

**BIOLOGY OF *TRICHOGRAMMA OSTRINIAE*
(HYM.: TRICHOGRAMMATIDAE) REARED ON *OSTRINIA NUBILALIS*
(LEP.: PYRALIDAE) AND SURVEY FOR ADDITIONAL HOSTS**

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Trichogramma ostriniae has been identified as a candidate for biological control of *Ostrinia nubilalis*. As little was known about the biology of this parasitoid when reared on *O. nubilalis*, we undertook experiments to quantify biological parameters important to mass-rearing and use of *T. ostriniae*. When reared continuously on *O. nubilalis*, female *T. ostriniae* on average lived 2.7 days and produced 24 progeny. Continuous access to honey resulted in a four-fold increase in longevity and fecundity and a significant increase in the percentage of females parasitizing eggs. Rates of fecundity and parasitism decreased with age of female. Likewise, emergence rates and percentage of female progeny decreased with age of parental female. *T. ostriniae* successfully parasitized *O. nubilalis* eggs until the blackhead stage. Most parasitism of eggs and eclosion of adults occurred during the first half of photophase. Eggs of 13 Lepidopterans were parasitized by *T. ostriniae*. Eggs of the Noctuidae, Pyralidae, and Plutellidae experienced higher levels of parasitism than others tested. *T. ostriniae* appears to be similar to other species of *Trichogramma* in several respects and does not possess any characteristics that limit its potential for mass rearing and use for augmentative biological control of *O. nubilalis*.

KEY-WORDS: *Trichogramma ostriniae*, *Ostrinia nubilalis*, biological control, host range.

The European corn borer, *Ostrinia nubilalis* (Hübner) (*Lepidoptera: Pyralidae*), a serious pest of corn, *Zea mays* (L.), has been the subject of classical biological control programs since shortly after its discovery in the USA. Several parasitoids have been introduced and some have become established (Clausen, 1978). However, control of *O. nubilalis* by these introduced species and endemic natural enemies is not sufficient, especially in sweet corn where direct feeding damage to ears makes the crop unmarketable.

As part of a continuing effort to establish natural enemies of *O. nubilalis* in the USA, the egg parasitoid, *Trichogramma ostriniae* Pang et Chen (*Hymenoptera: Trichogrammatidae*), an important native egg parasitoid of the Asian corn borer, *Ostrinia furnacalis* (Guenée)

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(Zhang, 1988), was selected for introduction from China. Although naturally-occurring populations of *T. minutum* Riley, *T. pretiosum* Riley and *T. nubilale* Ertle and Davis, have been reported to parasitize *O. nubilalis* eggs on corn in the USA, they generally contribute little to control (Baker *et al.*, 1949; Ertle & Davis; 1975, Andow, 1992; Hoffmann *et al.*, unpublished). In an effort to establish *T. ostriniae* in the northeastern USA, several million female *T. ostriniae* were released in New York from 1991 to 1993 (Hoffmann & Shelton, 1994) in cooperation with the USDA-APHIS. Additional releases were made in Massachusetts, Delaware and other locations. Although, *O. nubilalis* egg masses were collected each spring following summers of release, no *T. ostriniae* have been recovered thus far in New York (Hoffmann *et al.*, unpublished).

Trichogramma ostriniae was also identified as a possible candidate for augmentative biological control of *O. nubilalis* because of its effectiveness against *O. furnacalis* in Asia (Wang *et al.*, 1984; Chiu & Chen, 1986; Zhang, 1988). In addition, under laboratory conditions, Hassan & Guo (1991) found that a strain of *T. ostriniae* from China possessed a strong preference for *O. nubilalis* eggs and Pavlík (1993) reported high parasitization of *O. nubilalis* by *T. ostriniae* from North Korea. Both Hassan & Guo (1991) and Pavlík (1993) indicated that *T. ostriniae* possessed considerable potential for augmentative biological control of *O. nubilalis*. In the first field trials with *T. ostriniae* in the USA, Mason *et al.* (unpublished), recorded 97.3 % parasitism of naturally deposited *O. nubilalis* eggs in sweet corn. Given these reports, *T. ostriniae* appears to be a promising species for augmentative biological control of *O. nubilalis*.

The use of *Trichogramma* for augmentative biological control of *O. nubilalis* is well established with several species in commercial production for this purpose (Hassan, 1993; Yu & Byers, 1994). Relative to other areas of the world, progress in the USA toward the commercial use of *Trichogramma* for control of *O. nubilalis* has been slow (Li, 1994).

Because *T. ostriniae* is relatively new outside Asia, information about its biology when reared on *O. nubilalis* is limited to the effect of temperature on its developmental rate (Volden & Chiang, 1982). We therefore investigated several aspects of the biology of *T. ostriniae* that would be important to cost-effective mass-rearing and its use in augmentative biological control. We also evaluated 19 other species of Lepidoptera to determine their suitability for parasitism by *T. ostriniae*.

MATERIALS AND METHODS

Approximately 1,000 female *T. ostriniae* were obtained from the USDA APHIS Mission Biological Control Center, Mission, Texas and a colony was established at Cornell University, Ithaca, NY in October of 1993. At Mission, Texas, *T. ostriniae* had been maintained on *O. nubilalis* since arrival in the USA (personal communication, L. Wood). The USDA colony of *T. ostriniae* was established late in 1990 from parasitoids emerging from egg masses of *O. furnacalis* that had been collected in Jilin Province in northern China (45 °N latitude).

