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常规棉花粉和转 *Cry1Ac*+*CpTI* 棉花粉对拟澳洲赤眼蜂繁殖和存活的影响

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摘要:在室内评价了常规棉花粉和转 *Cry1Ac*+*CpTI* 棉(Bt 棉)花粉通过不同处理方式作为食物源对拟澳洲赤眼蜂 *Trichogramma confusum* 寿命、寄生卵数、子代羽化数和性比等繁殖和存活特征的影响。共设计 7 个饲喂处理,即不饲喂(UNFED)、水(W)、水+常规棉花粉(W+P)、水+Bt 棉花粉(W+BtP)、10%蜂蜜水(H)、10%蜂蜜水+常规棉花粉(H+P)和10%蜂蜜水+转 Bt 棉花粉(H+BtP)。在提供或不提供米蛾 *Corcyra cephalonica* 卵条件下,经 W+P 或 W+BtP 饲喂的雌蜂寿命与 W 或 UNFED 间无显著差异,但均显著短于 H 和 H+P 或 H+BtP 饲喂的雌蜂,而经 H+P 或 H+BtP 饲喂的雌蜂寿命又均显著长于经 H 饲喂的雌蜂($p<0.05$)。比较每雌寄生卵数和子代羽化数来看,各处理明显分为 3 类,即 UNFED、W、W+P 和 W+BtP 为最低,H 为居中,H+P 和 H+BtP 为最高。比较每雌子代性比来看,各处理也明显分为 3 类,即 H、H+P 和 H+BtP 为最低,W+P 和 W+BtP 为居中,UNFED 和 W 为最高。饲喂 W+P 和 W+BtP 的雌蜂寿命、寄生卵粒数、子代羽化数和性比分别与 W+BtP 和 H+BtP 饲喂间无显著差异($p<0.05$)。因而,棉花花粉需与蜂蜜组合才能成为拟澳洲赤眼蜂实现其最大存活和繁殖力的食物;Bt 棉花粉对拟澳洲赤眼蜂无影响。

关键词:拟澳洲赤眼蜂;花粉;寿命;生殖力;Bt 棉;非靶标昆虫

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Effect of pollen of conventional cotton and transgenic *Cry1Ac*+*CpTI* cotton on reproduction and survival of the parasitoid wasp *Trichogramma confusum* Viggiani (Hymenoptera: Trichogrammatidae)

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Abstract: The cotton bollworm, *Helicoverpa armigera* (Hubner) (Lepidoptera: Noctuidae), is the most important pest of cotton in China, causing both quantitative and qualitative losses. *Trichogramma confusum* Viggiani (Hymenoptera: Trichogrammatidae) is an endemic egg parasitoid of cotton bollworm H. armigera in China and is a potential biological control agent. The availability and quality of food played an important role in determing the effectiveness of parasitoids as control agents. Adult *Trichogramma* spp. are known to feed upon nectar, pollen and host fluid. Cotton has long period of flowing with large quantity of pollen. Its flowing stage is also the critical time for *H. armigera* control. On the other hand, transgenic pest-resistant cotton has displayed satisfactory resistance to *H. armigera* in many countries in recent years. It is known that the promoting the pest-resistant cotton has gained popularity in China. Beyond concern for the maintenance of susceptibility in

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target pest populations there also are a number of ecological and environmental questions associated with use of transgenic crops, one of the most prominent being effects on non-target organisms. Although transgenic crops are putatively selective, potential effects on non-target insects have been found, the most sensational involving the monarch butterfly (*Danaus plexippus* L.) and Bt corn. With the intense use of transgenic cotton, questions have arisen as to whether these transgenic crops harm any natural enemy populations. The objective of the study was to determine the influence of conventional cotton pollen and Bt cotton pollen as food source on the longevity, number of parasitized eggs, progeny emerged and sex ratio of *T. confusum*. The results of this study under laboratory conditions are then considered in relation to determine whether pollen availability is likely to be an important factor in field performance and whether transgenic cotton pollen could affect survival and reproduction of *T. confusum*.

The effects of pollen of conventional cotton and transgenic *Cry1Ac+CpTI* cotton as a food source on *T. confusum* were assessed in the laboratory by investigating the longevity, number of parasitized eggs and progeny emerged and sex ratio. The seven diet treatment combinations were designated, UNFED for wasps individually were not fed, W for wasps individually were given water alone, W+P for wasps individually were given conventional cotton pollen (20mg pollen in 1 ml water, confected daily), W+BtP for wasps individually were given transgenic cotton pollen (20mg pollen in 1 ml water, confected daily), H for wasps individually were given 10% honey alone, H+P for wasps individually were given individually a suspension of 10% honey and conventional cotton pollen (20mg pollen in 1 ml 10% honey solution, confected daily), and H+BtP for wasps individually were given individually a suspension of 10% honey and transgenic cotton pollen (20mg pollen in 1 ml 10% honey solution, confected daily).

