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Biological studies of the Australian predatory mite *Typhlodromips montdorensis* (Schicha) (Acari: Phytoseiidae), a potential biocontrol agent for western flower thrips, *Frankliniella occidentalis* (Pergande) (Thysanoptera: Thripidae)

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Abstract The biology of the Australian phytoseiid mite *Typhlodromips montdorensis* is described from material collected in Queensland and South Australia in 1994–1996. At 25°C, when fed on cumbungi (*Typha* sp.) pollen, the life cycle was completed in approximately 7 days, with an intrinsic rate of natural increase (r_m) of 0.32. Female–male pairs produced a mean total of 52.7 eggs within 28 days of oviposition. Females that were deprived of males after first mating stopped laying eggs after 7–19 days; however, if another male was added, they resumed egg laying and produced, on average, a total of 49.4 eggs. The sex ratio was 2.24 females to one male. At 25°C, fecundity on a diet of thrips larvae (first-instar *Frankliniella schultzei* Trybom) was high, ranging from 2.72 to 3.58 eggs per day on the third day, depending on previous diet. Consumption rate of thrips was also high, with an average of 7.23–14.44 first-instar larvae eaten per day on the third day, depending again on previous diet and also on number of thrips larvae made available. The species was also observed to feed on: (i) broad mite, *Polyphagotarsonemus latus* (Banks); (ii) tomato russet mite, *Aculops lycopersici* (Massee); and (iii) two-spotted mite, *Tetranychus urticae* Koch. No diapause was observed under conditions of 25°C, 8 h light and 10°C, 16 h dark. Eggs were sensitive to low humidity, with 50% failing to hatch below 70.8% relative humidity. This species is of interest as a candidate biological control agent for thrips, broad mite and tomato russet mite in protected crops.

Key words biology, natural enemy, phytoseiid mite, thrips biocontrol, *Typhlodromips montdorensis*.

INTRODUCTION

Our search within Australia for a biological control agent for western flower thrips, *Frankliniella occidentalis* (Pergande), identified several species of phytoseiid mites in association with thrips (Steiner & Goodwin 1995; Goodwin & Steiner 1996). The collections were made as part of a national survey in Australia for predators of thrips with potential for commercial development (Goodwin & Steiner 1996). Thirteen species of phytoseiids were reared and evaluated for fecundity, feeding rates on thrips, and ease of rearing. Here, we discuss one of those species, *Typhlodromips montdorensis* (Schicha).

Typhlodromips montdorensis was first described from collections made by Schicha in a nursery near Noumea, New Caledonia in 1978, where it was feeding on eriophyid mites (Schicha 1979). The holotype was from *Datura* leaves at Mount Dore. Further collections were made at the time from tomato (feeding on eriophyid mites) and from *Mucuna* sp. Schicha (1979) lists its distribution as Queensland, Fiji, New Caledonia, New Hebrides (Vanuatu) and Tahiti. Host plants are listed as *Ageratum* sp., *Cucumis sativa* (cucumber), *Datura* sp., *Eucalyptus* sp., *Fragaria annanassa* (strawberry), *Lycopersicon esculentum* (tomato), *Mucuna* sp., *Oxalis* sp., *Phaseolus atropurpureus* (purple bean), *Phaseolus vulgaris* (green bean), *Sechium edule* (Choko) and *Sida acuta.* Prey is reported as eriophyid and tetranychid mites. Recent collections have been made in Queensland: (i) at Samsonvale, Brisbane and Gatton on pale knotweed, *Polygonum lapathifolium* (J. Beard, pers. comm., 2001); (ii) on castor bean at Maroochy Horticultural Research Station (R. Parker, pers. comm., 1998); (iii) on silver beet with broad mite and citrus with thrips at Indooroopilly (R. Parker); and (iv) Atherton Tablelands on *Stylosanthes* (R. Parker).