At Cornell University, *T. ostriniae* were maintained continuously on *O. nubilalis* under conditions of 16L: 8D; 25 °C: 23 °C; ~ 80 % RH for approximately two months before our studies commenced. Photophase began at 0800 local solar time. Fresh *O. nubilalis* eggs were provided to the colony on a weekly basis. To provide wasps for various studies, parasitized host material was removed from the colony as needed. All experiments were conducted with *O. nubilalis* as the host (except those to determine host range) and under environmental conditions of the maintenance colony. A supply of undiluted honey was provided to the *T. ostriniae* maintenance colony by smearing a thin coating on a Post-itTM

Note, which was placed in the rearing cage. Unless stated otherwise, females used in these studies were held in the presence of males for ~ 24 h after eclosion to permit time for mating. All studies used individual females caged in clear plastic vials (3 cm diameter, 5 cm in height) with snap on lids. Honey was not provided unless indicated. Except for an occasional unusually small or deformed female, females used in studies were selected at random to minimize potential bias.

European corn borers used in these studies were obtained as pupae from USDA Corn Insects Research Unit, Ames, Iowa where they were being reared on a meridic (wheat germ) diet (personal communication, J. Dyer). Pupae were placed in oviposition cages consisting of hardware screening (0.63 cm mesh) cylinders (25 cm diameter, 38.1 cm in length) under conditions of 16L:8D; 25 °C: 20 °C; ~ 70 % RH. Wax paper was wrapped around the hardware screening and served as the substrate for oviposition. The wax paper was removed from the cages as needed and small sections, each with an egg mass, were used in all studies.

GENERAL PROCEDURES FOR STUDIES OF INDIVIDUAL FEMALES

The number of *O. nubilalis* eggs provided to female *T. ostriniae* was recorded and was typically in excess of what an individual female could parasitize in the time period of the particular study (1-2 egg masses). Consequently, results of parasitism are expressed as number of eggs parasitized per female and/or percentage parasitism of total eggs (total eggs from 1 to 2 egg masses). Following parasitization by female *T. ostriniae*, each egg mass was placed in a gelatin capsule (size 00) and held for later observation. After sufficient time for *O. nubilalis* larval and/or parasitoid development or emergence, the number of each of the following was recorded for each egg mass: *O. nubilalis* larvae that emerged (removed shortly after emergence) or did not emerge (in blackhead stage), desiccated (distinctly shriveled and brown) *O. nubilalis* eggs, parasitized (black) eggs, and number and sex of emerged adult *T. ostriniae*. The parasitized (black) *O. nubilalis* eggs from which parasitoids had not emerged were dissected and the number of partially developed (discernible as a parasitoid) or fully developed wasps present were recorded as "unemerged" parasitoids.

Parasitoid induced egg mortality caused by venom injection, drilling, superparasitism or pseudoparasitism (Bin & Vinson, 1990) was not determined. A percentage of the eggs in all studies were desiccated, but the cause of the desiccation was not known.

BIOLOGICAL PARAMETERS AND INFLUENCE OF THE AVAILABILITY OF HONEY AND MALES

The fecundity and longevity of individual female *T. ostriniae*, and the percentage of females and emergence rates (%) of their progeny were recorded under several conditions: male present with female for only 24 h and either no honey, honey for 24 h or honey continuously available and male present continuously and either no honey or honey continuously available. Honey was in undiluted form and provided by applying a small amount to the inside of the vial lid with a minutia pin. Each female was provided approximately 30 fresh (< 48 h) *O. nubilalis* eggs daily throughout her lifetime. The number of individual females observed ranged from 20 to 36 per treatment. The following were determined for each day of the life of the females: fecundity (emerged + unemerged parasitoids), percentage of progeny that were female (females producing only males were excluded and assumed not to have mated), percentage successful emergence of progeny ((emerged adult parasitoids + emerged + unemerged parasitoids) × 100) and longevity of females that produced progeny. Male longevity was recorded in treatments with continuous honey. Results were summarized as lifetime averages per female and as average per female per day for treatments with continuous honey.

One-way analysis of variance and single degree of freedom contrasts (Abacus Concepts, Inc., 1989) were used to test for the effects of the presence of honey and males on lifetime reproductive characteristics. Percentage data were transformed to arcsine prior to analysis of variance. Simple linear regression (Cricket Graph 1988) was used to determine if parameters changed significantly with age of female. Fecundity data were log transformed prior to regression analyses. When necessary, slopes of regression lines were compared using the method described by Zar (1984).

AGE OF *OSTRINIA NUBILALIS* EGGS AND PARASITISM

O. nubilalis egg masses 1, 6, 12, 18, 24, 48, 72, 96, 120, 144 and 168 h (± 0.5) old were each exposed to 10 individual mated female *T. ostriniae* for 24 h. Egg exposure began at 1000 hrs. Following exposure to *T. ostriniae*, egg masses were placed in gelatin capsules and their fate recorded as described above. Simple linear regression (Cricket Graph 1988) was used to determine if measured parameters changed significantly with age of *O. nubilalis* eggs.

TIME-OF-DAY AND OVIPOSITION.

To determine if the oviposition pattern of female *T. ostriniae* varied with time-of-day, 1 or 2 *O. nubilalis* egg masses (< 48 h old) were presented to individual mated female parasitoids each hour for the first ten hours of photophase (L: D 16: 8) and every two hours for the remainder of the photophase period. The first presentation of eggs commenced immediately after the start of photophase. One egg mass was present with the female during the scotophase period. This was repeated with 60 female *T. ostriniae*. Following exposure to female *T. ostriniae*, egg masses were placed in gelatin capsules and their fate, as described above, recorded. Simple linear regression (Cricket Graph 1988) was used to determine if measured parameters changed significantly during photophase (0800-2400 hrs).

TIME-OF-DAY AND ADULT ECLOSION

Twenty *O. nubilalis* egg masses parasitized by *T. ostriniae* were removed from the parasitoid maintenance colony and held individually in gelatin capsules and the number and sex of emerging adult parasitoids was recorded hourly from 0700 until 1600 and thereafter, every two hours until 2400, and then again at 0700. The second observation (0800) was made immediately after the start of the photophase period. This was repeated from 0700 on the first day until 1500 on the third day. Those few that emerged thereafter were recorded 48 h later.

