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Effect of Tomato spotted wilt virus on life table parameters of *Frankliniella intonsa* (TRYBOM) (Thysanoptera:Thripidae) under laboratory conditions

Mohammad POORKASHKOOLI, Maryam ALEOSFOOR & Kambiz MINAEI

Abstract

Flower thrips*, Frankliniella intonsa*, is one of the most important agricultural pests that can transmit tospoviruses. In this research life table parameters of *F. intonsa* was studied in the presence and absence of Tomato spotted wilt virus under laboratory conditions (25±2°C, 65±5% RH and 14:10 h L: D photoperiod) based on the age-stage, two-sex life table. Based on the results, viruliferus *F. intonsa* had not significantly different in egg, L1, L2, pre pupa, pupa and total pre adult longevity compared to unexposed one. In non viruliferus *F. intonsa*, intrinsic rate of increase (rm), Net reproduction rate (R_0), Mean generation time (T), Finite rate of increase(λ) and Gross reproduction rate (GRR) were 0.1068 day^{-1}, 17.22 offspring per individual, 26.65 day, 1.11 day^{-1} and 26.17 offspring per individual, respectively. In viruliferus *F. intonsa*, intrinsic rate of increase (rm), Net reproduction rate (R_0), Mean generation time (T), Finite rate of increase (λ) and Gross reproduction rate (GRR) were 0.107 day^{-1}, 18.13 offspring per individual, 27.02 day, 1.1145 day^{-1} and 30.57 offspring per individual, respectively. According to our results, no statistically significant differences were seen between viruliferus and non viruliferus individuals.

Key words: life table, flower thrips, Tomato spotted wilt virus.

Introduction

There is no doubt about the association between tospoviruses and thrips (MOUND 2002). However, scarcely 2% of thysanoptera species are known to be vectors (ULLMAN et al. 1997). One of this is the European species, *Frankliniella intonsa* (flower thrips), that probably originated from the western Asia (HODDLE et al. 2014).

Tomato spotted wilt tospovirus (TSWV), the type member of the genus *Tospovirus* (FAUQUET et al. 2005) (family Bunyaviridae), is one of the most destructive plant viruses damaging many crops cultivated in the open field as well as in the greenhouses (GOLDBACH & PETERS 1994; PRINS & GOLDBACH 1998; PAPPU et al. 2009). Currently, TSWV ranks among the top 10 most economically important plant viruses worldwide (MUMFORD et al. 1996; SHERWOOD et al. 2000; PARRELA et al. 2003). TSWV infects its plant hosts and insect vectors simultaneously and exclusively transmitted by thrips belonging to the family Thripidae (order Thysanoptera) (WHITFIELD et al. 2005).

Tomato spotted wilt virus is transmitted in a circulative, propagative and persistent manner (SHERWOOD et al. 2000; WHITFIELD et al. 2005), only when the virus is acquired by the 1st and 2nd thrips larvae (ULLMAN et al. 1992; WIJKAMP & PETERS 1996; VAN DE WETERING et al. 1996). Soon after uptake, an increase in the viral protein indicates replication of TSWV in the thrips vector (ULLMAN et al. 1995, 1997; MORITZ et al. 2004). The ability of thrips to transmit the tospovirus declines when the virus is taken up during the late larval development (VAN DE WETERING et al. 1996). After passing the midgut barrier successfully, TSWV finally reaches the salivary gland cells, where it propagates further and stored there until it is transmitted via the saliva during feeding (ULLMAN et al. 1993; WIJKAMP et al. 1993; NAGATA et al. 1999, 2004; WHITFIELD et al. 2005). Furthermore, TSWV has no trans-ovarian (vertical) transmission; therefore, each generation of thrips must reacquire the virus for the disease epidemic to continue (WIJKAMP et al. 1995; VAN DE WETERING et al. 1996; NAGATA et al. 1999; MORITZ et al. 2004).