In surveys across Australia from 1994 to 1996 (Goodwin & Steiner 1996; Steiner & Goodwin 1998a), we found it widely distributed in unforested coastal areas of Queensland (from Brisbane in the south to Cairns in the north) and in irrigated and higher rainfall areas inland including Biloela and the Atherton Tablelands. There was one record from

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Sydney, New South Wales; one from a public conservatory in Adelaide, South Australia; and one from Tichum Creek in Northern Territory. Plant hosts included: (i) native and introduced leguminous weeds; (ii) *Ageratum houstonianum*; (iii) sandpaper fig, *Ficus coronata*; and (iv) crop plants such as cotton, lucerne and melon. Most host plants were herbaceous. Thrips were present on most, but not all, such plants. It is possible that this species is extending its range.

This species, along with another indigenous Australian species, *Typhlodromalus lailae* (Schicha), is a promising candidate for development as a commercial biocontrol agent for western flower thrips in Australia and elsewhere. We present here biological data on *T. montdorensis*.

MATERIALS AND METHODS

Rate of development and life-history parameters

A greenhouse-maintained population of *T. montdorensis* originating in Queensland was introduced onto soybean, *Glycine max*, and eggs collected from leaf undersides within 24 h of deposition. A fine camelhair brush was used to transfer approximately 60 eggs, in batches of 10, to 47-mm diameter Millipore Petri dishes (Millipore Australia, North Ryde, NSW, Australia). Each Millipore dish held a 30-mm diameter soybean leaf-disc, placed upper surface down on a 1% agar substrate. Cumbungi (cattail) (*Typha* sp.) pollen was lightly dusted onto a small section of the leaf as food. A 30-mm diameter hole in the lid was screened with nylon mesh (57-μm sieve opening) to allow air and water vapour exchange, but prevent escape of mites. The dishes were secured to the lid of a plastic container (170 by 110 by 65 mm) with a Velcro strip (Velcro Australia, Hallam, Vic., Australia) so that the lower leaf surface faced downward. The container held 300 mL of a 51.32% w/w glycerol/water mix to give a relative humidity of 80% at 25°C (Forney & Brandl 1992). It was placed in a controlled environment room at 25°C, with light provided by cool white fluorescent tubes, on a 16 h light/8 h dark cycle. Units were examined every 24 h and change in stage of development of the mites was noted by looking for cast skins. Mites were moved to fresh discs each 3–4 days. Once egg laying by mature adult females was observed, female mites were separated, one per disc, into new Millipore units. Seventeen of these units were provided with a single male from the same batch, while 15 were without males. The sex ratio of the original batch of eggs was recorded. Daily records of eggs laid by the new females were kept until no eggs had been laid for 3 consecutive days. New males were added to the few units where males died, and to all units 3 days after any female stopped laying eggs. These males were from the same population as those used previously. Eggs were removed and pollen added daily. Overall appearance of the mites was noted. The experiments were conducted in May 1998.

We used the short method of Wyatt & White (1977) to calculate the intrinsic rate of natural increase, r_m, with $r_m = c(\log_e M_d)/d$, where c is a correcting constant, and M_d is the number of eggs laid in a time d equal to the pre-reproductive period. It is not clear from a description of the method whether time d for mites is measured from egg deposition or egg eclosion; however, we presumed it logical to consider the total generation time more important, therefore d is taken as time from egg deposition. Wyatt and White (1977) give an approximate value for c as 0.745 for aphids and 0.749 for spider mites, with the range between species suggesting that the same constant may be applicable. We took a value of 0.75 as a reasonable approximation for phytoseiid mites.

Incidence of diapause

Eggs were collected in the same way and at the same time as in the previous experiment. On hatching, mites were subjected to one of three feeding regimes: (i) cumbungi pollen; (ii) cumbungi pollen plus β-carotene; and (iii) cumbungi pollen plus five first-instar larvae of *Frankliniella schultzei* Trybom. We included β-carotene at 5 mg/100 mg pollen in one treatment because it is known to be necessary in the diet of predatory mites to elicit a diapause response, and not all pollens contain it (van Houten 1991). Three plastic containers, each holding six Millipore dishes (60 eggs per container per treatment), were placed in a growth room where they were subjected to a daily regime of 8 h light at 25 ± 1°C and 16 h dark at 10 ± 1°C. A control group of 60 eggs in six Millipore dishes was maintained at 25 ± 1°C and 16 h light/8 h dark and fed cumbungi pollen. Development was recorded at 24 h intervals until the adult stage was reached and the first egg was observed. Individual female mites were separated as before into Millipore dishes, with a single male from the same experiment added. Dishes were maintained under the same temperature/light/food regime to determine whether female mites could lay eggs or were in diapause.

