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Comparison of different European strains of *Trichogramma aurosum* (Hymenoptera: Trichogrammatidae) using fertility life tables

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Life table parameters were assessed for seven strains of *Trichogramma aurosum* Sugonjaev and Sorokina (Hymenoptera: Trichogrammatidae) collected in different European countries, in order to compare their performance when reared on eggs of *Ephestia kuehniella* Zeller (Lepidoptera: Pyralidae) as a potential factitious host for mass-rearing. The average number of progeny per female, cumulative fertility and emergence rate did not differ significantly, whereas female longevity and sex ratio significantly differed between the seven parasitoid strains. The Danish strain survived the longest (6.05 days) and the Dutch strain survived the shortest (2.75 days). Progeny was always female-biased with varying proportions (57.7–96.7%). Survival rates started to decrease after 3 days for some of the strains studied. The mean cohort generation duration (T_c) was 11.40, 10.15, 10.62, 10.63, 9.28, 9.70 and 11.30 days for the Austrian, Luxemburgian, Belgian, French, Dutch, Danish and German strains, respectively. Population doubling time (D_t) was 4.50, 7.96, 3.56, 5.30, 5.23, 7.36 and 3.30 days, respectively. Daily intrinsic rate of increase (r_m) and finite rate of increase (exp. r_m) ranged between 0.087 and 0.210 and 1.091–1.233, respectively. The German strain might be a potential candidate for mass rearing and releases against the codling moth, *Cydia pomonella* (L.) (Lepidoptera: Tortricidae), due to its high net reproduction rate ($R_0 = 10.65$ female), a high intrinsic rate of natural increase ($r_m = 0.210$), a high finite rate of increase (exp. $r_m = 1.23$), and a short population doubling time ($D_t = 3.3$ days). The relevance of intra- and interstrain variability as well as the usefulness of fertility life tables for pre-introductory research is discussed.

Keywords: egg parasitoids; longevity; cumulative fertility; realised fertility; life table; intrinsic rate of increase; *Ephestia kuehniella*; mass-rearing

Introduction

The codling moth, *Cydia pomonella* (L.) (Lepidoptera: Tortricidae), is considered to be one of the key pests in apple, peach, plum, pear and walnut worldwide (Blomefield 1989). Five species of the gregarious *Trichogramma* (Hymenoptera: Trichogrammatidae) egg parasitoids have been employed for attempts at controlling this pest. They include *T. platneri* Nagarkatti (Mansfield and Mills 2002), *T. minutum* Riley, and *T. pretiosum* Riley (Yu, Hagley and Laing 1984) from the nearctic region; and *T. dendrolimi* Matsumura, and *T. cacoeciae* (Marchal) (also erroneously identified as

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T. embryophagum Hartig) from the Palearctic (Hassan, Kohler and Rost 1993). In Germany, both *T. cacoeciae* and *T. dendrolimi* have been experimentally released obtaining 40–60% reduction of pest damage (Hassan et al. 1993). There is, however, a necessity to seek additional candidate species, since pest damage must fall below of 1% fruit damage at harvest under German conditions (Hapke 2003).

A clear tendency towards exploiting the potential of indigenous *Trichogramma* spp. is evident because (1) they are believed to be better adapted to the local climatic conditions (Hassan 1994) and (2) safety concerns relating to the release of exotic species has become an important issue (van Lenteren et al. 2003). *Trichogramma aurosum* Sugonjaev and Sorokina is an holarctic species that occurs in Central Europe (Samara 2005), the former USSR (central Russia, Altay region, western Siberia and Zabaykalie), Moldavia, Bulgaria (Livshits and Mitrofanov 1986; Sorokina 1993), and in North America (Pinto, Koopmanschap, Platner and Stouthamer 2002). *Trichogramma aurosum* has been reared from eggs of *C. pomonella* in the mentioned regions. We first collected this *Trichogramma* species in Germany in 2000 from eggs of *Nematus tibialis* Newman (Hymenoptera: Tenthredinidae) on *Robinia pseudoacacia* (L.). In host preference experiments, *T. aurosum* reared from eggs of *Ephestia kuehniella* Zeller (Lepidoptera: Pyralidae), has preferred eggs of *C. pomonella* compared to other lepidopteran eggs (Samara 2005). Therefore, it may be a potential candidate for attempts at controlling this insect pest. From 2001 to 2003, a wide collection of this species from eggs of *N. tibialis* on *R. pseudoacacia* was conducted in the German Federal Republic and on selected sites in six European countries, in order to obtain different strains. Although *T. aurosum* parasitises *C. pomonella* eggs (Sorokina 1993; Pinto et al. 2002), this species could not be obtained from field collected codling moth eggs in this study.

