Life table and age-dependent reproduction of the predatory bug *Orius niger* Wolff (Heteroptera: Anthocoridae) at three constant temperatures: a demographic analysis

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Abstract

The predatory bug *Orius niger* Wolff occurs throughout Iran in various climatic zones. Because of its apparent adaptation to these different climates, it is being considered as a potential biological control agent of the pest *Thrips tabaci* Lind. in various crops in Iran. We measured the basic life-history parameters of *O. niger* on a diet of corn pollen and eggs of the moth *Ephestia kuehniella* Zeller at 3 constant temperatures (26, 29 and 32°C under 16L–8D) to assess the possibility of culturing this predator for mass releases. Bean pods were supplied as oviposition sites. The intrinsic rate of increase was 0.113, 0.127 and 0.157 daughters/female/day at 26, 29, and 32°C respectively. Analysis of the mortality of eggs, juveniles and adults suggests that the population growth rate is restricted most by juvenile mortality. This mortality is probably caused by cannibalism, the occurrence of which should therefore be minimized in mass cultures.

Key words: Biological control; *Orius niger*; thrips; mass cultures; intrinsic rate of increase

INTRODUCTION

In recent years, the use of predatory bugs of the genus *Orius* as biological control agents of thrips like *Frankliniella occidentalis* Pergande and *Thrips tabaci* Lind. has greatly increased in many greenhouse vegetables and ornamental crops (Van den Meiracker and Ramakers, 1991; Van de Veire and Degheele, 1992; Cocuzza et al., 1997; Van den Meiracker, 1999). *Orius* consists of 67 species (Yasunaga, 1997) and *Orius niger* Wolff is a Palaearctic species (Loomans et al., 1995) and has been recorded from many parts of Iran. This species preys upon thrips (Ramakers, 1978), mites and aphids (Akramovskaya, 1978), eggs and larvae of Lepidoptera, and eggs of pentatomids (Pericart, 1972). The species is commonly found attacking *T. tabaci* throughout Iran, suggesting that it is adapted to the diverse climatic conditions of this country. Although this would make the species ideally suited for biological control of thrips in Iran, it has not yet been studied extensively.

Thrips tabaci is an important pest of greenhouse

crops in Iran and many other countries. It causes crop damage directly by feeding on parenchyma and puncturing the plant tissue for oviposition, resulting in a reduction of the photosynthetic capacity (Royer et al., 1986; Van Rijn, 2002) and indirectly by transmission of plant viruses such as the TSWV (Tomato Spotted Wilt Virus) (Broadbent et al., 1987; German et al., 1992).

Demography is a powerful tool to study natural enemies that must be reared on a large scale in order to optimise rearing conditions. Although this method has been used extensively in studying populations of plant pests and their natural enemies (Carey, 1982; Carey and Vargas, 1985; Liedo and Carey, 1994), there are limited literatures on estimating the biologic and reproductive parameters of *O. niger*. Van den Meiracker (1999) used the demographic analysis to optimise the mass rearing of *O. niger*.

Since *Orius* species are polyphagous predators, they can be reared on different types of prey. For example, eggs of *Sitotroga cerealella* Olivier have been used for *Orius minutus* Neimeczyk, eggs of

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Mamestra brassicae L. for *O. niger* (Van de Veire and Degheele, 1992), eggs of *Helicoverpa virescens* F. for *Orius insidiosus* Say (Isenhour and Yeargan, 1981), *Ephestia kuehniella* Zeller for *O. insidiosus* (Fisher et al., 1992; Alauzet et al., 1994).

The objectives of the current study were to determine life table and reproductive parameters such as intrinsic rate of increase, net reproductive rate, mean generation time and oviposition period of *O. niger* in three different temperatures when fed on eggs of *E. kuehniella* and corn pollen to provide information for mass rearing of the predator.

MATERIALS AND METHODS

Rearing. Predatory bugs used in the experiments were collected on marguerite flowers *Chrysanthemum frutescens* L. (Compositae) in Tehran, Iran. *O. niger* was separated and identified using the single rearing method (Yasunaga and Kashio, 1993; Yasunaga, 1997). They were reared at 26°C, r.h. 70±5% and a photoperiod of L16:D8 hours with eggs of *E. kuehniella* as food. Green bean pods and corn pollen were used as oviposition sites and supplementary food respectively (See Van den Meiracker, 1994, for details).