PARASITISM OF OTHER LEPIDOPTERAN SPECIES

To determine the potential host range of *T. ostriniae*, approximately 20 to 30 eggs (< 72 h old) from each of 19 Lepidopteran species were exposed to an individual mated female (≥ 24 h old) for 2 h in previously described vials. This was replicated with 20 to 40 females for each species of Lepidopteran. Eggs laid individually and arriving loose from suppliers, were stuck to Post-itTM Notes (Corrigan & Laing, 1991) for presentation to wasps. Eggs arriving on wax or plastic paper, Parafilm[®] or paper toweling were presented on their respective substrate. After exposure to female wasps, eggs were held and their fate recorded. All eggs were alive except *Ephesia kuhniella* Zeller eggs which were irradiated prior to shipment to us. Eggs were observed daily and emerging larvae were removed to minimize cannibalism and/or destruction of developing parasitoids.

After one week, individual parasitized (black) eggs from each of the repetitions were removed and placed individually in a gelatin capsule to determine the average number of parasitoids emerging per host egg. The eggs from each of the remaining repetitions were placed in gelatin capsules and the number and sex of the emerging parasitoids recorded.

RESULTS AND DISCUSSION

BIOLOGICAL PARAMETERS AND INFLUENCE OF AVAILABILITY OF FOOD AND MALES

Average lifetime values for female *T. ostriniae* are presented in table 1, whereas daily values are given in fig. 1. Fecundity, percentage female progeny, percentage emergence of progeny and rates of parasitism all decreased as female *T. ostriniae* aged (fig. 1). Simple linear regression showed that this decrease with age was significant ($p < 0.01$) in all cases. In general, whether males were present with females for 24 h or continuously had little effect on the variables measured (tables 1 & 2).

TABLE 1

Effect of the availability of honey and males on lifetime reproductive characteristics of female Trichogramma ostriniae and sex ratio and emergence rate of their progeny when reared on Ostrinia nubilalis

Availability		n	Females parasitizing eggs (%) ^a	Fecundity ^b	Female longevity (days) ^c	Female progeny (%) ^d	Progeny emergence (%) ^e
Male	Honey						
1	First 24h	None	33	58.9 (2.9)	22.4 (0.1)	2.7 (2.3)	86.9 (5.8)
2	First 24h	First 24h	20	100 (3.6)	25.0 (0.1)	2.6 (2.3)	85.9 (5.5)
3	First 24h	Continuous	36	100 (4.9)	86.0 (0.7)	13.9 (2.3)	73.5 (2.4)
4	Continuous	None	25	65.8 (3.3)	24.9 (0.2)	2.7 (2.1)	84.4 (4.7)
5	Continuous	Continuous	20	100 (6.5)	97.9 (0.7)	12.1 (1.5)	79.6 (1.4)

^aMean based on number of females [n] observed.

^bIncludes mean number (\pm SEM) emerged and unemerged parasitoids per female.

^cMean (\pm SEM) longevity of females that produced progeny.

^dDoes not include observations where all progeny were male, apparently due to failure of female to mate.

^eEmerged adult parasitoids + (emerged adult parasitoids + unemerged parasitoids) \times 100.

The availability of honey to *T. ostriniae* females had a significant effect on several biological parameters (tables 1 & 2). When honey was available continuously, lifetime fecundity and longevity of female *T. ostriniae* increased about four-fold compared to no honey available or honey only available for 24 h. Likewise, the percentage of female progeny decreased under these same conditions. The percentage of female progeny produ-

ced over the females' lifetime decreased because females that lived longer produced more male offspring (fig. 1). With continuous honey, about 70 adult parasitoids (proportion emergence \times fecundity) were produced per female versus 15 to 20 adult parasitoids when honey was not available. Honey availability for 24 h compared with no honey (males present 24 h), resulted in an increase in the percentage of females parasitizing eggs (χ^2 $p < 0.01$), but no other variable was significantly affected (table 1). Availability of honey had little effect on emergence rates.

The continuous presence of males significantly decreased the longevity of females under conditions of constant honey (tables 1 & 2). Fecundity and percentage emergence of adult wasps increased under these conditions, but not significantly ($p = 0.06$ & 0.07 , respectively). Males lived an average of $8.6 (\pm 0.08)$ days when supplied honey continuously. The longevity of males under other conditions was not recorded.

In general, our results are similar to those reported for other studies of *T. ostrinae* and other species of *Trichogramma*. Using *O. nubilalis* as a host, Volden & Chiang (1982) found that about 67 % of the progeny were female. Pavlík (1993) reported 83 % female progeny from *T. ostrinae* which had been reared for many generations on *E. kuehniella* and fed honey before transfer to *O. nubilalis* eggs. Under laboratory conditions (24 °C and presumably in the absence of food for adult parasitoids), Chiu & Chen (1986) reported an average 1.8 days longevity for adult *T. ostrinae* reared on *O. furnacalis*, and an average of 20.4 progeny per female. Gou (1988) investigated the biology of honey-fed (20 % solution) *T. ostrinae* reared on the rice moth, *Corcyra cephalonica*, and reported a fecundity rate of 82.3 progeny per female during an average ovipositional period of 7.8 days. Gou (1988) also reported that 80 % of the progeny were female. The higher rates of fecundity and longevity as a result of supplying females with a food source has been shown for other species of *Trichogramma* (Ashley & Gonzalez, 1974; Treacy *et al.*, 1987; Hohmann *et al.*, 1988).