Fecundity on a diet of pollen, thrips or *Tyrophagus putrescentiae* (Schrank) and consumption rate of thrips

We were interested in: (i) whether female *T. montdorensis* could survive on a diet of pollen and/or thrips; (ii) whether fecundity was influenced by diet; and (iii) how consumption of thrips and fecundity compared with those of *Neoseiulus cucumeris* (Oudemans) and *N. barkeri* (Hughes), two predatory mites sold overseas for thrips control. Most authors conducting similar studies first starve predators for 24 h. We were interested also in whether there was an adjustment period before accepting a new food material or adapting to a different environment, so data were collected for a 3-day period immediately after transfer.

Typhlodromips montdorensis used during the experiment were obtained from small laboratory rearing units (Steiner & Goodwin 1998b), where they had been reared on green-bean leaves on a variety of diets (Table 1). Diets were either pollen alone or combinations of pollen and either thrips or *T. putrescentiae*. Except for three experiments using the

Table 1 Mean daily consumption of thrips larvae (*Frankliniella schultzei*) and mean daily egg production by *Typhlodromips montdorensis* adult females on a diet of thrips, cumbungi pollen and/or *Tyrophagus putrescentiae*

Date	Food presented (initial rearing diet)	Mean thrips consumed per day			Mean eggs laid per female per day			*n*†
		Day 1	Day 2	Day 3	Day 1	Day 2	Day 3	
6 May 1996	P (Fs,P)				1.65	1.76	2.25	17/24
22 October 1996	P (Fs,P,Tp)				0.83	1.44	2.11	18/24
19 November 1996	P (Fs,P)				1.70	2.17	2.42	12/12
19 November 1996	P (Tp,P)				1.43	1.43	1.29	7/12
19 March 1996	10 thrips First stage (Fs,P)	7.09	6.59	7.23	2.36	3.00	3.36	22/24
17 July 1996‡	10 thrips First stage (Fs,P)	7.39	7.96	8.39	3.04	3.35	3.57	23/24
23 July 1996‡	10 thrips First stage (Fs,P)	6.71	7.71	8.18	2.41	2.53	2.82	17/24
22 October 1996	20 thrips First stage (P)	8.07	7.07	9.07	1.07	1.33	3.27	15/24
19 November 1996	20 thrips First stage (Fs,P)	10.33	14.78	14.44	2.33	3.06	2.72	18/24
22 October 1996	20 thrips First stage + P (P)	5.81	5.25	6.62	0.76	1.29	2.81	21/24
19 November 1996	20 thrips First stage + P (Fs,P)	9.95	8.38	8.19	2.71	2.86	3.58	21/24
7 January 1997	5 thrips Second stage (Fs,P)	1.32	1.23	1.62	0.18	0.95	1.33	22/24
22 October 1996	Tp (Tp,P)				0.72	1.28	1.59	18/24
19 November 1996	Tp (Tp,P)				0.91	0.77	1.36	19/24
14 January 1997‡	Tp (Tp,P)				0.08	1.83	2.46	24/24

Fs, thrips; P, cumbungi pollen; Tp, *Tyrophagus putrescentiae*. †Number surviving/number at start; ‡Queensland population.

Queensland population, mites were from a South Australian population. Adult female mites were taken at random and placed individually on a green-bean leaf disc held on agar in a screened Millipore dish. The number of mites tested ranged from 12 to 24, depending on availability (Table 1). Data from mites that died or disappeared during the experiment were excluded from the analysis. A few fibres of irrigation matting were placed on the leaf surface as egg-laying sites. Treatments were: (i) cumbungi pollen; (ii) 10 *F. schultzei* early first-instar larvae per day; (iii) 20 *F. schultzei* first-instar larvae per day; (iv) 20 *F. schultzei* first-instar larvae per day plus cumbungi pollen; (v) five *F. schultzei* early second-instar larvae per day; and (vi) all stages of *T. putrescentiae*. Treatments were carried out between March 1996 and January 1997 (Table 1). Dishes were inverted on a rack over a 58% w/w glycerol/water mix in a plastic lidded container, to give a relative humidity (RH) of ~75% at 25 ± 1°C (Forney & Brandl 1992). They were checked every 24 h for 3 days and records were kept of the number of eggs laid and the number of thrips larvae eaten per day. Thrips larvae grew quickly and were replaced daily to ensure that the correct life stage was available to the predatory mites.