The TSWV-thrips interaction is specific because the tospoviruses may originally have been insect-infecting viruses that subsequently adapted to plant infection (GOLDBACH & PETERS 1994). Rapid co-evolution between thrips and tospoviruses is shown by the variability of different thrips populations in their efficiency in transmitting different TSWV isolates (NAGATA et al. 2004; WHITFIELD et al. 2005). In the thrips-virus relationship, a factor to be considered is the specific effects of virus infection on the fitness of the thrips: these probably vary according to the specific thrips-virus combination, and remain unclear, with many studies giving contradictory results (WIJKAMP et al. 1995; ULLMAN et al. 1997; MARIS et al. 2004; BELLIURE et al. 2005; STUMPF & KENNEDY 2007). However, at the molecular level, TSWV replicates in thrips body and is likely to lead to a complex of responses there that may affect its fitness (GOLDBACH & PETERS 1994; WIJKAMP et al. 1996; BELLIURE et al. 2005; STUMPF & KENNEDY 2007). This characteristic allows the virus-vector relationship to be thought of as a virus causing an infection in the insect vector that may or may not be termed 'disease' according to each thrips species specific-virus interaction. Insects have the capacity to activate their innate defense mechanism against a variety of pathogens (STRAND 2008) and their cellular immune response to fungi, bacteria and protozoa is well known (IRVING et al. 2001; HOFFMANN & REICHHART 2002). In contrast, their

response to viral infections remains relatively poorly understood (LI et al. 2002; ROIGNANT et al. 2003; BANGHAM et al. 2006; STRAND 2008; GERARDO et al. 2010; MCNEIL et al. 2010). ROTENBERG & WHITFIELD 2010 reported after Tswv infection of thrips, several genes that are characteristically initiated as part of the insect defense response to pathogens expressed, providing evidence that thrips respond an immune response to TSWV (MEDEIROS et al. 2004). This can cause behavioural as well as physiological changes, potentially influencing vector performance (BELLIURE et al. 2008; STAFFORD et al. 2011).

This study aimed to examine more in detail the influence of TSWV on life table parameters of *F. intonsa*. The model systems *F. intonsa* (FT), TSWV and the host plant *Capsicum annuum* were chosen because of their economic importance and appropriate handling conditions. The effects of TSWV on FT longevity, fecundity and survival were determined, as well as the intrinsic rate of increase (r); the finite rate of increase (λ); the net reproductive rate (R_0) and the mean generation time (T) of flower thrips towards either TSWV-infected or uninfected leaflets.

Results of this research are envisaged to contribute to a clear understanding into the plant-vector-virus interaction, which is essential for accurate diagnosis and control of the TSWV epidemic, as well as the control of *F. intonsa* as a crop pest.

Material and methods

Insect culture

Thrips were collected from alfalfa (*Medicago sativa*) farms at the College of Agriculture, Shiraz University. Collected samples were taken to the germinator in enclosed plastic containers (35*24*9cm) that had 4 holes (2.5 cm diameters for each) at their lids that were covered up in white cloth and kept at 25 ± 2 ºC, 65 ± 5 % relative humidity (RH) and a photoperiod of 14:10h (L: D). Before thrips were used in the experiments, they had been reared for 2-3 generations on cucumber (Cucumis sativus) as described below.

After the cucumbers were disinfected with ethanol 70% for 1 min, they were put in plastic containers (7×11×18 cm) that had a 5*8 cm hole in their lids covered by nets to make desirable ventilation possible (MADADI et al. 2005). Several generations of thrips were reared in vitro and pollens were used to feed the larvae. The rearing containers were kept in the germinator as mentioned above (STUMPF & KENNEDY 2007, 2005).

Tospovirus isolates and maintenance

The infected sweet pepper, *Capsicum annuum* with symptoms of Yellow-green spots on plant leaves were collected from pepper farms of Kaftarak (east of Shiraz) and confirmed for TSWV by a double-antibody sandwich enzyme-linked immune absorbent assay (DAS-ELISA) according to CLARK & ADAMS (1977). The isolates were maintained in greenhouse conditions (28-30°C and 70-80% RH) by mechanical inoculation on C. annum (4-5 leaflet stage). The rapid and efficient method developed by MANDAL et al. (2008) was adopted for the mechanical inoculation of the TSWV into the host plant.