Most studies suggest that the provision of food at the time of release could increase the overall effectiveness of the parasitoids and improve biological control. All of the females provided honey for 24 h parasitized eggs, whereas in the absence of honey less than 66 % of the females parasitized eggs. By increasing the proportion of female wasps parasitizing host eggs it may be possible to lower the release densities and have longer intervals between releases. Ashley & Gonzalez (1974) reported that supplying honey for 1.5 h did not significantly increase fecundity or longevity of *T. pretiosum*, but they suggested that the behavior of the wasp may be affected, i.e., a fed wasp may be searching for hosts while an unfed wasp may be searching for food. Our results support this suggestion because of the increased rates of parasitism by females provided honey for 24 h.

The shift in sex ratio as the female *Trichogramma* ages is another consideration that relates to mass rearing and reproduction of populations in the field. Sex ratios of progeny can be influenced by several factors including host species, parasitoids per host, rate of oviposition and depletion of sperm. For the first 6 days of a females life, ~ 80 % of her progeny were female, thereafter the proportion decreased (fig. 1b). This change in sex ratio with age of *Trichogramma* female has also been reported for other species (Houseweart *et al.*, 1983). With continuous access to honey, the change (regression slope) in percentage female progeny did not differ significantly ($p > 0.05$) whether a male was present 24 h or continuously. This supports the belief that it is only necessary for *Trichogramma* females to mate once. However, when a male was continuously present, female longevity decreased significantly ($p = 0.01$) and increases in fecundity and emergence were nearly significant ($p = 0.06$ & 0.07 , respectively) (tables 1 & 2). The possible reasons for these increases are not apparent. Unlike our studies, Houseweart *et al.* (1983) did not record a significant

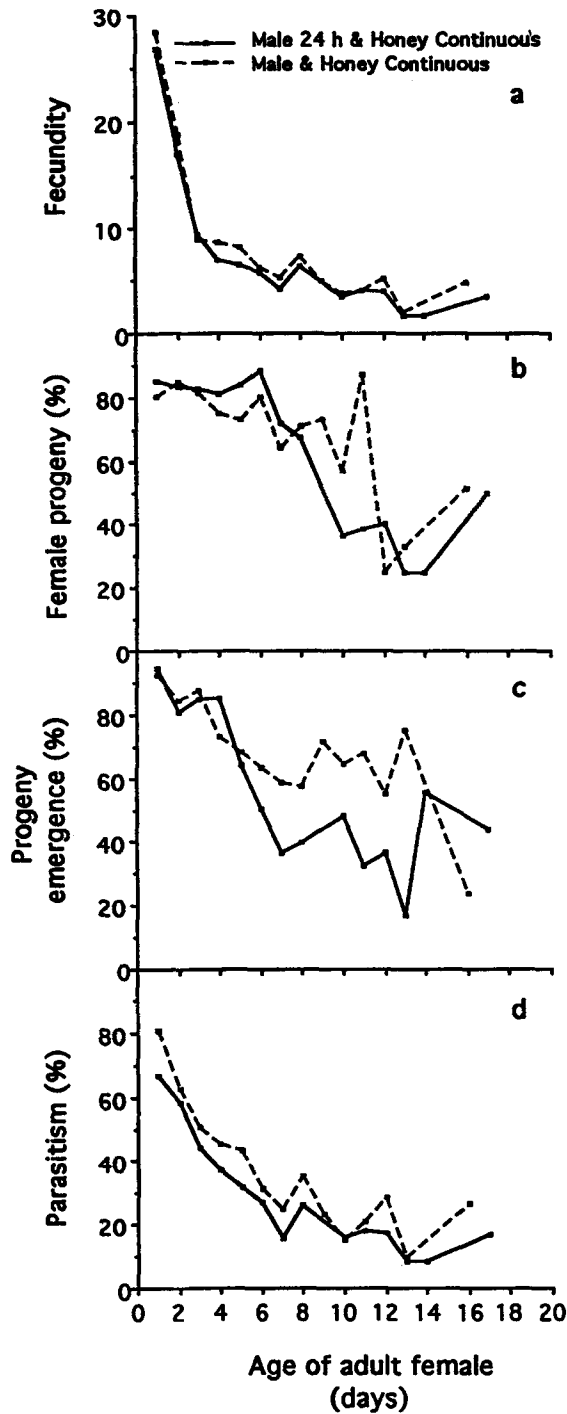


Fig. 1. Changes in reproductive parameters of *Trichogramma ostrinae* with age of female when provided continuously with honey. See text for definitions of parameters.

TABLE 2

Single degree of freedom contrasts comparing the effects of the presence of honey and males on lifetime reproductive characteristics of female *Trichogramma ostriniae* and sex ratio and emergence rate of their progeny when reared on *Ostrinia nubilalis*

Contrast ¹	Single degree of freedom- <i>p</i> values			
	Fecundity	Female longevity	Female progeny (%)	Progeny emergence (%)
1 vs. 4	0.68	0.97	0.19	0.12
1 vs. 2	0.69	0.84	0.55	0.86
3 vs. 5	0.06	0.01	0.16	0.07
1 & 4 vs. 3 & 5	0.0001	0.0001	0.0001	0.43

¹ See table 1 for description of treatments.

change in progeny production with length of time a male was present with a female *T. minutum*. Although this may be because their studies were of shorter duration.

AGE OF *OSTRINIA NUBILALIS* EGGS AND PARASITISM

O. nubilalis eggs were susceptible to parasitism by *T. ostriniae* at least to 120 h of age (fig. 2a, b). By the time the eggs were 144 h old, parasitism was not successful. At 144 h, eggs were at the blackhead stage and at 168 h, *O. nubilalis* larvae were beginning to emerge and were not successfully parasitized. Our research concurs with those of others who have found that *Trichogramma* generally parasitize lepidopteran host eggs over the first 75 % of their developmental period (Strand, 1986).