Adaptability to adverse abiotic conditions and suitability for mass rearing are important selection criteria for use of *Trichogramma* spp. in inundative releases/augmentative biological control (Pak 1988). Additionally, species/strains with high parasitic potential under laboratory conditions may achieve better results in the field, though this has not been confirmed in all species tested (Dutton, Cerutti and Bigler 1996; Thomson and Hoffmann 2002). Fertility life tables have received increasing attention in the last 5 years as a tool to evaluate the antagonistic potential of *Trichogramma* spp. (e.g. Haile, Hassan, Sithanatham, Ogol and Baumgärtner 2002), and also to compare the suitability of different species for mass rearing (Pratissoli, Fernandes, Zanuncio and Pastori 2004). The parameters usually calculated from fertility life tables are the net reproductive rate (R_0); the intrinsic rate of increase (r_m), which is a measure of the growth rate of a population per female (Pak and Oatman 1982); the mean cohort generation time (T_c); the doubling time (D_t), and the finite rate of increase (λ) (Southwood 1978; Maia, Luiz and Campanhola 2000).

In this study we compare the life table characteristics of *T. aurosum* strains collected from seven European countries, their parasitisation potential and the population growth parameters when reared on the factitious host, the Mediterranean flour moth, *E. kuehniella*.

Materials and methods

The experimental host species, *E. kuehniella*, was maintained in a growth chamber at $25 \pm 0.5^\circ\text{C}$, $85 \pm 5\%$ RH and 18:6 h L:D photoperiod following the procedure described by Cerutti, Bigler, Eden, and Bosshart (1992).

The parasitoids were obtained by collecting parasitised (blackened) eggs of *N. tibialis* on leaves of *R. pseudoacacia* trees in seven European countries (Table 1). After emergence, laboratory colonies were started and maintained on eggs of *E. kuehniella*. Males of each collection were slide-mounted following Platner, Velten, Planoutene and Pinto (1999), and identified using the key of Pinto (1999). Voucher specimens of all strains are deposited in the collection of the Department of Applied Entomology, University of Hohenheim. A strain is hereinafter defined as the progeny from all eggs collected at the same site on the same day. Strains were placed in glass rearing tubes (70 × 20 mm) closed with a plastic lid, which had a small hole for aeration. The tubes were kept in a climatic cabinet at ca. $25 \pm 0.5^\circ\text{C}$, $85 \pm 5\%$ RH and 18:6 h L:D photoperiod during pupal development of the parasitoids. To feed emerged adults, a strip of undiluted honey was placed in the tube prior to or upon their emergence. All emerged parasitoids were provided with <48 h old host eggs on an 'egg card'. Egg cards were prepared by sprinkling host eggs on a drop of Arabic gum on a piece of paper index card (ca. 50 × 15 mm). All parasitoid strains were maintained under the same conditions as described before. Eggs of *E. kuehniella* were sterilised before use by deep-freezing at -20°C for 4 h, and then stored at $5 \pm 1^\circ\text{C}$ in a refrigerator. When starting the experiments, the strains were reared for 20–25 generations on *E. kuehniella*. Thus, any difference in performance should not be related to varying adaptation to the host species in these experiments.

