Experimental and Applied Acarology **23:** 551–565, 1999.

Prey-food types of *Neoseiulus fallacis* (Acari:Phytoseiidae) and literature versus experimentally derived prey-food estimates for five phytoseiid species

P.D. PRATT*, P. SCHAUSBERGER and B.A. CROFT
Department of Entomology, Oregon State University, Corvallis, OR 97331–2907, USA

(Received 21 July 1998; accepted 7 January 1999)

Abstract. The ability of *Neoseiulus fallacis* (Garman) to survive, reproduce and develop on a range of prey-food types was studied by holding adult females with each of 27 different prey-foods for 7 days. Survival and activity of adult females, eggs produced per female per day and quantity of immatures produced per female per day were estimated. Survival, reproduction and development were the highest and activity the lowest when held with *Tetranychus* species. Reproduction, survival and development were lower on non-tetranychid food although examples from nearly all prey-food types provided higher measured values than when without food. Proportional reproduction of *N. fallacis* on *Tetranychus* spider mites, other spider mites, eriophyid mites, other mites, insects and pollen was calculated. Proportions then were compared to values derived from a prey-food model based on the frequency of literature citations. The overall fit between data sets was good for the specialist type II species *N. fallacis*. Reproductive proportions for experimentally derived and literature-based data were estimated for four other phytoseiids that represent the specialist and generalist life style types I–IV: *Phytoseiulus persimilis* A. H., *Typhlodromus pyri* Scheuten, *Euseius finlandicus* (Oudemans) and *Euseius hibisci* (Chant). The literature model, based on records of feeding tests, did well in predicting feeding preference based on ovipositional rates for the specialist type I, *P. persimilis*, but was less accurate for the generalist type III, *T. pyri* and the generalists type IV, *E. finlandicus* and *E. hibisci*. Means to improve prey-food preference estimates for all life style types of phytoseiid species are discussed.

Key words: *Neoseiulus fallacis*, *Phytoseiulus persimilis*, *Typhlodromus pyri*, *Euseius finlandicus*, *Euseius hibisci*, prey range.

Introduction

Phytoseiid mites are effective biological control agents of pest mites in many plant systems (Helle and Sabelis, 1985). For instance, *Neoseiulus fallacis* (Garman) has been shown to suppress spider mite populations on apple, hops, peppermint, strawberry (Strong and Croft, 1995; Morris et al., 1996; Croft and Coop, 1998) and, more recently, ornamental nursery crops (Pratt and Croft, 1998). Although typically

* To whom correspondence should be addressed at: Tel: 541 737 5524; Fax: 541 737 3643; e-mail: prattp@bcc.orst.edu

released to control *Tetranychus urticae* Koch, recent studies have shown that *N. fallacis* can suppress populations of other, non-*Tetranychus* mite species such as *Panonychus citri* (McGregor) (Pratt and Croft, 1998), *Oligonychus ununguis* (Jacobi) (Boyne and Hain, 1983) and *Phytonemus pallidus* (Banks) (Croft and Pratt, 1998). These studies suggest that *N. fallacis* may numerically respond to multiple mite pests on many different plant types. These attributes may be advantageous when multiple pests occur within a highly diverse multicropping system as is found in commercial ornamental nurseries.

Unfortunately, little is known about the prey or food range of *N. fallacis*. To our knowledge, no studies have measured feeding and development on a wide range of prey-food types using standard methods. McMurtry and Croft (1997) used qualitative methods to classify *N. fallacis* as a type II selective predator of tetranychid species that produce dense webbing. Their analysis was based on provisional food preference values. The classification of type II is consistent with the more quantitative model derived from the literature citation analysis of food types performed by Croft et al. (1998b). Croft et al. (1998b) suggested that a more accurate estimate of the feeding preference could be obtained through comprehensive studies on the effect of various prey-foods on reproduction. Thus, the objectives of this study were to (1) measure the ability of *N. fallacis* to survive, feed and reproduce on a range of prey-food types using standard methods, (2) compare the results of point (1) to data from the literature citation index model of Croft et al. (1998b) and (3) to compare similarly derived data for other selected species that represent a full range of life style types (McMurtry and Croft, 1997; Croft et al., 1998a).

Methods

Neoseiulus fallacis *cultures*

Laboratory cultures of *N. fallacis* were originally collected from agricultural crops in the Willamette Valley, OR, USA (Hadam et al., 1986). These cultures were maintained for 6 years with yearly additions from field-collected mites. Cultures were held at 25 ± 5°C, 16 : 8 h L : D and 80 ± 10% RH and mites were fed mixed life stages of *T. urticae* three times per week. Randomly selected gravid females were used in this study. Prior to tests, adult female mites were held without food for 24 h to produce similar levels of hunger.