Successful transmission of TSWV was confirmed by DAS-ELISA. After confirmation, infected leaves showing symptoms were used as an inoculum source for further series of mechanical inoculations (at intervals of 1-2 weeks depending on the greenhouse conditions) and also for virus acquisition by the newly hatched first instar larvae (L1) from the virus-free colony of FT used for life table experiments as described below. TSWV acquisition by FT Female adults were allowed to lay eggs for a period of 1 day on the cucumber fruit in Plexi glass cages, closed on top with nylon mesh. Newly hatched L1 (<4 h old) were collected 2 days later and put on virus infected *C. annum* leaflet in a Petri dish (9 cm diameter) for an acquisition access period (AAP) throughout their larval stages. The bottom of the Petri dish was covered by a filter paper and few milliliters of distilled water were added. For ventilation purposes, the lid of each Petri dish had three equally spaced 12-mm-diameter holes that were covered with nylon mesh. Once closed, all of the Petri dishes were sealed with Parafilm M® (Pechiney Plastic Packaging, Inc., Chicago, IL) to avoid escape. The larvae pupated after 4-6 days; then, the pupae were transferred individually onto a single virus-free *C. annum* leaf disc (17 mm diameter) in another clean Petri dish (6 cm diameter) for further experiments. Two different thrips treatments were used for flower thrips: exposed and unexposed FT. The term 'exposed' referred to adults that fed on TSWV-infected *C. annum* leaves throughout their larval stages, while unexposed (control) referred to the ones that fed on virus-free leaves.

Developmental time and mortality

Exposed female thrips were randomly selected from the stock culture and transferred onto excised sweet paper leaf disks placed upside down in Petri dishes (8 cm diameter). Offspring, who were born during the 24 h, were individually confined on sweet paper leaf disks in Petri dishes over a wet filter paper. One opening (2 cm in diameter) had been made on the lid of each Petri dish that covered by nylon mesh for ventilation and in order to prevent possible escapes; the Petri dishes were secured using parafilm. Those replications in which nymphs died within 24 h after transfer or were lost during the experiment were removed. The filter paper in the Petri dishes was wetted daily, and The leaf discs were replaced daily by fresh ones Experiments were conducted at 25 ± 2 ºC, 65 ± 5 % relative humidity (RH) and a photoperiod of 14:10h (L: D) in temperature cabinets. With daily observation of immature stages and adults, their survivorship was recorded. To determine molting time, the exuviae were used. After counting, newly born larvae were removed. Each experiment was replicated 50 times. Some of the adult thrips were randomly removed and tested for virus infection based on GHOTBI et al. 2003. Samples were considered positive if absorbance values were at least three times those of healthy controls. In ELISA tests with TSWV-Ab, the average calculated absorbance (OD_{405}) values of infected thrips were 0.4 $\pm$ 0.002 and were significantly different with values obtained for disinfected samples (0.109+ 0.003). Experiments were repeated similarly for unexposed flower thrips as mentioned above.

Life table parameters

According to age-stage, two-sex life table theory, data were analyzed. So, raw data on developmental time, survivorship, longevity and female fecundity were analyzed based on the age-stage, two-sex life table theory (CHI & LIU 1985; CHI 1988) using TWOSEX-MSChart computer program (CHI 2012).

The age-stage specific survival rate (*sxj*) (*x* = age and *j* = stage), the age-stage specific fecundity (*fxj*), the age-specific survival rate (l_x), the age-specific fecundity (m_x), and the life table parameters (the intrinsic rate of increase (*r*); the finite rate of increase (λ); the net reproductive rate (R_0); the mean generation time (*T*) were constructed accordingly.