Cumulative fertility, realised fertility, longevity, mean number of progeny, development time, emergence rate, sex ratio, and survival rate of *T. aurosum* from egg to adult emergence were determined by allowing 16–24 h old mated females to oviposit on *E. kuehniella* eggs (<48 h old). Females of each strain were placed singly ($n=20$) in glass test tubes (75 × 10 mm) with a fine strip of undiluted honey. This was the only food source during the experiments. Egg cards containing 50 *E. kuehniella* eggs were then introduced into the test tubes, removed after 24 h, and replaced every morning until the death of the test females. Each group of test tubes was placed in a

Table 1. List of the collected *T. aurosum* strains, their locations, latitude, longitude and time of the collection.

Strain	Country and locality of collection	Latitude	Longitude	Year
A	Austria, Vienna, Schönbrunn castle	48° 11' North	16° 18' East	July 2003
B	Belgium, Brussels, Hallepoort, Hallepootlaan	50° 50' North	4° 21' East	July 2003
D	Germany, Stuttgart, Plienigen	48° 42' North	9° 13' East	July 2001
DK	Denmark, Copenhagen, Vodroffs Tvaergade	55° 41' North	12° 34' East	Aug. 2003
F	France, Paris, Quai d' Orsay	48° 42' North	2° 10' East	Aug. 2003
L	Luxemburg, Luxemburg, Corniche	49° 36' North	6° 07' East	July 2003
NL	Netherlands, Amsterdam, Laagte Kadijk, Centrum	52° 22' North	4° 53' East	Aug. 2003

cabinet at $25 \pm 0.5^\circ\text{C}$, 16:8 h (L:D) photoperiod, and relative humidity of $80 \pm 5\%$. Development time from oviposition to adult emergence was determined by visual examination every 12 h (07:00, 19:00) for *Trichogramma* emergence. Longevity (number of days) until death of the adults was also recorded. Due to the absence of superparasitism, we define cumulative fertility of a female wasp as the number of parasitised host eggs (as evidenced by blackening) over its life span. Realised fertility is the number of eggs parasitised by individual females over the first 3 days of adult life (Kuhlmann and Mills 1999). The number of parasitised host eggs and the number of adults emerging from them were counted. Parasitised eggs with unemerged parasitoids were dissected to assess the onset of parasitoid mortality. We refer to the number of living female progeny per female in each age interval as age-specific fertility (m_x) (Southwood 1978). Assessment of fertility life table parameters was conducted using the Jackknife technique (Maia et al. 2000).

Data on female longevity and fertility were transformed to $\log_{10}(x+1)$, while the data on emergence rates and sex ratio were arcsine transformed. The transformed data were analysed by ANOVA test using the General Linear Models (PROC GLM) procedure (SAS Institute 1996). The Student–Newman–Keuls (SNK) procedure was used to separate the means.

Results

Mean cumulative female fertility ranged from 6.8 to 14.5 parasitised eggs, but differences between strains were not significant (Table 2, $F=2.11$; $\text{df}=6, 133$; $P=0.0565$). A significant difference in female longevity was found between the DK- and the NL-strain (Table 2, $F=2.33$; $\text{df}=6, 133$; $P=0.0357$). Noticeable female mortality (ca. 30–50%) was recorded on the second day of the experiment (Figure 1). This parameter reached ca. 80% on the fourth day in the F-, L-, and NL-strains. More than 60% of the females from the DK-strain survived 8 days, but total mortality was reached on the ninth day. A total of 100% mortality was reached after 7 days in the NL-strain, whereas this was the case in the rest of the strains between 11 and 15 days (Figure 1). No significant differences in adult emergence rate could be detected (Table 2, $F=1.93$; $\text{df}=6, 133$; $P=0.080$), also the number of progeny produced per female did not differ significantly ($F=2.48$; $\text{df}=6, 133$; $P=0.026$). Yet, a high number of females did not produce any adult offspring in some strains. Dissection of blackened host eggs revealed pre-imaginal death, predominantly during prepupal stage or as pharate adults (Table 2). Results obtained for the pre-imaginal mortality ranged between 11 and 24% but did not significantly differ between the strains studied ($F=0.79$; $\text{df}=6, 30$; $P=0.586$). Age-specific fertility was highest in the first 3 days except for the D-strain (Figure 2). It decreased gradually until the death of the females. The realised fertility in the first 3 days post-emergence differed significantly ($F=2.70$; $\text{df}=6, 133$; $P=0.0165$). The D-strain had the highest number of parasitised eggs, but this was only significantly greater than the F- and L-strains (Table 2). Sex ratio differed significantly ($F=8.33$; $\text{df}=6, 108$; $P=0.0001$). Progeny was extremely female-biased in the F-strain, followed by the D- and B-strains. The remaining strains had sex ratios below 70%. Development time differed significantly between the strains studied ($F=6.25$; $\text{df}=6, 110$; $P=0.0001$) due to the long development time of the D-strain (Table 2).