More than 80 % of the female wasps parasitized eggs and the level of parasitism of the available eggs exceeded 60 % (fig. 2a). More than 90 % of the parasitoids successfully emerged and of these, a high proportion were female (fig. 2c). The mean number of parasitized eggs per female for a given age of host egg was quite variable and ranged from 12.3 to 34.6. Regression analyses showed relatively little relationship ($p > 0.20$) between any of the variables and age (1-120 h) of eggs except for percentage emergence ($p < 0.05$) which decreased slightly with increasing age of egg. Hintz & Andow (1990) reported that emergence rates were higher from younger *O. nubilalis* eggs parasitized by *T. nubilale*.

Based on the patterns of parasitism of *O. nubilalis* eggs (fig. 2a, b), it appears that *T. ostriniae* most closely resembles the Type II relationship described by Pak (1986). In this relationship, the rate of parasitism is relatively high and consistent through the early and mid-developmental stages (first 5 days) and then rapidly declines as eggs mature to within 2 days of hatching. Among the Pyralidae, the Type II relationship was the most common reported in his review of the literature (Pak, 1986). Chiu & Chen (1986) also reported an apparent Type II relationship for *T. ostriniae* parasitizing eggs of *O. furnacalis*.

These results indicate that *O. nubilalis* eggs are susceptible to parasitism by *T. ostriniae* during much of their development. This relatively broad window of susceptibility to parasitism increases the likelihood of successful attack and control in an augmentative biological control program. Reproduction in the field may also be successful given the high emergence rates and the high proportion female progeny.

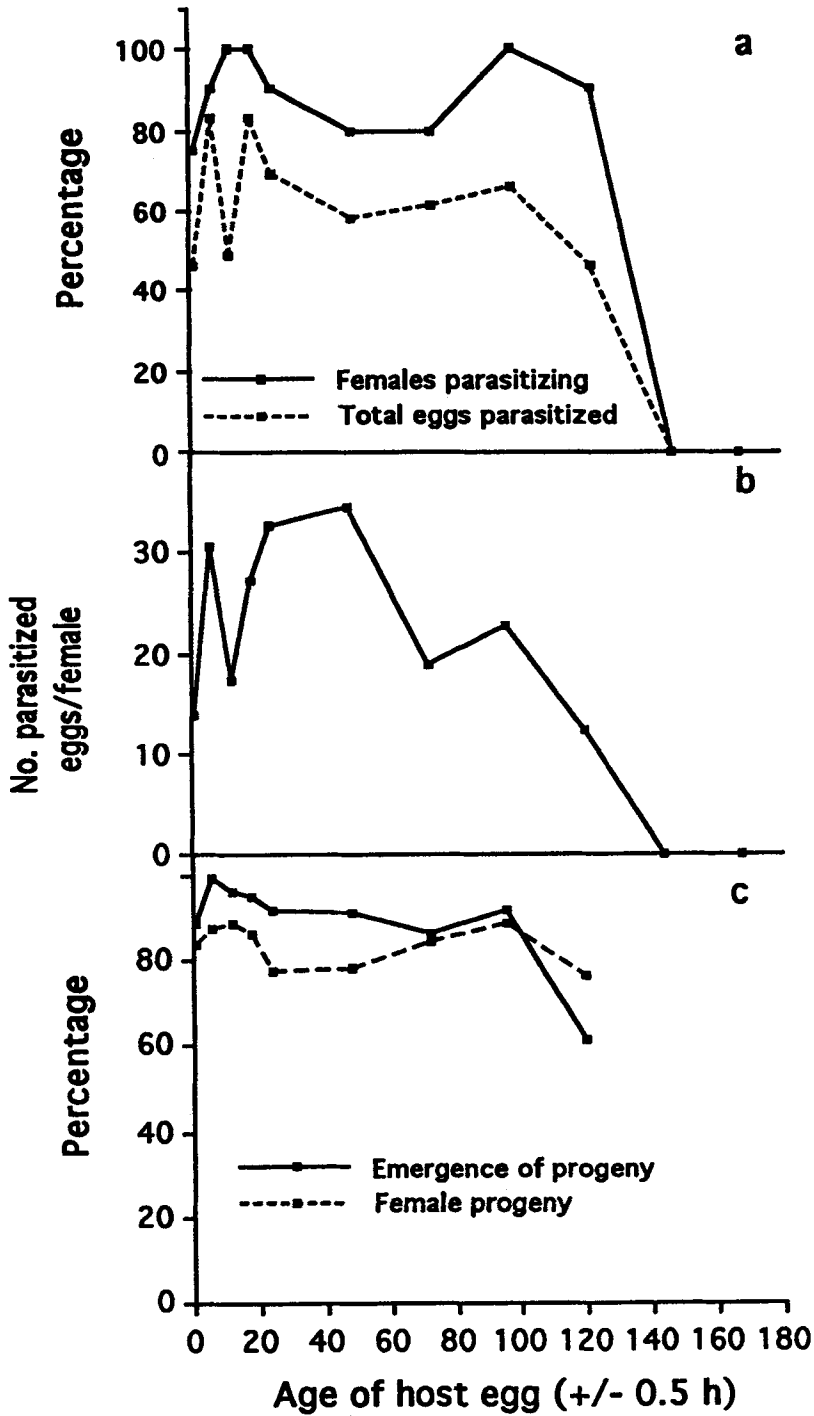


Fig. 2. Parasitism by *Trichogramma ostriniae* of *Ostrinia nubilalis* eggs of varying age.

TIME-OF-DAY AND OVIPOSITION ACTIVITY

Of the 60 individual female *T. ostrinae* observed, less than 55 % parasitized *O. nubilalis* egg masses (fig. 3a). This low rate of parasitism was presumably a reflection of the short time period (1 or 2 h) that the eggs were exposed to the female parasitoids during the photophase. Likewise, the parasitism of available eggs and parasitized eggs per female were relatively low (fig. 3b). No parasitism occurred during the scotophase.