Feeding tests

The 27 prey-food types presented to *N. fallacis* were collected from ornamental nursery plants or neighbouring agricultural fields during March–June 1997. Pollen grains were collected by aspirating anthers from respective host plants (Table 1).

Mites and insects were collected from ornamental nursery plants except for *Tetranychus lintearius* Dufour, which was collected from gorse plants (*Ulex europaeus* L.)

Table 1. Adult female survival, activity, oviposition and immature development of *N. fallacis* when held with excess amounts prey-food types over 7 days

Prey-food	Survivorship[a]	Activity[b]	Number of eggs produced per female per day	Number of immatures produced per female per day
Tetranychus spider mites (TSM)				
T. urticae	1.00a	0.17h	1.78a	1.15a
T. lintearius	0.94a–d	0.22g–h	2.00a	1.27a
Other spider mites (OSM)				
O. ununguis	0.68e–h	0.72a–e	0.75b–d	0.37b–g
O. illicis	0.63f–h	0.67a–e	0.54c–f	0.43b–d
P. citri	0.73b–g	0.52d–g	0.83b–c	0.41b–f
P. ulmi	0.99a	0.77a–e	0.51c–g	0.27d–h
Other mites (OM)				
Orthotydeus spp.	0.68e–h	0.59b–f	0.12j–k	0.10g–h
P. pallidus	0.91a–e	0.32f–h	0.73b–d	0.42b–e
Tyrophagus putrescentiae	0.45h–i	0.95a	0.13l–k	0.00h
Eriophoid mites (EM)				
A. schlechtendali	0.87a–f	0.94a	0.96b	0.60b
Insects (INS)				
Trialeurodes vaporariorum	0.92a–e	0.69a–e	0.54c–e	0.44b–e
Psocidae	0.92a–e	0.54c–g	0.24e–k	0.17e–h
Frankliniella occidentalis	0.79a–g	0.67a–e	0.08k	0.02h
Quadraspidiotus perniciosus	0.70c–g	0.47e–h	0.22e–k	0.15e–h
Pollen (POL)				
Z. mays	0.93a–e	0.69a–e	0.77b–d	0.56b–c
H. frondosum	0.94a–c	0.78a–e	0.47d–l	0.36b–g
T. cordata	0.93a–e	0.74a–e	0.51c–g	0.38b–g
R. discolor	0.95a–c	0.72a–e	0.48e–h	0.39b–f
Trifolium pratense	0.95a–c	0.80a–d	0.44de–j	0.29c–h
Nandina domestica	0.64f–h	0.93a	0.19f–k	0.06h
Cucurbita pepo	0.96a–b	0.74a–e	0.15h–k	0.09g–h
Weigela florida 'Red Java'	0.76a–g	0.84a–c	0.18g–k	0.15e–h
Catalpa speciosa	0.68d–g	0.83a–d	0.12j–k	0.09g–h
Spiraea × *bumalda* 'Gold Flame'	0.70c–g	0.86a–b	0.15h–k	0.13f–h
Fuscia hybrida	0.78a–g	0.91a	0.21e–k	0.19d–h
Others				
Honey water	0.83a–g	0.52d–g	0.34e–k	0.28c–h
Honeydew	0.58g–i	0.33f–h	0.18g–k	0.18d–h
Starvation (arena)	0.36h	0.57b–f	0.04k	0.00h
Starvation (apple leaf)	0.64f–g	0.71a–e	0.21e–k	0.16e–h
p value[c]	< 0.0001	< 0.0001	< 0.0001	< 0.0001

[a] Percent female survival after 7 days in arenas.
[b] Percent female activity (ambulation) within arena per 1 min observation per day.
[c] Means of all tests were analysed simultaneously by ANOVA; df = 28, 203.
Means followed by different letters are significant at $\alpha = 0.05$ (Tukeys HSD).

near Clackamas OR, USA. When held with insects, *N. fallacis* was always provisioned separately with first instar thrips, scale or whitefly or first and second nymphal instars of psocids. Honeydew droplets were collected from the aphid *Illinoia lambersi* MacGillivray that had fed on rhododendron ('Anah Kruschke'). A mixture of honey water was created from equal parts of *Apis mellifera* L. honey and distilled water.