After 3 days, mites from the experiment were checked for internal diseases by smearing them on a glass microscope slide in a small drop of distilled water, fixing in methanol for 30 min, and staining for 2 h with 20% Giemsa solution (Steiner 1993). This method can detect pathogens such as microsporidia, rickettsia-like organisms, bacteria and some viruses.

Egg hatch in response to relative humidity

The eggs of phytoseiid mites vary in their response to RH/vapour pressure deficit (VPD) (van Houten *et al.* 1995a; Shipp & van Houten 1997). Not surprisingly, eggs of dryland species tend to be resistant to desiccation, whereas those species found in areas with greater rainfall may not hatch without adequate moisture. The *T. montdorensis* evaluated in our experiments were from two sources: (i) from a conservatory in Adelaide, South Australia; and (ii) field-collected from the Atherton Tablelands, Queensland. Both can be considered warm temperate/subtropical environments with no extended dry periods.

To obtain eggs, adult female mites were placed in a screened Petri dish on a green-bean leaf with upper surface in contact with wet cotton wool. Dishes were inverted over a glycerol/water mix to obtain 75% RH and held at 25 ± 1°C with cumbungi pollen provided as food. Eggs were collected within 18 h of deposition and transferred using a camelhair brush onto black lines, drawn with a waterproof felt marker on a glass microscope slide. The eggs were placed in a row and were readily visible against the black background. Several batches of eggs with variable numbers were used for each RH. The total number of eggs ranged from 86 to 473 between the critical range of 60–75% RH. A piece of Velcro strip was placed on the back of the slide and used to fix the slide into position on a complementary Velcro strip on the screw-top cap of a plastic cylinder (145 by 67-mm diameter). Cylinders contained 300 g of sulfuric acid of known

concentration, which provided RH in the range 35–95% (VPD of 2.06–0.16 kPa) in 5% increments (Solomon 1951). They were held in a controlled-environment cabinet at 25 ± 1°C with 24 h light provided by cool white fluorescent tubes. After 3 days, eggs were checked for hatching. A non-linear logistic-regression model was used to relate percentage egg hatch to relative humidity in the following form:

$$\% \text{ egg hatch} = A + C/(1 + \exp(-B*(\text{humidity} - M)))$$

where: A = lower asymptote; B = rate of change; C = upper asymptote; and M = value of humidity at point of inflexion. Parameter values were obtained by the Gauss–Newton iterative algorithm using Genstat 5 Release 3 (Genstat 5 Committee 1993). The relative humidity value for 50% egg hatch was calculated from the above equation.

RESULTS

Rate of development and life-history parameters

There was an 85% survival rate (some may have been lost) of *T. montdorensis* from egg to adult at 25°C when fed on cumbungi pollen. Most eggs hatched on day 2, though the 24 h egg-laying period meant that some of these eggs could have been aged up to 48 h on hatching. Of the surviving females, 81% developed to the egg-laying stage within 7 days of the original eggs being collected (Fig. 1a). On day 6 after the parent eggs were placed on the discs, mean eggs per paired female per day was 1.22 (n = 14). This increased to 2.21 eggs on day 7, and 3.50 on day 8 (range 0–5). For unpaired females (n = 15), daily egg production was initially the same as for a female–male pair (Fig. 1a), declining after 7–19 days. This is quite a variable period; more so than for *T. lailae* (Schicha), where egg production declined after 4–9 days (Steiner *et al*. 2003). In most cases, addition of a male to *T. montdorensis* female-only units 3 days after egg laying ceased, resulted in a resumption of egg laying after 1–2 days. As with *T. lailae*, addition of another male to units with female–male pairs where egg laying had ceased did not result in any further eggs being laid. Where males were present throughout the study period, females laid an average of 52.65 eggs (range 36–65). Where males were re-introduced only after egg laying ceased, this average was slightly lower at 47.94 eggs (range 35–59). From the results, it appears that a short initial mating period was inadequate for fertilising all available eggs in the majority of individuals. The experiment was terminated after day 31 when all remaining females had stopped laying eggs.