Life table and reproduction. Fresh bean pods were placed in rearing jars of *O. niger* for oviposition. After 4 h, the pods with eggs were incubated at 26, 29 or 32°C, r.h. 70±5%, and L16:D8 in plastic soft drink bottles (150 ml) lined with paper tissue, and closed with a screw cap. Three cohorts of 159, 103 and 96 eggs were used at 26, 29 and 32°C respectively. Ventilation was through two lateral holes covered with fine nylon mesh. Water was supplied in a small glass test tube closed with cotton wool. *E. kuehniella* eggs were provided for nymphs and adults on a small piece of paper which was replaced every day. Bottles were checked daily for egg hatching, nymphal survival and adult eclosion. A total of 30 eclosed females at 26°C and 20 females for the two other temperatures were separated and kept individually with 2–3 males in a small test tube for 1 h to ensure mating. Each mated female plus males were transferred to a plastic cup (100 ml) with lid and two lateral holes covered with mesh to provide ventilation. The bugs were daily provided with fresh *E. kuehniella* eggs and corn pollen and a piece of bean pod (2 cm) as

food and oviposition sites respectively. Bean pods were checked daily for *Orius* eggs and were kept in vials until hatching. Survival of eggs was recorded after the hatching of all of the eggs. To prevent disturbance of nymphs, their survival and sex were recorded at the emerging of the adults.

RESULTS

The basic life table of *O. niger* at different temperatures is given in Table 1. The main parameters in a life table are l_x (proportion of females surviving to start of age interval x) and m_x (average number of female eggs laid by a female of age x). The most basic measure of reproduction is the average number of eggs laid by a female in the cohort in the interval x to $x+1$ and is denoted M_x (Table 1). The fraction of these eggs that hatch represents the hatch schedule, h_x (Table 1). We followed the methods of Birch (1948), Andrewartha and Birch (1954) and Carey (1993) for calculating life table parameters and reproductive parameters from this reference. Net reproductive rate (R_0), intrinsic rate of increase (r_m), finite rate of increase (λ), intrinsic birth rate (b), intrinsic death rate (d), doubling time (DT) and mean generation time (T) were calculated using the formulae shown in Table 2.

The estimates of reproductive parameters with their formulae and units are also shown in Table 2. These statistics show that females are expected to lay a total of 76.7 eggs and 60.7 fertile eggs at 26°C. The net fecundity rate is 71.9 eggs and the net fertility rate is 57.1 fertile eggs. This suggests that egg mortality alone reduced potential reproduction by approximately 0.20 at 26°C ($=1 - \text{fertile eggs}/\text{total eggs}$), female mortality alone reduced potential reproduction by approximately 0.06 ($=1 - \text{net fecundity}/\text{gross fecundity}$, see Carey, 1993) and the combination of egg mortality and female mortality reduced potential reproduction by 0.25 (Table 3). For 29 and 32°C, these values are given in Table 3.

Orius niger females start ovipositing 5.08 ± 0.99 (SD) days after they became mature and oviposited on average for 14.5 ± 3.11 (SD) days at 26°C (Fig. 1a). At 29°C and 32°C, oviposition started at 5.06 ± 1.6 days and 3.57 ± 0.57 days respectively (Fig. 1b, c). The average number of eggs laid by a female per day was 2.84 at 26°C, 4.29 at 29°C and 5.55 at 32°C. Generally, the average number of

Table 1. Basic life-history measurements of *Orius niger* on a diet of corn pollen and eggs of *E. kuehniella* at 3 different temperatures. x =age of female in days; l_x =survival of female until x ; m_x =number of female offspring produced at age x ; M_x =total number of offspring (=number of eggs) produced at age x , h_x =hatch rate of eggs.