Except for two diets (see below), all feeding tests were conducted on 2.5 × 2.5 cm arenas constructed of waterproof paper and ringed with a sticky material (Tanglefoot®, The Tanglefoot Co., Grand Rapids, MI 49504) to prevent escape. When *N. fallacis* was provisioned with *Panonychus ulmi* Koch or *Aculus schlechtendali* (Nalepa), a 2.5 cm^2 apple leaf arena (containing midrib) ringed with water-soaked cotton tissue was used. All feeding arenas were replicated eight times per prey-food type and placed on a piece of water-saturated foam rubber contained in a tray of water (Croft et al., 1998a). Three *N. fallacis* adult females of similar age were transferred to each arena with a camel's hair brush. Excess amounts of each prey-food were provisioned every 24 h and arenas were placed in a 1 × 2 m environmental chamber at 25 ± 1°C, 80 ± 10% RH and 16 : 8 h L : D for 7 days. *Neoseiulus fallacis* was also held without food on each of the feeding test substrates (paper or apple leaf). Survivorship, activity (percent of time spent in ambulation per minute in the arena), oviposition per female per day and the number of immatures (larvae, protonymphs and deutonymphs) present per female per day were assessed every 24 h. Eggs and immatures were not removed from the arenas but eggs and immatures per female per day were derived by comparing stage composition changes between days. Cannibalism was also assessed daily by reviewing each arena for dead or shrivelled corpses. The means of each measured attribute were analysed by analysis of variance (ANOVA) and Tukeys Honest Significant Difference (HSD).

Literature-based versus oviposition-based feeding preference models

To compare our findings with a proposed literature citation index (LCI) model (Croft et al., 1998b), we categorized diets into six groups: *Tetranychus* spider mites (TSM), other spider mites (OSM), eriophyoid mites (EM), other mites than those previously mentioned (OM), insects (INS) and pollen (POL). Assuming that ovipositional rates reflect feeding specialization (Dicke et al., 1990), feeding preference indices (FPI) were calculated by averaging the ovipositional rates of *N. fallacis* within each of the six prey-food types in Table 1 and then determining the proportion associated with each prey-food type mean to the sum of the six means of each type (see the Appendix). Because proportion data have unknown underlying distributions we used randomization tests, which are more powerful than other non-parametric tests, to compare the LCI with the FPI (Manly, 1991). Our null hypothesis was that the squared difference of the LCI model and the FPI would equal zero, whereas the alternative hypothesis was that the squared difference was greater than zero. We randomly reordered the FPI 1000 times, found the difference between the LCI and the FPI and calculated the sums of squares for each randomization. We then identified the sums of squares greater than the observed sums of squares and divided by 1000 to compute the empirical probability (proportion) of accepting the null hypothesis (Manly, 1991).

We also sought to compare the results of the LCI of Croft et al. (1998b) with an FPI calculated from oviposition rates from previous studies of *Phytoseiulus persimilis* A.H., *N. fallacis*, *Typhlodromus pyri* Scheuten, *Euseius finlandicus* (Oudemans) and *Euseius hibisci* (Chant). The criteria for selecting these species was that they have been the most commonly studied ones relative to prey types, they spanned the range of life style types I–IV and, for *N. fallacis*, we could determine the effect of the data reported herein on the FPI (McMurtry and Croft, 1997). The criteria for selecting the specific feeding test data consisted of tests with (1) excess prey-food provided, (2) conditions of 22–27°C and RH of 60–90% and (3) duration of the test $\geqslant 7$ days. Again, proportions for each species were derived and randomization tests were performed as before (see the Appendix).

Results

Feeding tests

Survivorship of *N. fallacis* was significantly different between prey-food treatments ($F = 10.71$, df = 28, 203 and $p < 0.0001$). *Neoseiulus fallacis* had highest survival when feeding on tetranychid species and reached maximum survival when feeding on *T. urticae* (Table 1). When compared to *T. urticae*, survival significantly decreased when held with OSM and OM ($p < 0.05$), except *P. ulmi* or the tarsonemid *P. pallidus*, respectively. *Neoseiulus fallacis* survived equally well when held with *T. urticae* or the eriophyid *A. schlechtendali*. Whiteflies, psocids and thrips provided similar survival for *N. fallacis* to *T. urticae* and insects in general improved survival as compared to starvation conditions. Pollen increased survival when compared to starvation and approximately 73% of the pollen types provided similar survival to *T. urticae*. When fed honey water, survival was similar to that when held with *T. urticae* but aphid honey dew was not different from starvation. In contrast, *N. fallacis* held without food survived at lower levels, but longer on apple leaves than on waterproof paper arenas.

The activity of *N. fallacis* was also significantly different between prey-food treatments ($F = 12.27$, df = 28, 203 and $p < 0.0001$). *Neoseiulus fallacis* tended to be arrested most when held with *T. urticae*. None of the other treatments differed from the starvation treatments.

Egg production by *N. fallacis* was significantly different between prey-food treatments ($F = 52.26$, df = 28, 203 and $p < 0.0001$). When held with TSM, *N.*

fallacis produced nearly twice as many eggs as compared to all other treatments (Table 1). OSM provided a lower oviposition rate but was significantly greater than starvation treatments. Among OM, only *P. pallidus* provided egg production above that of the starvation level. When *N. fallacis* was held with *A. schlechtendali*, egg production was higher than all other treatments except for TSM. *Neoseiulus fallacis* produced more eggs on whiteflies than when starved but mean values for other insects were not significantly different. Among several pollens, honey water and honeydew, corn pollen was the only source that provided for greater egg production than starvation. Egg production did not differ between starvation treatments.