The intrinsic rate of natural increase (r_m) of *T. montdorensis* on cumbungi pollen was 0.75 ($\log_e$20.57)/7 or 0.324.

The generation time T_d (Wyatt & White 1977) (d/c) was 7/0.75 or 9.33.

The sex ratio of eggs used initially for the present study was 1.68 : 1 female : male (n = 51). This ratio in several more recent developmental studies was 2.24 : 1 female : male (n = 544) (Steiner *et al*., unpubl. data, 2001). Crowding was unlikely to be a factor in this ratio.

Incidence of diapause

In the 25°C, 16 h light/8 h dark treatment, the first eggs were recorded on day 6, with all females laying eggs by day 8. Under 25°C, 8 h light/10°C, 16 h dark conditions, the first eggs were observed on day 15. The mites were not separated into individual units until day 16 to ensure that all females had had an opportunity to be mated. All females had laid eggs by day 20, most by day 17, the number ranging from one to three per day. There was therefore no diapause under these short-day conditions.

Fecundity on a diet of pollen, thrips or *T. putrescentiae*, and consumption rate of thrips

Mean daily egg production at 25°C on a diet of cumbungi pollen averaged 1.71 eggs per day over four experiments (range 0.83–2.42 per batch) (Table 1), with fecundity generally increasing over the 3-day period. Comparable figures for a diet of 10 and 20 first-instar thrips (*F. schultzei*) larvae were higher at 2.94 (range 2.36–3.57) and 2.30 (range 1.07–3.27) eggs per day, respectively. The lower egg-laying rate for 20 larvae per day as against 10 larvae per day is a result of a lower egg-laying rate on days 1 and 2 for mites in the 22 October 1996 trials. These mites were previously reared on pollen alone, while the other mites, from both treatments, were reared on both thrips and pollen. This suggests an adjustment period, although thrips-consumption rate did not change markedly over the 3 days. Provision of cumbungi pollen with 20 thrips larvae resulted in no clear increase in egg laying over thrips alone, with an average of 2.34 (range 0.76–3.58) eggs laid per day, compared with 2.30 eggs per day with thrips alone. Mean daily egg production from females offered second-instar thrips larvae was only 0.82 per day (range 0.18–1.33). Egg production on a diet of *T. putrescentiae* was 1.22 eggs per day (range 0.8–2.46). Predatory mites used for this latter treatment had been reared on *T. putrescentiae* with pollen for at least one generation.

Consumption of thrips was consistently high. An average of 7.47 (range 6.59–8.39) first-instar thrips were eaten per day when presented with 10 thrips, and 10.63 (range 7.07–14.78) when presented with 20 thrips. Prior exposure to thrips in the diet increased the number eaten. When pollen was provided in addition to the 20 first-stage thrips larvae, mean consumption was 7.37 larvae per day (range 5.25–9.95), less than the 10.63 larvae eaten on a diet of thrips alone, but equal to or higher than that reported for *N. cucumeris* feeding on *F. occidentalis* larvae (Shipp & Whitfield 1991; van Houten *et al*. 1995a,b).

A mean of only 1.39 (range 1.23–1.62) second-stage thrips larvae were eaten per day by *T. montdorensis*.