The intrinsic rate of increase (*r*) was determined by iteratively solving the Euler-Lotka equation with age indexed The intrinsic rate of increase (r) was determined by iteratively solving the Euler-Lotka equation with age indexed from 0 (GOODMAN 1982):

$$\sum_{x=0}^{\infty} e^{-r(x+1)} l_x m_x = 1$$

The finite rate of increase (λ) and the net reproductive rate (R0) were calculated as follows:

$$\lambda = e^r$$

$$R_0 = \sum_{x=0}^{\infty} l_x m_x$$

The mean generation time (T) is then calculated using the following equation:

$$T = \frac{\ln(R_0)}{r}$$

Statistical analysis

The raw data for 50 individuals were analyzed using the age- stage, two-sex life table approach (YU et al. 2013).To estimate the means, variances and standard errors of the population parameters, both jackknife (SOKAL & ROHLF 1995) and the bootstrap (EFRON & TIBSHIRANI 1993) techniques were used. In bootstrap technique, even with a small number of replications, Random resampling will produce variable means and standard errors, so, in order to reduce the variability of results, 10.000 replications were used in this study (YU et al. 2013).

Results and Discussion

Juvenile and Adult Parameters

The longevity of FT was influenced slightly after being exposed to the TSWV isolate compared to the control. Within the exposed treatments, FT had a slightly lower egg, L1, L2, pre pupa, pupa and total pre adult longevity compared to unexposed one. However, this difference was not significant when using the *t*-test at the 5% significance level (Tab. 1). BELLIURE (2005) found that when thrips feed on plant, plant defense mechanism induced, which reduced the suitability of plant for thrips. But these effects were cancelled when the plants infected with TSWV. These findings corroborate results from the STUMPF & KENNEDY 2007; BAUTISTA et al. 1994; WIJKAMP et al. 1996 and MARIS et al. 2004 who found that male and females reared on plant tissue infected with TSWV had similar development times and males and females reared on TSWV infected plant tissue developed to adult in less time.

In unexposed FT, 27 of 50 eggs emerged as females and 10 emerged as males. Among these 50 eggs, 10% died in the first larval stage and 12% in the pupal stage. In exposed FT, out of 50 eggs, 28 emerged as females and 13 emerged as males. Among these 50 eggs, 6 and 2% died in the first larval and pupal stage, respectively. The results of our study show that individual WFT exposed to TSWV exhibited lower mortality rate when compared to their unexposed counterparts. Similar response was observed by OGADA et al. 2012. This suggests that TSWV has a positive influence on WFT longevity and survival. MEDEIROS et al. (2004) showed that TSWV triggers an immune response in WFT tissues, which involves the transcriptional up regulation of antimicrobial proteins such as defenses and other immune system-related proteins like Toll, Toll-like receptors, lectins and complement- like proteins. Therefore, the thrips fitness will be improved and lower mortality will be seen compared to un exposed thrips.

Mean lifetime fecundities of un exposed and exposed FT were 31.9 and 28.2 eggs/female, respectively. Such difference was not significant at the 5% significance level (Tab. 2). WIJKAMP et al. (1995) reported that a Brazilian isolate of TSWV had no effect on *F. occidentalis* fecundity and reproductive rate at 25°C.This result is consistent with our result. In contrast, OGADA et al. 2012 and ROBB 1989 reported that although *F. occidentalis* had an increased in developmental rate, but its survival and reproductive potential decreased compared to those maintained on virus-free plant tissue. These differences could have been as a result of differences in virulence of the TSWV to *F. occidentalis*. However, the adult pre reproductive period and total pre reproductive period for the un exposed individuals was slightly longer compared to the exposed individuals (Tab. 2), but the difference was not statistically significant. This result is contrary to the results of OGADA et al. (2012). These conflicting reports could be explained by different TSWV isolate, host plants, thrips population and different experimental conditions.

Population Parameters

Age-stage-specific survival rates (sxj) of exposed and un exposed FT were similar to each other (Fig. 2). The survival rate represents the probability that an egg will survive to age x while in stage j. This parameter gives a detailed description not only of survival but also of stage transitions. These curves also show the survivorship and stage differentiation as well as the variable developmental rate. For example, the probability that an egg survives to the adult stage in exposed and un exposed treatment is 0.58 and 0.56, respectively. Variation in developmental rates among individuals cause some overlap between different stages (Fig. 1).