Immature production by *N. fallacis* was significantly different between prey-food treatments ($f = 29.9$, df = 28, 203 and $p < 0.0001$). When *N. fallacis* was held with TSM more immatures were produced per female per day than other prey-food treatments ($p < 0.05$). Among OSM, *Olygonychus illicis* (McGregor), *O. ununguis* (Jacobi) and *P. citri* provided for more production than starvation treatments. *Neoseiulus fallacis* produced more immatures on *P. pallidus*, *A. schlechtendali* and whitefly crawlers than when starved, although prey-food types OM, EM and INS were not significantly different. Only *Zea mays* L., *Hypericum frondosum* Michaux, *Tilia cordata* Miller and *Rubus discolor* Weihe & Nees pollens allowed for more immature production than starvation treatments. Neither honeydew nor honey water influenced immature production as compared to starvation treatments.

Literature-based versus oviposition-based feeding preference models

The literature-based model accurately predicted feeding specialization of the type II *N. fallacis* as measured by reproduction and pre-existing literature (Table 2 and Fig. 1b). Only ten of 1000 random sums of squares tests had a better fit of the model than values determined from our reproduction tests. When comparing the FPI generated from the literature only, 32 of 1000 random sums of squares had a better fit to the

Table 2. Randomization test comparing literature citation indices versus feeding perference indices for five phytoseiid mites (Manly, 1991)

	Life style type[a]	Number of models with better fit[b]	Empirical proportion[c]	Goodness of fit rank[d]
P. persimilis	I	1	< 0.99	1
N. fallacis (Table 1)	II	10	< 0.99	2
N. fallacis (literature)	II	32	0.96	3
T. pyri	III	136	0.86	4
E. finlandicus	IV	370	0.63	5
E. hibisci	IV	431	0.57	6

[a] Based on assignments made by McMurtry and Croft (1997).
[b] Number of sums of square values less than the observed sums of squares.
[c] Proportion of extreme values in randomization test.
[d] Ranking of goodness of fit between literature citation model and reproductive values.

data. Similarly, feeding specialization was predicted well for the type I *P. persimilis* (Table 2 and Fig. 1a), with only one of 1000 randomizations greater than actual reproduction data from various studies. In contrast, the model output for the type III *T. pyri* was only moderately similar to reproductive data from the literature and the type IVs, *E. finlandicus* and *E. hibicsi*, had even more disparity between the literature and measured reproductive values (see the Appendix and Fig. 1c and d).

Discussion

Type II selective predators of tetranychid mites are described as having a broad range of prey within the Tetranychidae and limited reproduction on other mite groups, insects and pollen (McMurtry and Croft, 1997; Croft et al., 1998a). Our experimental data suggest that *N. fallacis* has a prey range similar to species that are classified as type II selective predators of tetranychid mites. Survival, reproduction and development were consistently highest and activity lowest when held with *Tetranychus* species. Reproduction was limited when with non-tetranychid species although representatives from nearly all prey-food types provided for reproduction that was higher than under starvation conditions.

One possible explanation for the better performance of *N. fallacis* when feeding among *Tetranychus* species would be the preconditioning of metabolic functions or experience gained from having been reared on *T. urticae*. Would a strain of *N. fallacis* reared strictly on pollen behave differently then the one tested herein? Such strain tests have yet to be conducted, but they would be useful in estimating how adaptive phytoseiids might be in adjusting to predominant food sources. While our findings were not adjusted for previous food sources, *Tetranychus* species may be typical prey items of type II predators and any preconditioning experienced in these studies may be similar to those prey conditions found in nature (McMurtry and Croft, 1997).

Our data have relevance for the use of *N. fallacis* as a biological control agent of mite pests and even for a broader range of species that occur in a diversified cropping system such as ornamental nurseries (Pratt and Croft, 1998). McMurtry (1992) proposed that species with broad prey ranges may remain longer on plants and regulate pest mite outbreaks effectively. Such species may also readily disperse between plant systems where they can prey on different prey types and supplemental foods (Pratt et al., 1998). Ahlstrom and Rock (1973) suggested that pollen might enhance stability of the predator populations during periods of low spider mite populations. We showed that *N. fallacis* will feed and reproduce on various pests and that other less-injurious mites, insects or pollen may enhance survival when pest mites are scarce. As predators leave hibernacula in spring, alternative prey may have importance while tetranychid mites are still in diapause (Overmeer, 1985). In