26°C					29°C					32°C				
x	l_x	m_x	M_x	h_x	x	l_x	m_x	M_x	h_x	x	l_x	m_x	M_x	h_x
0-5	1	0	0	0	0-4	1	0	0	0	0-4	1	0	0	0
5-16	0.89	0	0	0	4-13	0.85	0	0	0	4-13	0.83	0	0	0
17	0.56	0	0	0	14	0.52	0	0	0	14	0.58	0	0	0
18	0.56	0	0	0	15	0.52	0	0	0	15	0.58	0	0	0
19	0.56	0	0	0	16	0.52	0.78	1.40	0.93	16	0.58	0.81	1.55	0.84
20	0.56	0.94	1.60	0.79	17	0.52	1.96	3.50	0.89	17	0.58	4.65	8.95	0.89
21	0.56	2.26	3.83	0.80	18	0.52	3.92	7.00	0.93	18	0.58	4.73	9.10	0.92
22	0.56	2.22	3.77	0.88	19	0.52	3.41	6.10	0.91	19	0.58	4.52	8.70	0.94
23	0.56	2.36	4.00	0.88	20	0.52	4.06	7.25	0.90	20	0.58	4.43	8.30	0.85
24	0.56	2.83	4.80	0.76	21	0.52	3.58	6.40	0.95	21	0.55	4.21	8.11	0.88
25	0.56	2.38	5.73	0.80	22	0.52	4.04	7.05	0.90	22	0.55	3.65	6.84	0.92
26	0.56	2.48	4.20	0.87	23	0.49	0.87	1.52	0.86	23	0.53	3.68	6.89	0.92
27	0.56	3.10	5.25	0.86	24	0.46	3.88	6.55	0.91	24	0.50	3.09	5.94	0.89
28	0.54	3.62	6.14	0.79	25	0.41	4.65	8.31	0.90	25	0.47	3.47	6.47	0.81
29	0.54	2.18	3.69	0.86	26	0.41	4.15	7.18	0.89	26	0.41	3.85	6.94	0.87
30	0.54	3.15	5.34	0.83	27	0.39	2.61	4.66	0.80	27	0.32	2.33	4.00	0.91
31	0.54	2.28	3.86	0.87	28	0.39	1.76	2.93	0.96	28	0.23	0.99	1.64	0.83
32	0.54	1.89	3.21	0.64	29	0.31	1.21	1.07	0.96	29	0.23	0	1.65	0.90
33	0.52	1.99	3.38	0.63	30	0.28	1.31	2.25	0.88	30	0	0	0	0
34	0.50	1.71	2.89	0.82	31	0.23	1.40	2.27	0.90					
35	0.48	1.16	1.96	0.67	32	0.21	1.31	2.22	0.88					
36	0.48	2.16	3.65	0.65	33	0	0	0						
37	0.47	0.68	1.15	0.30										
38	0.43	0.43	0.73	0.66										
39	0.41	1.08	1.82	0.63										
40	0.39	0.38	0.64	0.85										
41	0.35	0.55	0.93	0.80										
42	0.32	0.34	0.57	0.91										
43	0.24	0.35	0.59	0.75										
44	0.20	0.71	1.21	0.91										
45	0.17	0.11	0.18	1.00										
46	0.11	0.41	0.69	0.88										
47	0	0	0	0										

eggs laid by a cohort of females increased rapidly during the 4–12 days of the adult life, reaching a maximum of 6.1 eggs on day 12 at 26°C, 8.3 eggs on day 11 at 29°C and 9.1 eggs on day 4 at 32°C (Fig. 1). Around 20% of the females did not oviposit at 26°C, 25% at 29°C and 5% at 32°C.

The interpretation of these statistics is that the average reproduction for a cohort that lives to its last day of possible life at 26°C (i.e., mean age gross fecundity) is 13.5 days. This mean age is reduced to slightly over 13.2 days by egg mortality alone, but is reduced to around 12.8 days due to adult female mortality alone. For 29 and 32°C, these values are 9.41, 9.37, 8.44, and 10.5, 7.5, 7.2

days, respectively. Together, egg mortality and female mortality set the actual mean age of reproduction at 12.5 days at 26°C, 8.4 days at 29°C and 7.2 days at 32°C. Life expectation at age 0, (e_0) was 28.9 days at 26°C, 18.0 days at 29°C and 17.5 days at 32°C.

DISCUSSION

There is another study that reports the intrinsic rate of increase of *O. niger* at 25°C (Van den Meiracker, 1999). Although others have studied the life history of this species (Tommasini and Nicoli, 1993, 1994), they do not report the intrinsic rate of

Table 2. Description, symbol, formula, values and units for population parameters of *Orius niger*