Table 2. Cumulative fertility, realised fertility, longevity, development time, emergence rate, sex ratio, number of progeny and pre-imaginal mortality of female wasps of seven strains of *T. aurosum* (Means \pm S.E., $n = 20$).

Strain	Cumulative fertility (eggs/female)* ¹	Realised fertility (eggs/female)* ¹	Longevity (days)*	Development time (days)*	Emergence rate (%)** ¹	Sex ratio (%)**	Number of progeny*	Pre-imaginal mortality (%)**
A	12.50 \pm 2.96 ^a (0/8.5/15)	6.40 \pm 5.69 ^{ab} (0/7/10.5)	4.80 \pm 3.85 ^{ab}	10.29 \pm 0.77 ^b	65.12 \pm 44.32 ^a (0/91/99)	66.56 \pm 13.65 ^{bcd}	11.45 \pm 13.44 ^a (0/8/14)	19 \pm 14 ^a
B	11.75 \pm 8.87 ^a (5.5/9/15)	7.90 \pm 4.96 ^{ab} (5/7/9.5)	5.25 \pm 3.46 ^{ab}	10.18 \pm 0.81 ^b	87.37 \pm 35.53 ^a (73/96/100)	77.14 \pm 23.23 ^{bc}	9.45 \pm 7.42 ^a (4/8/12.5)	12 \pm 9 ^a
D	14.55 \pm 13.20 ^a (5.5/10.5/19.5)	11.55 \pm 7.77 ^a (5.5/10.5/18)	3.85 \pm 4.63 ^{ab}	11.35 \pm 1.04 ^a	90.00 \pm 13.18 ^a (88/92/100)	81.33 \pm 23.00 ^b	13.10 \pm 11.95 ^a (4/9/17.5)	11 \pm 10 ^a
DK	7.25 \pm 7.72 ^a (0/5.5/9.5)	7.10 \pm 7.61 ^{ab} (0/5.5/9.5)	6.05 \pm 3.07 ^a	10.00 \pm 0.85 ^b	59.52 \pm 41.19 ^a (0/80/91)	57.76 \pm 16.84 ^d	6.35 \pm 7.05 ^a (0/4.5/8.5)	14 \pm 13 ^a
F	6.95 \pm 7.40 ^a (0.5/6.5/9.5)	5.00 \pm 4.45 ^b (0/6/8.5)	3.60 \pm 2.84 ^{ab}	10.21 \pm 0.80 ^b	60.35 \pm 40.85 ^a (17.5/75/100)	96.72 \pm 9.27 ^a	5.00 \pm 4.67 ^a (0.5/5.5/7)	24 \pm 11 ^a
L	6.85 \pm 7.57 ^a (0/5.5/10.5)	5.20 \pm 5.47 ^b (0/4.5/8)	3.75 \pm 2.86 ^{ab}	9.95 \pm 0.76 ^b	64.20 \pm 43.67 ^a (0/83/100)	58.48 \pm 22.69 ^d	6.10 \pm 6.68 ^a (0/5/8.5)	17 \pm 8 ^a
NL	7.70 \pm 5.46 ^a (3.5/7.5/13)	7.15 \pm 4.94 ^{ab} (3.5/7.5/11)	2.75 \pm 1.52 ^b	10.07 \pm 0.83 ^b	72.00 \pm 41.42 ^a (44/100/100)	61.70 \pm 18.41 ^d	6.90 \pm 5.4 ^a (3.5/6/12.5)	20 \pm 10 ^a