The age- specific survival rate (lx), female age-specific fecundity (mx), and the female age-specific maternity (lxmx) are depicted in Fig. 2. The curve of lx is a simplified version of the curves in Fig. 1. It seems that in both conditions (exposed and un exposed), the adult survival pattern belongs to survival cure Type I. The first oviposition of exposed and un exposed FT occurred simultaneously on day 17. The peak of age-specific fecundity (mx) was obvious at 24 d (28 larva) after birth for un exposed FT. There was no obvious reproductive peak for exposed individuals. The first death of adults started on day 23 and 26 for exposed and un exposed FT, respectively.

The means and standard errors of r, λ, R_0, GRR, and T estimated by using the Bootstrap method are shown in Tab. 3. The intrinsic rate of increase for exposed and un exposed FT was 0.107 d^{-1} and 0.106 d^{-1}, respectively. GRR, R_0 , and T for un exposed FT were 26.17 offspring, 17.22 offspring, and 26.65 d, respectively. GRR, R_0 , and T for exposed FT were 30.57 offspring, 18.13 offspring, and 27.02 d, respectively. No differences were found in any of the population parameters for exposed and un exposed FT using a t-test at the 5% significance level (Tab. 3).

Life Expectancy

The age-stage life expectancy (e_{xj}), the expectation life span of an individual of age x and stage j to live after age x, is plotted on the age-stage life expectancy (e_{xj}) curve (Fig. 3). Life expectancy represents the time that an individual of age x and stage j is expected to live. The life expectancy of an egg was 33 d for exposed and un exposed FT.

Reproductive Value

The age-stage reproductive value (v_{xj}) describes the expectation of future contribution of an individual of age x and stage j (Fig. 4). If the preoviposition period is counted as time from birth to first reproduction in females (TPOP), the mean TPOP for exposed and un exposed FT was 21.21d and 21.84d, respectively (Tab. 2). These values are close to the age of peak reproductive value (Fig. 4).

In conclusion, TSWV infects its plant host and insect vectors (GERMAN et al. 1992; ULLMAN et al. 1992). This can cause behavioural and physiological changes, potentially influencing vector performance (BELLIURE et al. 2008; STAFFORD et al. 2011). In this regard, conflicting reports have emerged on the effects of TSWV on the development rate, survival and reproduction rate of its thrips vectors (SAKIMURA 1963; ROBB 1989; WIJKAMP et al. 1996; MARIS et al. 2004; OGADA et al. 2012). This could have been as a

result of using different TSWV isolates, host plants, thrips populations as well as different experimental conditions and protocols.

Generally viruses isolate as well as host plant and insect ecotype has effect on life table experiments. Life table construction and its application in pest management programs seems to be a very boring process; but planning a successful and environmental friendly pest management strategy is impossible without the basic knowledge of life table and therefore, construction of life tables on economically important pests is a safe way to manage pests in order to achieve sustainable agriculture.

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Authors' addresses:

Mohammad POORKASHKOOLI

Former MS. Student, Department of Plant Protection, College of Agriculture,

Shiraz University, Shiraz, Iran.

E-mail: m.pourkashkuli@urmia.ac.ir

Maryam ALEOSFOOR

Assistant Prof., Department of Plant Protection, College of Agriculture,

Shiraz University, Shiraz, Iran.