Egg hatch in response to relative humidity

The following logistic regression model accounted for 91.3% of the variation in percentage egg hatch:

$$Y = 5.53 \pm 2.04 + 92.12 \pm 4.53\,(1 + \exp(-0.4605 \pm 0.0705*(X - 70.953 \pm 0.356)))$$

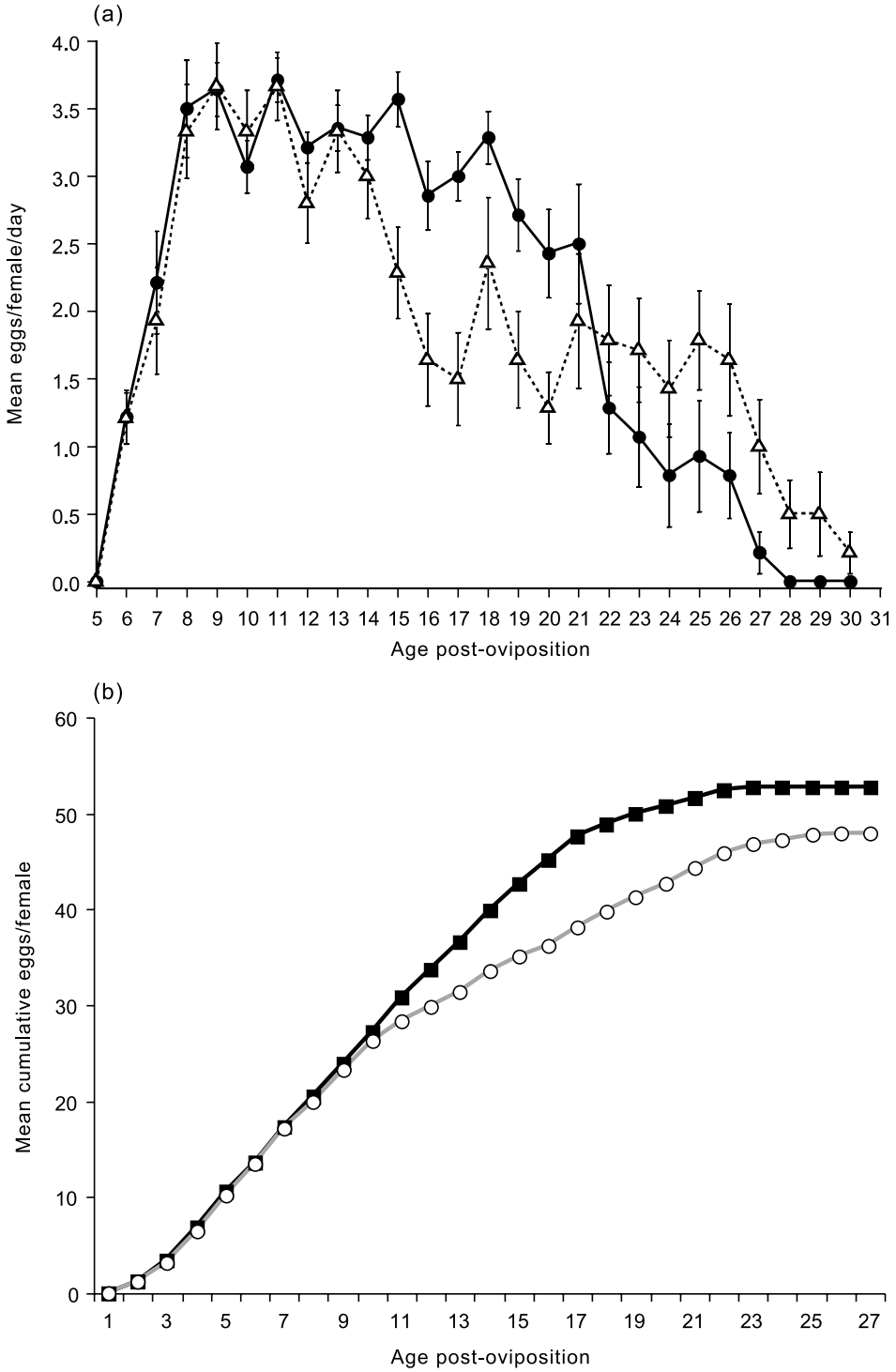

Fig. 1. Egg production of *Typhlodromips montdorensis* (Queensland population) on a diet of cumbungi pollen at 25°C. New females were all mated, with male present throughout in some units and only added 3 days after egg laying ceased in others. (**a**) Mean daily egg production: (–●–) male always; (··△··) male periodically. (**b**) Cumulative egg production: (–■–) male always; (–○–) male periodically.