¹(25th percentile/Median/75th percentile). *Log transformed data were used to compare the mean values. **Arcsine transformed data were used to compare the mean proportion. Within a column, means followed by the same letter are not significantly different ($P > 0.05$, Student–Newman–Keuls test, SNK).

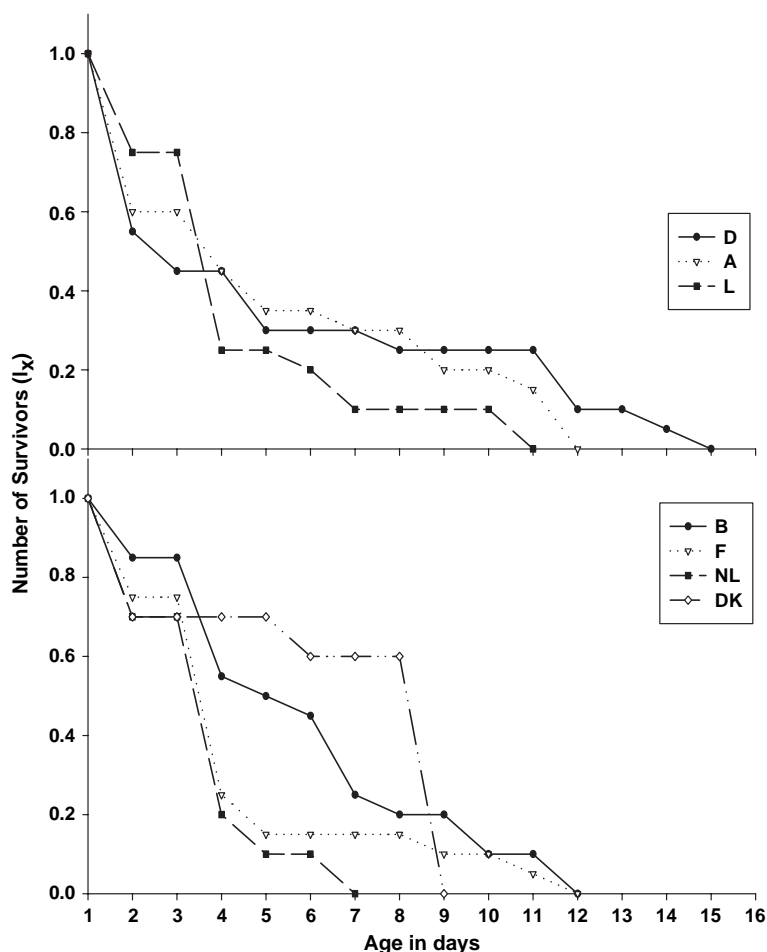


Figure 1. Age-specific survival (l_x) of adult females of seven strains of *T. aurosum* at 25°C, reared from eggs of *E. kuehniella* ($n=20$).

The net reproduction rate (R_0) differed significantly between the D- and the F-, NL-, DK-, and the L-strains (Table 3). The intrinsic rate of increase (r_m) and the finite rate of increase (λ) did not differ significantly between the strains studied. The mean cohort generation duration (T_c) was significantly greater for the D-, A-, B-, and L-strains compared to the NL-strain. Population doubling time (D_t) was significantly higher for the L- and DK-strains compared to those of the D- and B-strains (Table 3).