The rate of egg parasitism per female *T. ostrinae* was greatest early in the day (44 % of eggs parasitized by 1200, 78 % by 1600) and gradually declined as the scotophase approached (fig. 3b). This decline in activity may have been more rapid than is apparent in this figure because *O. nubilalis* eggs were present with female parasitoids for two hours (from 1800 to 2400), allowing more time for parasitism. Regression analysis showed that the decline in ovipositional activity with hour of photophase (0800-2400 hrs) was significant ($P < 0.05$) for percentage of females parasitizing eggs, total eggs parasitized, and number of parasitized eggs per female (fig. 3a & b). Percentage emergence and percentage females did not change significantly with hour of photophase (fig. 3c).

Pak & Oatman (1982) reported that *T. brevicapillum* (Pinto & Platner) parasitized the greatest number of *Trichoplusia ni* eggs during the first half of a 12L:12D photoperiod. Very few eggs were parasitized during scotophase. The lack of parasitism during scotophase may be related to the use of vision by *Trichogramma* to locate hosts (Laing, 1937). These results indicate that *T. ostrinae* released in augmentative biological control programs would have the highest rates of parasitism during the first half of the 16 h photophase.

TIME-OF-DAY AND ADULT ECLOSION

Emergence rates were expressed as percentages of the total number (620) of emerging parasitoids observed between 0700 on the first day and 1500 on the third day. An additional 22 parasitoids emerged after the last observation, but the exact time of emergence was not recorded. Most adult emergence occurred during the first few hours of photophase with 83.2 % emerging before 1300 (fig. 4). Only one adult (female) emerged during scotophase. Of the total number of adults that emerged: 68, 28 and 4 % emerged on the first, second, and third day, respectively. Percentage females at each time-of-day is based on pooled data across days. Generally, more than 70 % of the emerging adults were female except for the first hour of photophase when 32 % were female. This is presumably a reflection of the habit of *Trichogramma* males to emerge before females (Waage & Ming, 1984).

In most insects, eclosion occurs only during a specific time-of-day and insects that do not eclose during that particular time cannot eclose until the appropriate time the next day (Mathews & Mathews, 1978). This appears to be true for *T. ostrinae*. The fact that most *T. ostrinae* eclosed and parasitized *O. nubilalis* eggs during the morning hours needs to be considered when releasing for augmentative biological control. If placed in the field when parasitoids are fully mature and ready to eclose, it may be advisable to release either early or late in the day. The former would provide maximum emergence of adults early in the day, the latter, possibly a more practical time for release, would ensure early emergence the next day. A possible third option would be to rear *T. ostrinae* at a photoperiod offset from the natural photoperiod such that emergence and placement in the field would coincide. The objective in each case is to minimize the time that the immature parasitoids are susceptible to loss (Losey & Calvin, 1991; Yu & Byers, 1994) and maximize the number of adult parasitoids during their optimal time for oviposition.

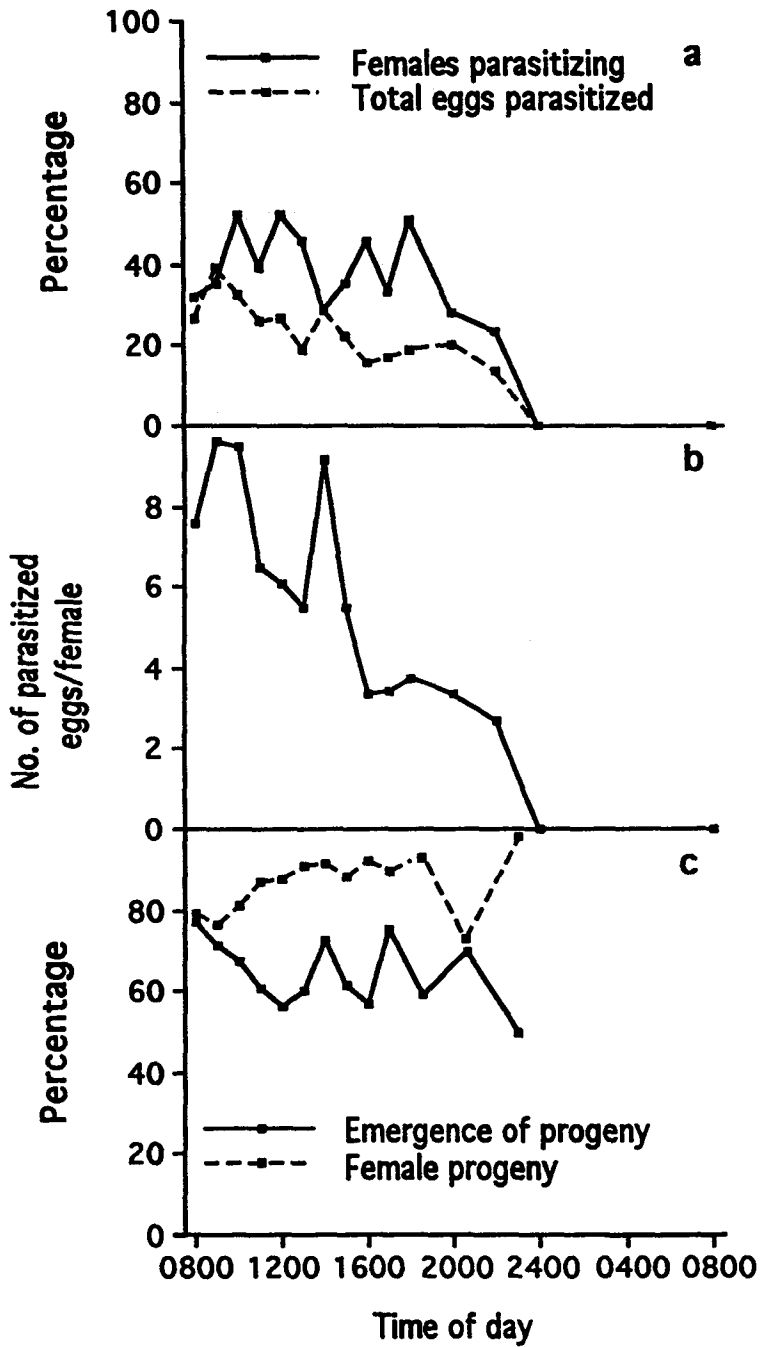


Fig. 3. Parasitism of *Ostrinia nubilalis* eggs by *Trichogramma ostrinae* as influenced by time of day. Photophase began at 0800.

