Plant-quality effect on life-history parameters of the two-spotted spider mite (Acari: Tetranychidae) on Cotton. *Journal of Economic Entomology*, 87: 1665–1673.

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مدل رشدی جمعیت *Tetranychus urticae* Koch (Acari: Tetranychidae)

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چکیده

کنه تارتن دو لکه‌ای، *Tetranychus urticae* Koch آفت جدی محصولات مختلف در سراسر جهان است. از راهکارهای گوناگونی برای تنظیم جمعیت این آفت استفاده می‌شود. بدین منظور، به عنوان نخستین گام، یک مدل رشدی جمعیت توسعه داده شده است تا دینامیسم رشد جمعیت کنه تارتن دو لکه‌ای را شرح دهد. در این رابطه، فراوانی جمعیت کنه تارتن دو لکه‌ای از ۸ تیر تا ۷ مهر ۱۳۹۵ در دو مزرعه لوبیا به صورت هفتگی تخمین زده شد. هر مزرعه با رقم‌های گلی و اختر به صورت جداگانه کاشته شد. در طی دوره نمونه‌برداری در هر مزرعه، ۳۰ گیاه به طور تصادفی انتخاب و یک برگ به عنوان واحد نمونه‌برداری از قسمت میانی گیاه انتخاب و یک مدل رشدی ساده برای *T. urticae* روی دو رقم لوبیا در نظر گرفته شد. نتایج نشان داد که کنه تارتن دو لکه‌ای الگوی فراوانی فصلی مشخصی دارد که بین دو رقم متفاوت است. بر اساس ارتباط بین تراکم تجمعی کنه تارتن دو لکه‌ای و زمان (روز) یک مدل رشدی لجستیک توسعه داده شد و این مدل ظرفیت بالای پیش‌بینی جمعیت کنه تارتن دو لکه‌ای روی دو رقم گلی و اختر را نشان داد. بنابر معادله لجستیک، ظرفیت تحمل محیط (carrying capacity) به ترتیب روی رقم‌های گلی و اختر $463/9 \pm 9/73$ عدد کنه در برگ و $59/67 \pm 8/72$ کنه در برگ ثبت شد. افزون بر این، مدل رشدی لجستیک می‌تواند برای پیش‌بینی جمعیت استفاده شود. آماره‌های تخمین زده شده مدل برای دو رقم، ابزار ریاضی جدیدی را برای اکولوژیست‌ها فراهم می‌کند تا بتوانند طغیان کنه تارتن را پیش‌بینی کنند و در نهایت راهکارهایی برای کنترل موثر کنه تارتن دو لکه‌ای به وجود آورند.

واژگان کلیدی: ارقام لوبیا؛ ظرفیت تحمل محیط؛ معادله لجستیک؛ دینامیسم جمعیت؛ کنه تارتن دو لکه‌ای.

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