Discussion

Selection of the most appropriate species or strain of *Trichogramma* is considered to be one of the most critical factors affecting the success of biological control. A considerable part of the recent studies aiming to select promising candidates has relied on assessing interspecific differences between single, or, in the best case,

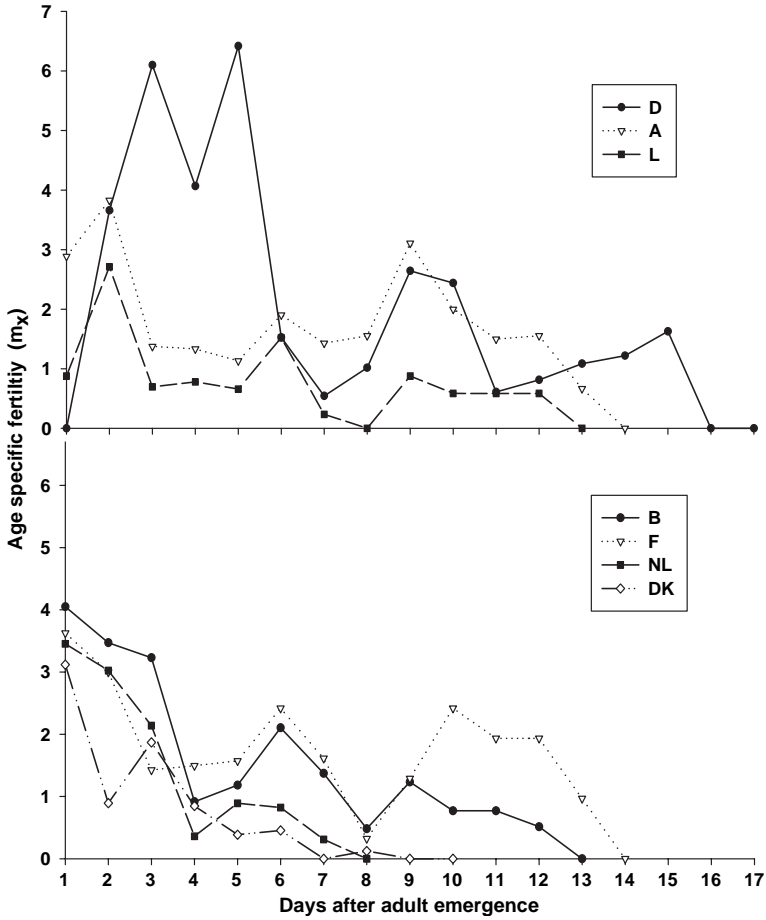


Figure 2. Age-specific life time fertility (m_x) of seven strains of *T. aurosum* at 25°C, reared from eggs of *E. kuehniella* ($n=20$).

Table 3. Life table parameters of seven *T. aurosum* strains.

Strain	R_0	T_c	r_m	D_t	λ
A	$5.70 \pm 3.15abc$	$11.4 \pm 0.92a$	$0.156 \pm 0.04a$	$4.366 \pm 1.40ab$	$1.165 \pm 0.05a$
B	$7.92 \pm 2.87ab$	$10.62 \pm 0.76a$	$0.196 \pm 0.03a$	$3.521 \pm 0.55b$	$1.215 \pm 0.04a$
D	$10.65 \pm 4.52a$	$11.30 \pm 2.02a$	$0.210 \pm 0.028a$	$3.283 \pm 0.45b$	$1.233 \pm 0.03a$
DK	$2.49 \pm 1.24bc$	$9.69 \pm 0.82ab$	$0.097 \pm 0.05a$	$6.559 \pm 4.50a$	$1.099 \pm 0.06a$
F	$4.03 \pm 2.08bc$	$10.63 \pm 1.54ab$	$0.133 \pm 0.04a$	$5.073 \pm 1.76ab$	$1.140 \pm 0.05a$
L	$2.42 \pm 1.34bc$	$10.15 \pm 0.75a$	$0.091 \pm 0.05a$	$6.853 \pm 5.44a$	$1.091 \pm 0.06a$
NL	$3.42 \pm 1.14bc$	$9.28 \pm 0.51b$	$0.134 \pm 0.03a$	$5.101 \pm 1.36ab$	$1.141 \pm 0.04a$