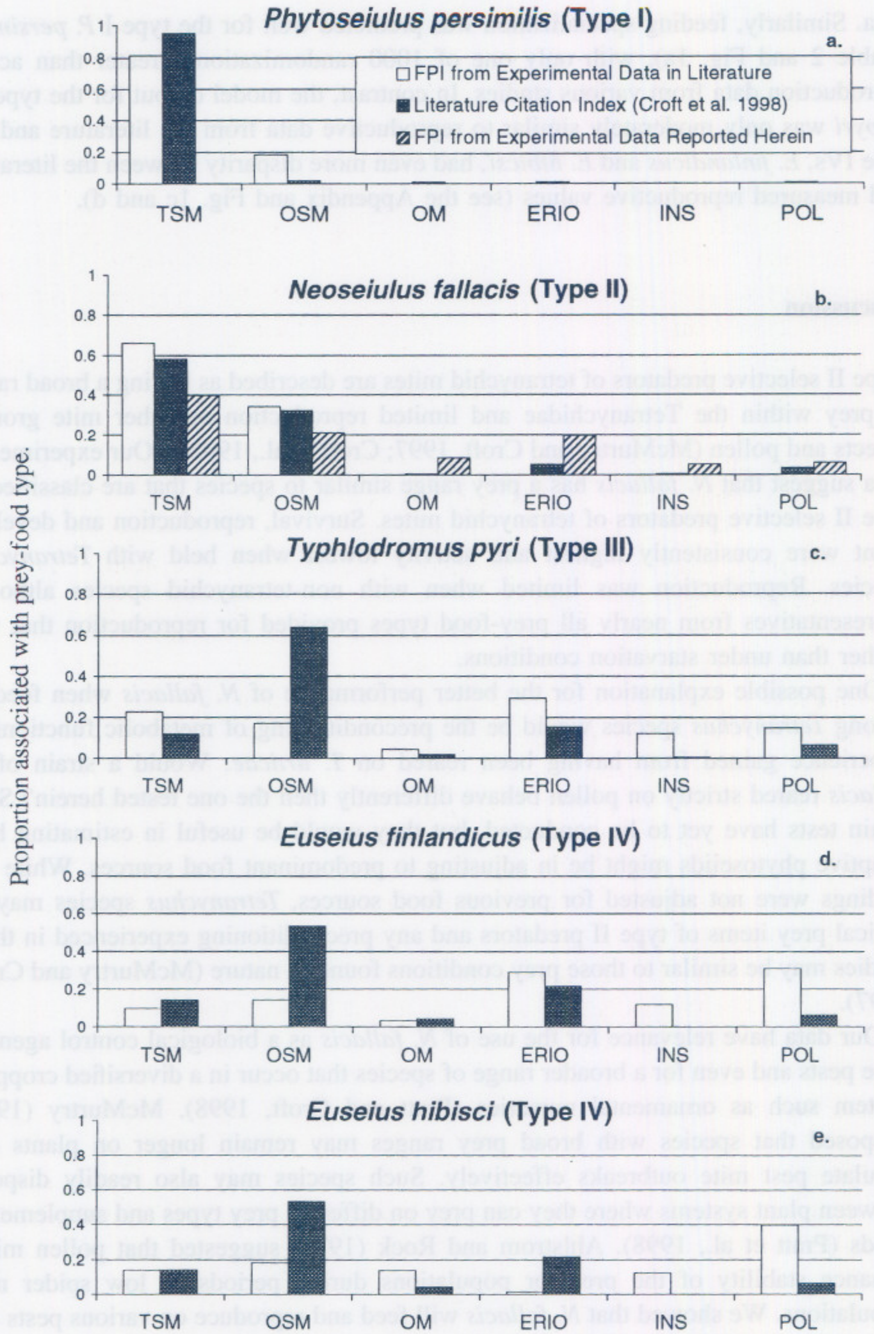

Figure 1. Graphic comparison of feeding preference as described by feeding studies (*N. fallacis* only), a literature citation index and a reproductive-based feeding preference index.

addition, alternate prey or foods may aid in the establishment of predators released to control low densities of primary target pests (Ramakers and Voet, 1995).

Our data give perspective to the literature-based model of Croft et al. (1998b). Based on our limited analyses, this model predicts prey-food suitability of type I and II predators of spider mites quite well (Fig. 1a and b) when compared to experimental data for oviposition, but predictions for generalist type III and IV species are less accurate (Fig. 1c and e). One explanation for high predictability of the type I predators may be due to lack of reproductive values for *P. persimilis* on non-tetranychid food (see the Appendix). These missing parameters may be a function of the lack of reporting due to unsuccessful results, them not being found in our literature search or they have simply not been studied. Another explanation is that there has been greater emphasis on testing reproductive performance on pests of economic importance in the past rather than on alternate prey or supplemental foods (Sabelis and Janssen, 1994; Croft et al., 1998b). Literature-based values consistently underestimate reproductive success among the rarely tested groups of OM, INS and POL (Fig. 1c–e). Types III and IV readily feed upon these foods. Expanding tests to include a fuller range of these prey-foods will likely improve estimates of prey preference for all life style types.