Less than 10% of eggs hatched at RH <60% (Fig. 2). There appeared to be some differences between mites from the two sources at 60–75% RH. Eggs from the South Australian-collected mites required slightly higher RH to hatch than those from Queensland; however, the differences were not significant at the 5% level, and one curve was used to describe the response of both populations. The critical point for 50% egg hatch was approximately 70.8% RH (VPD of 0.93 kPa) (Fig. 2).

DISCUSSION

Using the formula for calculating r_m (Wyatt & White 1977) with a correction constant of 0.75, *T. montdorensis* has a high intrinsic rate of natural increase (r_m = 0.324) at 25°C, which exceeds that reported for possible target pests such as western flower thrips, *F. occidentalis* (r_m = 0.17 on chrysanthemum (Robb 1989) and 0.30 on cucumber (Gaum *et al.* 1994)) and onion thrips, *Thrips tabaci* Lindeman (r_m = 0.17)

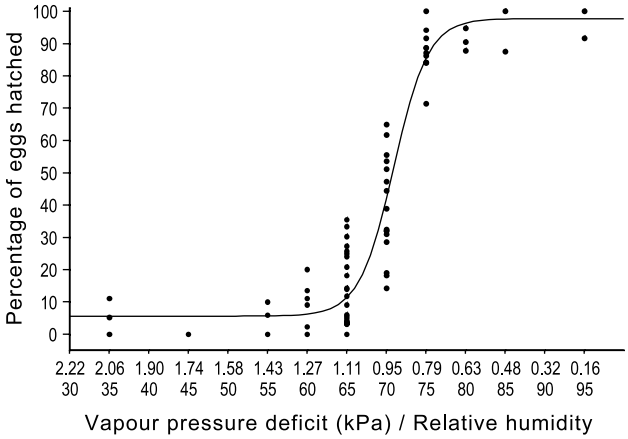

Fig. 2. Percentage of *Typhlodromips montdorensis* eggs from two sources hatching at different relative humidities/vapour pressure deficits. A non-linear logistic regression model was used to relate percentage egg hatch to relative humidity.

(Bonde 1989). It also exceeds that for most other phytoseiid mites reported as predators of thrips (Sabelis & van Rijn 1997), but is lower than the 0.38 determined for *T. lailae* (Steiner *et al*. 2003). Although our data were developed from predators fed on pollen, egg production was within the maximum range reported in Table 1 for *T. montdorensis* fed on thrips, with most young females laying three to four eggs per day. Comparable r_m values for the commercially produced phytoseiid predators *N. barkeri* and *N. cucumeris* were 0.22–0.24 and 0.16–0.22, respectively, on a variety of diets (Sabelis & van Rijn 1997). The high female : male ratio (2.24 : 1) for *T. montdorensis* is an added benefit in a biocontrol agent.

Females of *T. montdorensis* that were mated at maturity and then deprived of males ceased egg laying; however, they resumed egg laying once re-mated. This supports the observation by Mégevand & Tanigoshi (1995) that oviposition is physiologically, rather than chronologically, age-dependent (as measured by past egg production). Their observation was that food shortages caused a re-allocation of resources away from reproduction. In our experiments, a shortage of sperm appears to have had the same effect. For most *T. montdorensis* females, at least two mating encounters were needed to ensure that a full complement of eggs was laid. There was wide variation between individuals on when a second mating was needed, which may reflect the number of spermatophores received initially, although *T. montdorensis* females commonly have only two endospermatophores, compared with several in *T. lailae* (Steiner *et al*. 2003). Multiple matings are reported necessary for other phytoseiid species (e.g. *N. barkeri* and *N. cucumeris* (Bonde 1989)).

Living for extended periods after cessation of egg laying at first appears to serve no useful function; however, it may be an advantage at very low population densities where males are rarely encountered and full fertilisation of eggs has not been achieved early in the life cycle.