R_0 is the net reproductive rate; T_c is the mean cohort generation time, r_m is the daily intrinsic rate of increase; λ is the finite rate of increase; D_t is the population doubling time. Within a column, means followed by the same letter are not significantly different ($P > 0.05$, Student–Newman–Keuls test, SNK).

between two strains of different *Trichogramma* species (e.g. Pak and Oatman 1982; Schöller and Hassan 2001; Kalyebi et al. 2004; Kalyebi, Sithanatham, Overholt, Hassan and Mueke 2005). With few exceptions, intraspecific differences of strains representing the range of distribution of a species have not been assessed (Smith and Hubbes 1986; Ram, Tshernyshev, Afonina and Greenberg 1995). Our experiments have shown differences between strains of *T. aurosum* from seven European countries with respect to their longevity, realised fertility, and sex ratio. In contrast, cumulative fertility and emergence rate did not differ. The data on net reproductive rate and cohort generation time also indicate that the strains studied differ from each other. Hence, interspecific differences may have been overestimated in the past, as the degree of variation between the strains of the one species we tested might be as great as the range reported for different species of *Trichogramma*. We assume that the differences observed might be due to ecological pressure from local climatic conditions and, consequently, to genetic variability. Intraspecific genetic variability has been reported in *T. brassicae* Bezdenko (= *T. maidis* Voegelé and Pintureau) for traits including locomotion (Pompanon, Fouillet and Bouletreau 1999), the area searched by a female (Bruins, Wajnberg and Pak 1994; Wajnberg and Colazza 1998), and progeny allocation (Wajnberg, Pizzol and Babault 1989). Unfortunately, only one population (probably the same) of *T. brassicae* was tested in the cited studies and hence, neither differences between populations/strains of a species nor between different species can be drawn.

Survivorship curves (Southwood 1978) also differed between the strains studied. Survivorship curve for the B-strain was of type II, i.e. a relatively constant number of individuals died per unit of time. The D- and A-strains had the type III (logarithmic curve), where the mortality rate is constant, while the F-, NL- and L-strains showed a type IV curve, in which mortality does affect mostly young individuals. In contrast, the DK-strain had a type I curve, i.e. mortality acted more upon older individuals. Mean values for female longevity ranged between 2.7 and 6.0 days in our experiments. In work conducted under comparable conditions, values ranged between 8.3 days for *T. brassicae* (Zhang, Zimmermann and Hassan 2004), 5–7 for *T. sp. nr. mwanzai* and *T. bruni* (Kalyebi et al. 2005) and 21.0 for *T. cacoeciae* Marchal (Quednau 1957). Hence, *T. aurosum* can tentatively be regarded as a 'short-lived' species, at least for the experimental conditions we used. Several authors (e.g. Zhang, Agamy and Hassan 2001) have shown however that *Trichogramma* and *Trichogrammatoidea* females deposit the majority of their eggs within the first 3 days after emergence, and hence, the relatively short life span in *T. aurosum* may not impede acceptable levels of parasitisation depending on availability of hosts and food sources.

Cumulative fertility ranged between 6.8 and 14.5 parasitised eggs in our study. In comparable studies with *E. kuehniella* as host, values ranged between 38.0 for *T. cordubensis* Vargas and Cabello (Garcia, Wajnberg, Oliveira and Tavares 2001), and 112.0 for *T. ostrinae* Pang and Cheng (Pavlik 1993). At first glance, the low cumulative fertility of *T. aurosum* may represent a disadvantage for using this species in augmentative biological control. Under field conditions, however, adults of some other species live for a maximum of 3 days (e.g. Mansfield and Mills 2002). Hence, realised fertility may be a more reliable parameter for estimating the parasitic potential of candidate species or strains. Realised fertility for *T. aurosum* ranged between 5 and 12 eggs per female in our study, which represent 50–90% of the

cumulative fertility (Table 2). If the realised fertility is taken into consideration instead of the cumulative fertility, then the performance of the *T. aurosum* strains tested can be regarded as acceptable. The mean number of progeny produced was very close to the cumulative fertility, but with a noticeably high standard deviation, i.e. a huge variation was recorded between individuals of the same strain. This in turn suggests that intraspecific, and intra-strain genetic variability is a very important factor for the evaluation of potential parasitism in *Trichogramma*. By comparing it with the level of pre-imaginal mortality, we found that death occurring in the pupal stage was quite noticeable. This suggests that the eggs of the factitious host *E. kuehniella* are not very suitable for mass rearing *T. aurosum*.