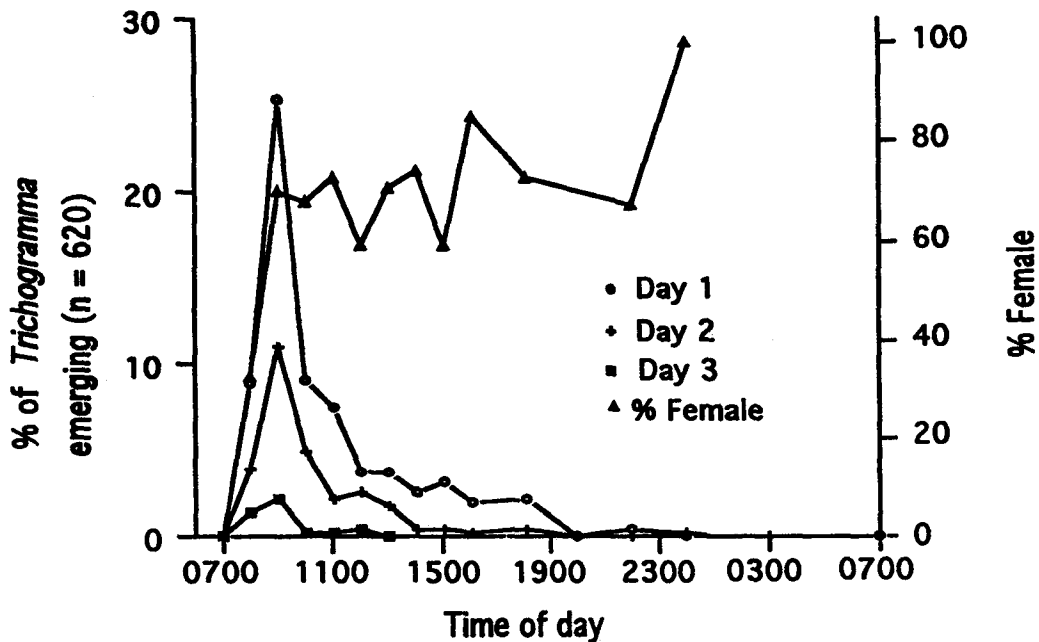


Fig. 4. Daily emergence pattern of *Trichogramma ostrinia* from eggs of *Ostrinia nubilalis* expressed as a percentage of the total number of parasitoids observed. Percentage females based on pooled data across 3 days. Photophase began at 0800.

PARASITISM OF OTHER LEPIDOPTERAN SPECIES

Many species of *Trichogramma* are known to be polyphagous (Burks, 1979). Strains of *T. ostrinia* have been reported to parasitize several different hosts in the field (Oatman *et al.*, 1982; Wang *et al.*, 1984) and they have been successfully reared on several hosts in the laboratory for use, or potential use, in augmentative biological control programs (Li, 1984; Chui & Chen, 1986; Klemm *et al.*, 1990; Hassan & Guo, 1991; Pavlík, 1993). Our objective was to determine if the strain of *T. ostrinia* we had in culture would parasitize potential factitious hosts for mass rearing and also Lepidopteran species of economic importance to North America. These initial screening tests were no-choice, confined to 2 h and a small test arena (previously described small plastic vials), so results can only be used to suggest what might occur under field conditions.

The eggs of 19 Lepidopteran species, representing seven families, were exposed to *T. ostrinia* females. Of these, 13 species were parasitized (parasitoid progeny emerged) (table 3). Eggs of the Gelechiidae, Sphingidae, Pieridae, and Tortricidae experienced lower levels of parasitism than eggs of the Noctuidae, Pyralidae, and Plutellidae. For species where more than 20% of the female *T. ostrinia* parasitized eggs, emergence ranged from 59.1 to 98.8%. The highest number of progeny per female *T. ostrinia*, and per egg, was recorded from eggs of *Helicoverpa zea* (Boddie). Across all successfully parasitized Lepidopteran species, generally more than 60% of the progeny were female.

These results suggest that *T. ostrinia* has a broad host range, including several families of the Lepidoptera. Despite reports (Hassan & Guo, 1991; Pavlík, 1993) of *T. ostrinia*