Corresponding author, E-mail: aosfoor@shirazu.ac.ir

Kambiz MINAEI

Associate Prof., Department of Plant Protection, College of Agriculture,

Shiraz University, Iran

E-mail: kminaei@gmail.com

Tab. 1. mean number of time units ± standard errors spent by each individual in each life stage of *F. intonsa.*

\Statistics	Stage or sex	Unexposed FT	exposed FT	T	df	P
Developmental time (d)	Egg	2.12±0.113	1.9±0.112	1.35	71	0.181 (>0.05)
	L1	1.84±0.084	1.51±0.091	1.30	74	0.19 (>0.05)
	L2	4.49±0.164	4.3±0.155	0.76	75	0.44 (>0.05)
	Pre pupae	1.91± 0.124	1.74±0.103	1.15	71	0.25 (>0.05)
	Pupae	2.86±0.104	2.83±0.158	0.33	67	0.744 (>0.05)
Total preadult duration (d)	Female and male	12.95±0.29	12.25±0.408	1.44	71	0.155 (>0.05)
Adult longevity (d)	Female	30.85±1.13	31.22±1.090	1.24	50	0.229 (>0.05)
	Male	18.4±1.51	13.863±1.562	0.12	16	0.908 (>0.05)
Total longevity	Female and male	32.15±2.27	32.32±2.064	1.14	75	0.25 (>0.05)

Means with in a column followed by the same letter are not significantly different at the 5% confidence level according to Tukey's studentized range test.

Tab. 2. means and standard errors (in parentheses) of Adult Pre oviposition period, Total pre oviposition period, Female longevity and Mean number of fecundity of *F. intonsa.*

Stage	Unexposed FT	exposed FT	t	df	P
Adult Pre reproductive period	8.44±0.40	8.04±0.26	0.83	41	0.411 (>0.05)
Total pre reproductive period	21.84±0.43	21.21±0.40	1.06	47	0.29 (>0.05)
Female longevity	30.85±1.13	31.22±1.090	1.24	50	0.229 (>0.05)
fecundity	31.9±3.6	28.2±4.8	0.62	49	0.53 (>0.05)
Oviposition days	8.33±0.91	8.39±1.3	0.04	47	0.97 (>0.05)

Means with in a column followed by the same letter are not significantly different at the 5% confidence level according to Tukey's studentized range test.

Tab. 3. Population parameters (with r as the intrinsic rate of increase, **λ**, the finite rate of increase, R_0, the net reproductive rate, T, the mean generation time and GRR, Gross reproductive rate) ± the standard errors of *F.intonsa***,** estimated by using all individuals and the bootstrap techniques.

Population parameters	Mean ± SE		T	p	df
	Unexposed FT	exposed FT			
Intrinsic Rate of Increase (r)	0.1068±0.0093	0.10723± 0.01	0.02	0.983(>0.05)	49
Net Reproductive Rate (R0)	17.22±4.35	18.13±4.91	0.03	0.974(>0.05)	49
Gross Reproductive Rate (GRR)	26.17±5.22	30.57±7.6	-0.28	0.784(>0.05)	43
Mean Generation Time (T)	26.65±0.84	27.02±1.24	-0.04	0.970(>0.05)	43
Finite rate of increase (λ)	1.11±0.0103	1.1145 ±0.0111	0.02	0.983(>0.05)	49

Means with in a row followed by the same letter are not significantly different at the 5% confidence level according to Tukey's studentized range test.

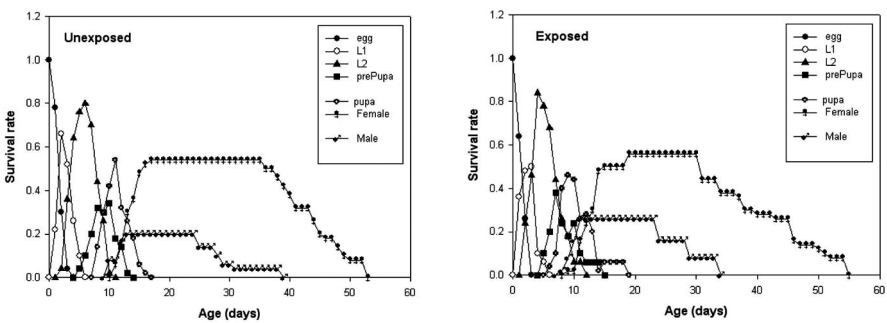

Fig. 1. Age- stage survival rate (s_{xj}) of exposed and Unexposed *F. intonsa* on *Capsicum annuum*.