In general, development time at 25°C has been found to be about 10 days for several species of *Trichogramma* (e.g. Harrison, King and Ouzts 1985; Hansen 2000; Haile, Hassan, Sithanatham, Ogol and Baumgärtner 2002), which is in accordance with the results we obtained. Development time was significantly longer in the D-strain, while it did not differ in the rest of the strains. If the D-strain is to be selected for mass-rearing, the longer development time should be taken into consideration. The emergence rate is an essential parameter to measure the suitability of factitious hosts for mass-rearing (e.g. Hassan 1994). Emergence rates ranged from 60 to 90% in our study. Although differences were not significant, we suggest strains with emergence rates above 80% (e.g. the D- and B-strain), since this is of economic importance for rearing facilities. Sex ratio in the progeny differed significantly, but no relationship to lower or higher emergence rates was apparent (Table 2). Similarly, Ram et al. (1995) recorded a high variability of sex ratio (30.6–74.2%) in strains of *T. evanescens* despite of very high emergence rates (89.6–91.4%). Additional studies are needed to clarify whether the differences observed in sex ratio are of genetic origin or if symbionts are possibly involved.

The daily intrinsic rate of increase and the net reproductive rate appear to offer some potential as a biological method for differentiating strains or species (Orphanides and Gonzalez 1971; Stouthammer and Warren 1993; Vavre, de Jong and Stouthammer 2004). This approach has received increasing attention only in the last 4 years. A number of species have been subject of study for various biological parameters but unfortunately, only single or very few strains of different species have been compared (Smith and Hubbes 1986; Kalyebi et al. 2004; Kalyebi et al. 2005). In general, r_m values range between 0.170 and 0.380 (Schöller and Hassan 2001; Zhang et al. 2001; Haile et al. 2002). R_m values for the tested *T. aurosum* strains ranged between 0.091 and 0.210, which is within the range reported for different species of *Trichogramma*. As for *T. aurosum*, the increase of the r_m value could be the product of a high net reproductive rate (R_0) and a relatively long cohort generation time (T_c). This results in a short, but intensive reproduction period with the majority of the eggs being laid in the first 3 days post-emergence. Still, one has to be cautious when using r_m values for selection purposes, as the host species seems to have a major influence on this parameter (Orphanides and Gonzalez 1971; Pak and Oatman 1982; Zhang et al. 2001).

Our study has shown differences between strains of the same species towards biological and growth parameters. As stated by Smith and Hubbes (1986), this has important consequences for mass production and release, as some strains might be better suited to the factitious host and hence, can be easier mass-produced than others. The D- and the B-strain had high values for R_0 , r_m , T_c and λ and short D_t ,

whereas the L- and the DK-strains had very low R_0 , r_m , T_c and λ values and long D_L . From these results we can tentatively conclude that the D-, and perhaps the B-strain have good potential for rearing and release purposes.

An important aspect remains to be addressed by means of semi- and field tests, namely the habitat plasticity of *T. aurosum*. If one considers (1) the widespread occurrence of this species in eggs of a Tenthredinid on *R. pseudoacacia*, and (2) the failure of obtaining *T. aurosum* from naturally laid codling moth eggs on apple trees, then it seems reasonable to argue that this parasitoid may be adapted to the former habitat. If it is possible to experimentally demonstrate that females of *T. aurosum* will remain in apple orchards after release, then targeting codling moth for control attempts with this parasitoid will be realistic.

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