TABLE 3
Parasitism of lepidopteran eggs by *Trichogramma ostriniae*

Species	No. females parasitizing/total females ^a	% parasitism of total eggs (total eggs)	Mean fecundity/female ^b (± SEM)	Mean % emergence from parasitized eggs ^c (± SEM)	Mean % female (± SEM) ^d	Mean progeny emerging/eggs ^e (n, ± SEM)
<i>Helicoverpa zea</i> (Noctuidae)	28/40	31.8 (907)	17.3 (2.3)	88.0 (6.0)	71.9 (2.9)	2.1 (48,0.1)
<i>Ostrinia nubilalis</i> (Pyralidae)	22/40	22.6 (712)	12.4 (1.6)	70.2 (7.3)	65.2 (5.2)	1.7 (6,0.3)
<i>Trichoplusia ni</i> (Noctuidae)	18/40	18.2 (857)	14.5 (1.5)	98.8 (0.8)	75.4 (3.5)	1.8 (63,0.1)
<i>Spodoptera frugiperda</i> (Noctuidae)	12/40	8.6 (1,006)	9.2 (2.2)	98.5 (1.2)	71.0 (11.9)	1.3 (27,0.9)
<i>Pseudaletia unipuncta</i> (Noctuidae)	8/27	17.9 (464)	17.3 (3.1)	96.6 (2.4)	61.9 (11.9)	1.7 (6,0.2)
<i>Plutella xylostella</i> (Plutellidae)	8/40	3.8 (1,173)	5.9 (1.8)	59.1 (14.4)	69.5 (8.1)	1.0 (9,0.0)
<i>Corcyra cephalonica</i> (Pyralidae)	3/20	4.5 (426)	6.3 (0.7)	66.1 (10.5)	81.1 (11.6)	1.0 (9,0.0)
<i>Spodoptera exigua</i> (Noctuidae)	4/40	4.9 (999)	12.5 (5.1)	88.7 (7.9)	80.5 (7.2)	1.0 (10,0.03)
<i>Plodia interpunctella</i> (Pyralidae)	3/40	2.3 (956)	7.3 (3.0)	81.2 (9.9)	90.0 (10.0)	1.0 (11,0.0)
<i>Choristoneura rosaceana</i> (Tortricidae)	2/40	0.2 (1,200)	1.0	50.0	0	1 (1,-)
<i>Sparganothis sulfureana</i> (Tortricidae)	1/40	0.3 (1,200)	5.0	100.0	60.0	1.3 (4,-)
<i>Galleria mellonella</i> (Pyralidae)	1/40	0.2 (1,139)	3.0	100.0	67.0	1.5 (2,-)
<i>Ephestia kuehniella</i> ^f (Pyralidae)	1/40	0.3 (1,112)	4.0	75.0	0	1 (3,-)
<i>Sitotroga cerealella</i> (Gelechiidae)	0/40	0 (945)	—	—	—	—
<i>Pieris rapae</i> (Pieridae) ^g	0/30	0 (871)	—	—	—	—
<i>Pieris napi</i> (Pieridae)	0/30	0 (562)	—	—	—	—
<i>Manduca sexta</i> (Sphingidae)	0/30	0 (328)	—	—	—	—
<i>Cadra cautella</i> (Pyralidae)	0/20	0 (448)	—	—	—	—
<i>Argyrotaenia velutinana</i> (Tortricidae) ^g	0/30	0 (820)	—	—	—	—

^a Number of *T. ostriniae* females (out of 20 to 40) that parasitized eggs during a 2 h period. One female per 7 dm vial containing approximately 20 to 30 potential host eggs.

^b Includes emerged and unemerged *T. ostriniae*.

^c Adult parasitoids + (adult parasitoids + unemerged parasitoids) * 100.

^d Does not include observations where all progeny were male, apparently due to failure of female to mate.

^e Subsample size (n) indicates number of individual eggs (held in 00 gelatin capsules), from which adult parasitoids emerged. If subsample size was small, no SEM presented. For *Ostrinia nubilalis* and *Pseudaletia unipuncta*, mean (± SEM) was estimated.

^f *Ephestia kuhniella* eggs were irradiated (dead) prior to exposure to parasitoid.

^g For unknown reasons, no larvae emerged from *Argyrotaenia velutinana* or *Pieris rapae* eggs.

being successfully reared on the two widely used factitious hosts for mass-rearing, *Sitotroga cerealella* (Oliv.) and *E. kuehniella*, our strain of *T. ostriniae* performed very poorly under the conditions of these tests. Subsequent efforts in our laboratory however, have shown that these species are readily parasitized by *T. ostriniae* after two to three generations of selection (Hoffmann *et al.*, unpublished). We have also shown that even after ten generations of being reared on these factitious hosts, *T. ostriniae* readily parasitizes *O. nubilalis* eggs.

Results from these various studies indicate that *T. ostriniae* is similar to other species of *Trichogramma* in most respects and does not possess any characteristics that limit its potential for mass rearing and use for augmentative biological control of *O. nubilalis*.

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RÉSUMÉ

Biologie de *Trichogramma ostriniae* (Hym. : Trichogrammatidae) élevé sur *Ostrinia nubilalis* (Lep. : Pyralidae) et sur d'autres hôtes.

Trichogramma ostriniae a été identifié comme un auxiliaire potentiel contre *Ostrinia nubilalis*. Comme la biologie de ce parasitoïde élevé sur *O. nubilalis* est encore peu connu, nous avons entrepris des expériences pour quantifier des paramètres biologiques importants pour l'élevage de masse et l'utilisation de *T. ostriniae*. Lorsqu'elle est élevée uniquement sur *O. nubilalis*, la femelle de *T. ostriniae* a une durée de vie moyenne de 2,7 jours et produit une moyenne de 24 descendants. L'accès continu au miel provoque une augmentation de la longévité et de la fécondité multipliée par 4 ainsi qu'un accroissement significatif du pourcentage de femelles parasitant les œufs. Les taux de fécondité et de parasitisme diminuent avec l'âge des femelles. De même, le taux d'émergence et le pourcentage de descendance femelle décroissent avec l'âge de la femelle. *T. ostriniae* parasite avec succès les œufs d'*O. nubilalis* jusqu'au stade de noircissement de la capsule céphalique. Le parasitisme des œufs et l'éclosion des adultes ont lieu essentiellement durant la première moitié de la photophase. Les œufs de treize espèces de Lépidoptères ont été parasités par *T. ostriniae*. Les œufs de Noctuidae, Pyralidae et Plutellidae présentent des niveaux de parasitisme plus élevés que ceux des autres Lépidoptères testés. *T. ostriniae* est semblable à d'autres espèces de Trichogrammes sur plusieurs points et ne possède pas de caractères limitant ses potentialités en vue d'un élevage de masse et de son utilisation en lutte biologique contre *O. nubilalis* par des lâchers de renforcement.

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