Finally, we note that Dicke et al. (1990) found that prey-food preference was usually correlated with reproductive values, but there may be exceptions where a high prey-food preference does not indicate a source upon which a natural enemy will show its greatest survival, development and reproduction. For example, they found that *T. pyri* preferred feeding on the spider mite *P. ulmi*, but had higher rates of population increase (r'_m) when feeding on the eriophyid mite *A. schlechtendali*. In our study, we assumed that prey preference would be closely correlated to reproductive success but we propose that a better estimate of prey-food preference may be derived from multiple food tests with differing amounts of each presented simultaneously and that several different parameters of survival and reproduction should be included. Such tests are difficult and expensive to carry out, but they would better represent the feeding preference of phytoseiid predators in natural systems.

Acknowledgements

We thank J.A. McMurtry, G.W. Krantz and H.-K. Luh (of Oregon State University) for comments on the manuscript. This paper is article 11,428, Oregon Agricultural Experiment Station.

Appendix. Oviposition rates, calculations of feeding proportions and references for four species of phytoseiid mites

Species	Prey-food group[a]	Prey- food	Eggs per female per day	Group mean[b]	Group proportion[c]	Reference[d]
P. persimilis	TSM	*T. cinnabarinus*	3.80			Pickett and Gilstrap (1986)
		T. pacificus	3.15			McMurtry (1977)
		T. pacificus	3.69			Takafuji and Chant (1976)
		T. pacificus	2.91			Amano and Chant (1977)
		T. pacificus	2.69			Badii and McMurtry (1984)
		T. urticae	3.16			Kennett and Hamai (1980)
		T. urticae	4.30			de Moraes and McMurtry (1985)
		T. urticae	4.10			Beglyarov (1967)
		T. urticae	3.80			Friese and Gilstrap (1982)
				3.51	0.81	
	OSM	*O. ununguis*	0.80			Ashihara *et al*. (1978)
				0 80	0.19	
	OM		No data			
				0.00	0.00	
	ERIO		No data			
				0.00	0.00	
	INS		No data			
				0.00	0.00	
	POL	*H. croceus*	0.00			McMurtry (1977)
				0.00	0.00	
N. fallacis	TSM	*T. urticae*	2.20			Ballard (1954)
		T. urticae	2.10			McClanahan (1968)
		T. urticae	3.50			Ball (1980)
		T. urticae	3.00			Croft and Blyth (1979)
		T. urticae	1.20			Lee (1972)
		Tetranychus spp.[g]	3.20			Smith (1961)
				2.53	0.62	
	OSM	*P. ulmi*	1.50			Burrell and McCormick (1964)
		B. arborea	0.00			Burrell and McCormick (1964)
		O. ununguis	2.50			Boyne and Hain (1983)

		O. pratensis	2.10			Heintz (1988)
				1.52	0.37	
	OM		No data			
				0.00	0.00	
	ERIO		No data			
				0.00	0.00	
	INS		No data			
				0.00	0.00	
	POL		No data			
				0.00	0.00	
T. pyri	TSM	*T. urticae*	1.00			Engel and Ohnesorge (1994)
				1.00	0.22	
	OSM	*B. arborea*	0.76			Herbert (1961)
		E. carpini	1.18			Duso and Camporese (1991)
		E. tiliarium	0.43			Kropczynska *et al*. (1988)
		P. ulmi	0.40			Engel and Ohnesorge (1994)
		P. ulmi	1.02			Duso and Camporese (1991)
		P. ulmi	0.68			Herbert (1961)
				0.75	0.17	
	OM	*K. aberrans*	0.30			Schausberger (1997)
		E. finlandicus	0.08			Schausberger (1997)
				0.19	0.04	
	ERIO	*C. vitis*	1.28			Engel and Ohnesorge (1994)
		C. vitis	1.24			Duso and Camporese (1991)
		E. vitis	1.45			Engel and Ohnesorge (1994)
		E. tristriatus	1.18			Kennett and Hamai (1980)
				1.29	0.29	
	INS	*D. reuteri*	0.57			Engel and Ohnesorge (1994)
		Q. perniciosus	0.49			Schausberger (1998)
				0.53	0.12	
	POL	Average of 18 pollens	0.64[e]			Engel and Ohnesorge (1994)
		M. criniflorum	1.01			Duso and Camporese (1991)
				0.65[f]	0.15	