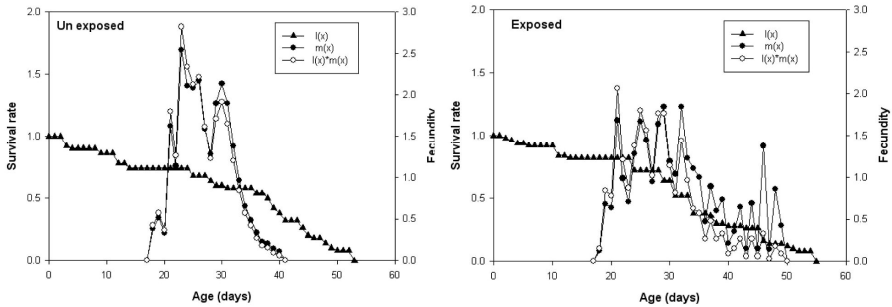

Fig. 2. Age- specific survival rate (l_x), age-specific fecundity (m_x) and age- specific mortality (lxmx) of exposed and unexposed *F. intonsa* on *Capsicum annuum.*

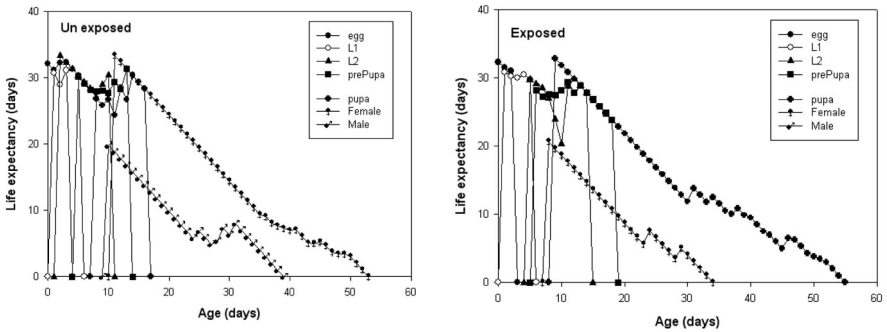

Fig. 3. Age- stage life expectancy (e_{xj}) of exposed and unexposed *F. intonsa* on *Capsicum annuum.*

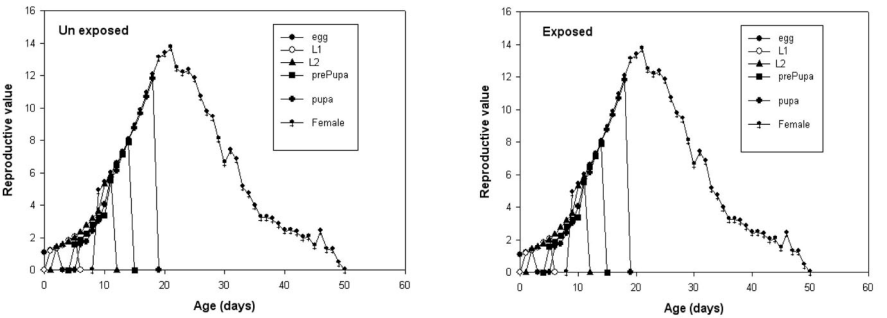

Fig. 4. Age-stage reproductive value (v_{xj}) of exposed and Unexposed *F. intonsa* on *Capsicum annuum.*

Buchbesprechung

OLSEN L.-H.: **Tracks and Signs** of the animals and birds of Britain and Europe. – Princeton University Press, Princeton 2013. 273 S.