Parameter	Formula	26°C	29°C	32°C
Net reproductive rate (female egg/female)	$R_0 = \sum l_x m_x$	22.95	18.62	24.42
Growth rates				
Intrinsic growth rate (daughters/female/day)	$1 = \sum l_x m_x e^{-r(x+0.5)}$	0.113	0.127	0.157
Finite rate of increase (day ⁻¹)	$\lambda = e^r$	1.119	1.135	1.169
Intrinsic birth rate (day ⁻¹)	$b = \sum e^{-r(x+0.5)} l_x$	0.129	0.152	0.180
Intrinsic death rate (day ⁻¹)	$d = b - r$	0.016	0.025	0.023
Growth times				
Doubling time (days)	$DT = (\ln 2)/r$	6.1	5.5	4.4
Mean generation time (days)	$T = \ln R_0 / r$	27.7	23.0	20.4
Life time reproductive rates				
Gross fecundity rate (eggs/female)	$\sum M_x$	76.7	80.8	85.1
Gross fertility rate (fertile eggs/female)	$\sum h_x M_x$	60.7	73.2	75.7
Gross hatch rate (proportion)	$\sum h_x M_x / \sum M_x$	0.79	0.90	0.88
Net fecundity rate (eggs)	$\sum L_x M_x$	71.9	68.6	77.5
Net fertility rate (fertile eggs)	$\sum L_x h_x M_x$	57.1	62.2	67.7
Daily reproductive rate				
Eggs/female/day	$\sum L_x M / \sum L_x$	2.8	4.3	5.6
Fertile eggs/female/day	$\sum L_x h_x M_x / \sum L_x$	2.0	3.9	4.9
Mean ages of reproduction				
Mean age gross fecundity (days)	$\sum x M_x / \sum M_x$	13.5	9.4	10.6
Mean age gross fertility (days)	$\sum x h_x M_x / \sum h_x M_x$	13.2	9.4	7.6
Mean age net fecundity (days)	$\sum x L_x M_x / \sum L_x M$	12.8	8.4	7.2
Mean age net fertility (days)	$\sum x L_x h_x M_x / \sum L_x h_x M_x$	12.5	8.4	7.3
Mean age hatch (days)	$\sum x h_x / \sum h_x$	17.5	10.5	8.3

Table 3. Reduction of reproduction of *Orius niger* (as fraction of the potential reproduction) through various mortality factors at three different temperatures

Mortality of stage	26°C	29°C	32°C
Egg	0.20	0.09	0.11
Adult female	0.06	0.15	0.08
Combined	0.25	0.23	0.20

increase. Our estimate of r_m (0.113 day⁻¹) for *O. niger* at 26°C is similar to that found by Van den Meiracker (1999) at 25°C on a diet of *E. kuehniella* only (0.118 day⁻¹). However, large differences between the two studies occur for R_0 and M_x (68.3 and 166.0 in Van den Meiracker's study and 22.9 and 76.7 in this study, respectively). The similarity of the intrinsic rates of increase of both studies suggests that the differences in reproduction mainly occur later in the reproductive period, where offspring production has a negligible effect on the intrinsic rate of increase.

The advantage of using the intrinsic rate of increase is that it integrates the effects of mortality and fertility factors into a single value. Thus, in-

stead of comparing several life history characteristics (i.e., developmental rate, longevity, fertility, mortality, sex ratio) among populations, a single comparison can be applied (Havelka and Zemek, 1999). Sabelis and Van Rijn (1997) based on the literature stated that the r_m value for *O. niger* was the lowest among all *Orius* species studied using *E. kuehniella* as food source. The intrinsic rate of increase can also be used to estimate the effect of the mortality of each stage on the population growth rate, and this can then subsequently be used to optimize mass rearing. Therefore, we recalculated the intrinsic growth rate at 26°C, assuming that no egg mortality, juvenile mortality or adult mortality would occur. Adult mortality had the lowest effect on the intrinsic growth rate; excluding it resulted in an increase of the r_m from 0.113 to 0.114. Without egg mortality, the r_m would be 0.118, and without juvenile mortality, it would be 0.131. This suggests that juvenile mortality is the most important factor reducing the growth rate of this species, and this also holds for the other temperatures (Fig. 1b, c). Possibly, this mortality is caused by cannibalism among juveniles, or by adults on juveniles. It is

Fig. 1. Reproduction and survival curves of *Orius niger* at three different temperatures (a: 26°C, b: 29°C and c: 32°C) on a diet of pollen and eggs of *E. kuehniella*. l_x =survival of females until age x ; m_x =number of female offspring produced at age x ; and M_x =total number of offspring (=number of eggs) produced at age x (days).

therefore advisable to attempt to reduce cannibalism in mass rearing, for example by providing hiding places for juveniles (Van den Meiracker, 1994). Furthermore, mass rearing of *O. niger* is best done at temperatures around 32°C, although it is possible that growth rates would increase even more with higher temperatures.

In conclusion, the predatory bug *O. niger* can easily be reared on a diet of *E. kuehniella* eggs and pollen, and is therefore a possible candidate for mass releases for biological control of thrips species such as *T. tabaci* and *F. occidentalis*. Because of its adaptation to varying climates in its area of origin, we expect that it will be efficient in a broader range of climatic conditions than the

other species of *Orius* investigated so far.

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