Appendix. *Continued*

Species	Prey food group[a]	Prey food	Eggs per female per day	Group mean[b]	Group proportion[c]	Reference[d]
E. finlandicus	TSM	*T. urticae*	0.56			Schausberger (1992)
				0.56	0.10	
	OSM	*P. ulmi*	0.81			Schausberger (1991)
		E. tiliarium	0.69			Kropczynska *et al.* (1988)
				0.75	0.14	
	OM	*K. aberrans*	0.35			Schausberger (1997)
		T. pyri	0.04			Schausberger (1997)
				0.19	0.03	
	ERIO	*C. ribis*	1.72			Schausberger (1992)
		D. gigantorhynchus	1.50			Amano and Chant (1986)
				1.61	0.29	
	INS	*Q. perniciosus*	0.68			Schausberger (1998)
				0.68	0.12	
	POL	*B. pendula*	1.88			Schausberger (1992)
		Prunus sp.	1.67			Schausberger (1992)
		M. domestica	1.15			Schausberger (1992)
		Typha sp.	2.27			Kostiainen and Hoy (1994)
				1.74	0.31	
E. hibisci	TSM	*T. cinnabarinus*	0.37			McMurtry and Scriven (1964)
		T. cinnabarinus	1.05			Swirski *et al*. (1970)
				0.71	0.14	
	OSM	*P. citri*	1.00			McMurtry and Scriven (1964)
		P. citri	0.64			Zhimo and McMurtry (1990)
		O. punicae	1.22			McMurtry and Scriven (1964, 1965)
		E. orientalis	0.93			Swirski *et al*. (1970)
				0.94	0.18	
	OM	*B. phoenicis*	0.71			Swirski *et al*. (1970)
				0.71	0.14	
	ERIO	*P. oleivora*	0.14			McMurtry and Scriven (1964)
		P. oleivora	0.00			Swirski *et al*. (1970)
				0.07	0.01	

INS	*H. lataniae*	0.40			McMurtry (1963)
	A. aurantii	0.70			Swirski *et al*. (1970)
	B. tabaci	0.70			Swirski *et al*. (1970)
	B. tabaci	0.40			Meyerdirk and Coudriet (1985)
	R. syriacus	0.55			Swirski *et al*. (1970)
	F. occidentalis	1.70			Van Houten *et al*. (1995)
	S. littoralis	0.04			Swirski *et al*. (1970)
	P. citri	0.01			Swirski *et al*. (1970)
	E. ceratoniae	0.01			Swirski *et al*. (1970)
			0.64	0.13	
POL	*Mesembryanthemum sp.*	2.10			McMurtry and Scriven (1964)
	M. crocea	1.80			Zhao and McMurtry (1990)
	Z. mays	1.11			Swirski *et al*. (1970)
	C. edulis	1.05			Swirski *et al*. (1970)
	P. amygdalus	1.02			Swirski *et al*. (1970)
	Quercus sp.	2.00			Kennett and Hamai (1980)
	M. crocea	2.22			Tanigoshi (1981)
	C. annuum	2.80			Van Houten *et al* (1995)
			2.04	0.40	

[a] As described in Croft *et al*. (1998b).
[b] Mean within prey food group.
[c] Proportion of the group mean as divided by the sum of group means within species.
[d] References as found in Kostiainen and Hoy (1996), if not full citation found in reference section herein.
[e] Pooled mean of all oviposition rates in reference.
[f] Group mean was calculated by including all oviposition rates in reference and not from pooled mean.
[g] Mixture of the tetranychid mites *Tetranychus yusti* and *Tetranychus desertorum*.

References

Ahlstrom, K.R. and Rock, G.C. 1973. Comparative studies on *Neoseiulus fallacis* and *Metaseiulus occidentalis* for azinphosmethyl toxicity and effects of prey and pollen on growth. Ann. Entomol. Soc. Am. 66: 1109–1113.

Boyne, J.V. and Hain, F.P. 1983. Responses of *Neoseiulus fallacis* to different prey densities of *Oligonychus ununguis* and to different relative humidity regimes. Can. Entomol. 115: 1607–1614.

Croft, B.A. and Coop, L.B. 1998. Heat units, release rate, prey density, and plant age effects on dispersal by *Neoseiulus fallacis* after inoculation into strawberry. J. Econ. Entomol. 91: 94–100.

Croft, B.A. and Pratt, P.D. 1998. Reproduction and impact of phytoseiid mites on cyclamen mite, *Phytonemus pallidus* (Acari: Tarsonemidae) on strawberry. Proc. W. Wash. Horticult. Soc. 25: 130–139.

Croft, B.A., Monetti, L.N. and Pratt, P.D. 1998a. Comparative life histories and predation types: are *Neoseiulus californicus* and *N. fallacis* (Acari: Phytoseiidae) similar type II selective predators of spider mites? Environ. Entomol. 27(3): 532–538.