Van Houten *et al*. (1995a) found that oviposition rates at 25°C for two commercially available and five candidate phytoseiid mite species fed on first-instar thrips larvae ranged from 0.2 to 3.2 eggs per day, compared with approximately three eggs per day for *T. montdorensis*. Oviposition on a diet of sweet-pepper pollen for five of these species ranged from 1.4 to 2.8 eggs per day, compared with 1.71 eggs per day for *T. montdorensis* fed on cumbungi pollen in these trials; however, it should be noted that the present oviposition rate of the Queensland population of *T. montdorensis* on cumbungi pollen is consistently greater than three eggs per day. Whether the anomaly in the feeding experiments is due to lack of conditioning, population differences or quality of pollen is not known. The health of the population studied was generally good.

The mean daily consumption rate of 10.63 first-instar thrips larvae (*F. schultzei*) for *T. montdorensis* was very high relative to that reported for *N. cucumeris* (6 per day) and *N. barkeri* (2.6 per day) (van Houten *et al*. 1995a) when fed *F. occidentalis*. It also exceeded that of the five other phytoseiid species evaluated in the same study (*Typhlodromalus limonicus* (Garman & McGregor), *Iphiseius degenerans* (Berlese), *Euseius hibisci* (Chant), *Euseius scutalis* (Athias-Henriot) and *Euseius tularensis* (Congdon)) (van Houten *et al*. 1995a). *Frankliniella occidentalis* is slightly larger than *F. schultzei* in the second instar but not in the first. *Typhlodromips montdorensis* is not able to tackle second-stage larvae well. The high attack rate on first-stage larvae (one individual killed all 20 thrips larvae in a day) does not necessarily imply consumption of all the thrips, but kill. Larval and nymphal predatory mites have been observed feeding on partially consumed thrips, and are probably scavengers in part on kill by adult females. Both egg laying and consumption rate of thrips tended to increase over a 3-day period, particularly where thrips were not included in the diet prior to the experiment. Egg laying also increased over the 3 days on a diet of *T. putrescentiae*.

The onset of diapause in response to low temperature and short day length can make a predator ineffectual in winter months when used as a biocontrol agent (Rodriguez-Reina *et al*. 1994; van Houten & van Stratum 1995; van Houten *et al*. 1995a,b). We subjected *T. montdorensis* to relatively extreme conditions for a greenhouse situation. Because there was no diapause at a 25°C, 8 h light/10°C, 16 h dark cycle, this species is potentially useful during winter months, although threshold developmental temperature and rate of development under a range of higher and lower temperatures needs to be determined.

The relatively high humidity required for egg hatch suggests that this species would be best used in situations that are not subjected to extremely low humidity and preferably where RH exceeds 70% for several hours per day. The critical humidity for 50% egg hatch was approximately 70% RH (VPD 0.89 kPa). In nature, humidity levels are rarely constant over a 24 h period and eggs might be adapted to tolerate some fluctuation. The broad distribution of this species suggests that it might be fruitful to search for it in drier areas of its range.

At 25°C, daily egg production and thrips consumption is higher than the commercial thrips predator *N. cucumeris*; the latter is used worldwide, but is not sold and has been recorded only rarely in Australia (Beard 1999). However, there are many other factors to consider before *T. montdorensis* can be considered a good biocontrol agent for thrips, including ease of rearing and adaptability to a range of temperatures and crops. The reported host range of *T. montdorensis* and general observations in small greenhouse trials (Steiner & Goodwin 1998a, 2001) suggest that *T. montdorensis* is a generalist feeder, distributes rapidly, and has the potential to control thrips and other pests on a range of herbaceous crop types, given suitable climatic conditions. Apart from thrips, we have also observed them feeding on broad mite, tomato russet mite, and spider mites. Prey preference in a particular crop may dictate its usefulness against one or more of these pests if they occur together. Some pollens (i.e. *Typha* sp. and *Plantago lanceolata*) promote normal development of this species and may be favoured over prey if abundant. In feeding trials reported here, thrips kill was still high when cumbungi pollen was present in liberal amounts. The species was not thought to inhabit flowers to any great extent (Steiner & Goodwin 2001); however, we have since seen it in flowers of capsicum and gerbera in relatively high numbers. It is expected that this predator will be a useful addition to the armoury of commercial biocontrol agents used in protected crops that are grown in warm and relatively humid conditions.

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