In diesem hervorragend illustrierten Feldführer werden Spuren und Zeichen von Vögeln und Säugetieren aus England und Europa vorgestellt. Insgesamt behandelt dieser Band 175 Arten. Zu Beginn werden die Fußspuren der Säugetiere vorgestellt (Grafisch, mit Größenangaben sowie im Spurverlauf), es folgen 4 Seiten mit Hörnern und Geweihen, Vogelspuren (wie bei den Säugern, aber auch mit Abdruckfotos in Sand und Schnee). Sehr ausführlich wird auch die Losung dargestellt, gefolgt von Fraßspuren an Bäumen, Löchern, bearbeiteten Zapfen, Zweige, Nüsse und Früchte. Es geht weiter mit Nester und Baue, Gewölle (inkl. Schädel in Gewöllen), Federn und Fraßspuren von Greifvögeln. Die letzten beiden Drittel des Buches sind der Besprechung der Säugetiere gewidmet. Hier findet man gebündelte Informationen über Größe, Verbreitung, Verhalten, Habitat, ähnliche Arten und weitere spezifische Details über Spuren und Losungen sowie Verbreitungskarten.

Ein sehr informativer und empfehlenswerter Feldführer.

R. Gerstmeier

KEGEL B.: **Tiere in der Stadt.** Eine Naturgeschichte. – DuMont Buchverlag, Köln 2013. 478 S.

"Tiere in der Stadt" ist eigentlich das Resultat einer relativ jungen Disziplin biologischer Wissenschaften, der Stadtökologie. Städte werden eigentlich eher als Betonwüsten, Müllproduzenten und Giftschleudern, zumindest naturfern gesehen, gipfelnd in der Bemerkung "Städte seien Friedhöfe der Natur". Bernhard Kegel belehrt uns eines besseren; unübersehbar drängt die Wildnis in die Städte: Kaninchen fressen gemütlich im Mittelstreifen einer vielspurigen Straße, Füchse und Wildschweine marschieren durch Vorgärten, Waschbären haben Kassel zu ihrer Hauptstadt erkoren und Halsbandsittiche bringen einen exotischen "touch" in unser eintöniges Großstadtleben.

Bernhard Kegel hat Biologie und Chemie studiert, als ökologischer Gutachter gearbeitet, war Lehrbeauftragter und spielte Gitarre in diversen Berliner Jazzbands. Er nimmt uns auf seine Exkursionen zur Untersuchung der Berliner Stadtbiotope mit, schreibt von seinen Erlebnissen mit "Kampfhundebesitzer" beim Eingraben durchsichtiger Joghurtbecher und verliert dabei nie wissenschaftliche Einsichten und Fakten aus den Augen. Es gibt nicht viele Fachleute, die mit solch einem schriftstellerischen Talent gesegnet sind, auf den ersten Blick eher langweilige oder gar eklige Tatsachen so amüsant wie fachlich fundiert für den interessierten Laien zu "servieren". Der Fachmann wird aber auch mit den nötigen (wissenschaftlichen) Zitaten versorgt. Müsste man "Stadtökologie" lehren, bräuchte man eigentlich keine Vorlesung halten, sondern den Studierenden nur dieses Buch in die Hand drücken.

Eine genial formulierte, spannende, witzige und informative Naturgeschichte, die eigentlich spielend alle Bestsellerlisten erklimmen sollte.

R. Gerstmeier

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Maximilian SCHWARZ, Konsulent f. Wissenschaft der Oberösterreichischen Landesregierung, Eibenweg 6, A-4052 Ansfelden, E-Mail: maximilian.schwarz@liwest.at.

Redaktion: Erich DILLER, ZSM, Münchhausenstraße 21, D-81247 München;
Roland GERSTMEIER, Lehrstuhl f. Tierökologie, H.-C.-v.-Carlowitz-Pl. 2, D-85350 Freising
Fritz GUSENLEITNER, Lungitzerstr. 51, A-4222 St. Georgen/Gusen;
Wolfgang SPEIDEL, MWM, Tengstraße 33, D-80796 München;
Thomas WITT, Tengstraße 33, D-80796 München.

Adresse: Entomofauna, Redaktion und Schriftentausch c/o Museum Witt, Tengstr. 33, 80796 München, Deutschland, E-Mail: thomas@witt-thomas.com; Entomofauna, Redaktion c/o Fritz Gusenleitner, Lungitzerstr. 51, 4222 St. Georgen/Gusen, Austria, E-Mail: f.gusenleitner@landesmuseum.at