Croft, B.A., McMurtry, J.A. and Luh, H. 1998b. Do literature citation frequencies for six prey-food groups reflect feeding specialization and preferences among four phytoseiid predation types? Exp. Appl. Acarol. 22: 467–480.

Dicke, M., Sabelis, M.W., Jong, M.d. and Alers, M.P.T. 1990. Do phytoseiid mites select the best prey species in terms of reproductive success? Exp. Appl. Acarol. 8: 161–173.

Hadam, J.J., Aliniazee, M.T. and Croft, B.A. 1986. Phytoseiid mites of major crops in Willamette Valley, Oregon, and pesticide resistance in *Typhlodromus pyri*. Environ. Entomol. 15: 1255–1263.

Heintz, J.C. 1988. Influences of temperature and humidity on egg developmental rate, consumption and fecundity of a predatory mite, *Neoseiulus fallacis*. MS thesis, University of Nebraska.

Helle, W. and Sabelis, M.W. 1985. Spider Mites: Their Biology, Natural Enemies and Control, Vol. 1B. Elsevier, Amsterdam.

Kostiainen, T.S. and Hoy, M.A. 1996. The Phytoseiidae as Biological Control Agents of Pest Mites and Insects: A Bibliography. Monograph 17. University of Florida, Gainesville.

McMurtry, J.A. 1992. Dynamics and potential impact of 'generalist' phytoseiids in agroecosystems and possibilities for establishment of exotic species. Exp. Appl. Acarol. 14: 371–382.

McMurtry, J.A. and Croft, B.A. 1997. Life-styles of phytoseiid mites and their roles in biological control. Ann. Rev. Entomol. 42: 291–321.

Manly, B.F.J. 1991. Randomization and Monte Carlo Methods in Biology. Chapman & Hall, London.

Morris, M.A., Croft, B.A. and Berry, R.E. 1996. Overwintering and effects of autumn habitat manipulation and carbofuran on *Neoseiulus fallacis* and *Tetranychus urticae* in peppermint. Exp. Appl. Acarol. 20: 249–258.

Overmeer, W.P.J. 1985. Diapause. In: Spider mites: their biology, natural enemies and control, Vol. 1B, W. Helle and M. Sabelis (eds), p. 95–101. Elsevier, Amsterdam.

Pratt, P.D. and Croft, B.A. 1998. *Panonychus citri* (Acari: Tetranychidae) on ornamental *Skimmia* in Oregon and assessment of predation by native phytoseiid mites. Pan-Pacific Entomol. 74(3): 163–168.

Pratt, P.D., Monetti L.N. and Croft, B.A. 1998. Within and between plant dispersal and distributions of *Neoseiulus fallacis* and *N. californicus* (Acari: Phytoseiidae) in simulated bean and apple plant systems. Environ. Entomol. 27: 148–153.

Ramakers, P.M.J. and Voet, S.J.P. 1995. Use of castor bean, *Ricinus communis*, for the introduction of the thrips predator *Amblyseius degenerans* on glasshouse-grown sweet peppers. Med. Fac. Landbouww. Univ. Gent. 60: 885–891.

Sabelis, M.W. and Janssen, A. 1994. Evolution of life history patterns in the Phytoseiidae. In: Mites. Ecology and evolutionary analyses of life-history patterns, M.A. Houch (ed.), pp. 70–98. Chapman & Hall, New York and London.

Schausberger, P. 1997. Inter- and intraspecific predation on immatures by adult females in *Euseius finlandicus*, *Typhlodromus pyri*, and *Kampimodromus aberrans*. Exp. Appl. Acarol. 21: 131–150.

Schausberger, P. 1998. Survival, development and fecundity in *Euseius finlandicus*, *Typhlodromus pyri*, and *Kampimodromus aberrans* feeding on the San Jose scale *Quadraspidiotus perniciosus*. J. Appl. Entomol. 122: 53–56.

Strong, W.B. and Croft, B.A. 1995. Inoculative release of phytoseiid mites (Acarina: Phytoseiidae) into the rapidly expanding canopy of hops for control of *Tetranychus urticae* (Acarina: Tetranychidae). Environ. Entomol. 24: 446–453.

van Houten, Y.M., van Rijn, P.C.J.L., Tanigoshi, K., van Stratum, P. and Bruin, J. 1995. Preselection of predatory mites to improve year-round biological control of western flower thrips in greenhouse crops. Entomol. Exp. Appl. 74: 225–234.

Zhimo, Z. and McMurtry, J.A. 1990. Development and reproduction of three *Euseius* species in the presence and absence of supplementary foods. Exp. Appl. Acarol. 8: 233–242.