When female *T. confusum* individually either were not fed or were given different diets, in combination with and without host eggs, there was significant variation between treatments. In the absence of eggs of rice moth *Corcyra cephalomica*, females fed on W+P or W+BtP didn't live significantly longer (1.50 days and 1.35 days) than those feed on W alone (1.48 days) and UNFED (1.55 days), but significantly shorter those feeding on H (3.98 days) and H+P (6.74 days) or H+BtP (6.92days), respectively. Females fed on H+P and H+BtP lived significantly longer that fed on H, W, W+P, W+BtP and Unfed treatment ($p<0.05$). In the presence of *C. cephalonica* eggs, females fed on H, H+P or H+BtP with host eggs lived longer than those fed on the same diets but without host eggs ($p<0.05$). Throughout the experiment, longevity of wasps did not suffer any significant alteration between W+BtP and W+P or H+BtP and H+P ($p>0.05$).

There was significant variation in the number of parasitized eggs of *T. confusum* fed on selected food sources. In comparison of the mean of number of parasitized eggs, the treatments can be categorized into three groups: UNFED (40.95), W (44.00), W+P (37.67), and W+P (40.41) are the lowest; H (93.74) is in the middle; H+P (141.09) and H+BtP (154.53) are the highest. Within each category, no significant difference is observed among treatments ($p>0.05$). *T. confusum* females parasitized the greatest number of host eggs on the first day of adult life, irrespective of feeding diets. The number of parasitized eggs rate subsequently decreased dramatically, especially for UNFED, W, W+P and W+P treatments. In comparison of the number of progeny emerged, the results are very close to the number of parasitized eggs and can also being divided into three group: UNFED (37.00), W (41.86), W+P (36.20), and W+P (35.68) are the lowest; H (86.32) is in the middle; H+P (127.74) and H+BtP (138.97) are the highest. Within each category, no significant difference is observed among treatments ($p>0.05$). The trends of daily progeny emerged numbers are very similar to the above parasitized eggs observed situation. The lifetime progeny sex ratio was significantly influenced by the different diet treatments ($p<0.05$). In this case, *T. confusum* fed on H+P and H+BtP had a significantly more male biased progeny than those fed on other foods ($p<0.05$). The sex ratio decreased with parental female age for all treatments.

In conclusion, pollen and honey supplied a complete diet for reproduce and survival of *T. confusum* compared to honey or water alone and pollen of transgenic *Cry1Ac+CpTI* cotton could not affect survival and reproduction of to *T. confusum*.

Key words: *Trichogramma confusum*; pollen; longevity; fecundity; transgenic cotton; no-ntarget insect

棉花是我国重要的经济作物，又是受害虫为害最为严重的作物之一。尤其自20世纪90年代以来，棉铃虫 *Helicoverpa armigera* 在北方棉区连年暴发成灾，严重制约了棉花生产的发展[1]。赤眼蜂 *Trichogramma* 是生物防治中广泛用来防治鳞翅目害虫的一类卵寄生蜂[2]。人工繁殖释放赤眼蜂及赤眼蜂的自然控制作用可有效控制或减轻棉铃虫的为害[3~8]，成为棉铃虫综合

治理体系的重要组成部分。食物的可利用性和质量很大程度上决定了以寄生蜂为作用物的生防效能[9]，花粉、花蜜、昆虫分泌的蜜露和寄主卵液是其成虫在田间潜在的食物源[10~13]。室外和将这些天然食物源以稀释蜂蜜和蔗糖替代的室内研究表明赤眼蜂成虫取食食物可提高其田间寄生率、寿命和生殖力[14~20]。棉花花期长，花粉含量丰富，而棉花花铃期又是控制棉铃虫危害的关键时期。但针对花粉作为食物源对赤眼蜂存活和繁殖的影响尚鲜见报道。Zhang 等报道甘蓝夜蛾赤眼蜂 *Trichogramma brassicae* 取食玉米花粉可显著提高提高其寿命和生殖力[21]。

同时，大面积推广转 Bt 基因抗虫棉已成为当今棉花发展的总趋势[22]。我国华北地区 1999 年转 Bt 基因棉种植面积已超过当地棉花总面积的 50%，2002 年我国转基因棉花种植面积已占我国棉花总面积的 37.1%[23]。自从 Losey 等报道 Bt 玉米花粉能够危害斑蝶 *Danaus plexippus* 幼虫[24]以来，Bt 作物对非靶标生物的潜在影响引起了很多注意[25]。已有一些研究者对 Bt 作物花粉对天敌可能存在的负面影响进行了研究[26]。然而，有关 Bt 棉花粉对赤眼蜂的影响尚未见报道。

本试验以我国棉田主要释放蜂种和田间自然优势蜂种——拟澳洲赤眼蜂 *Trichogramma confusum* 为研究蜂种，在室内研究了常规棉花粉和转 *Cry1Ac+CpTI* 棉花粉对赤眼蜂繁殖和存活的影响，以期为花粉的存在是否是决定赤眼蜂生防效能的重要因子之一及 Bt 棉花粉是否对赤眼蜂具有负面影响提供依据。

1　材料与方法

1.1　供试昆虫

拟澳洲赤眼蜂由吉林农业大学现代化农业研究所提供，原寄主为棉铃虫卵，采自山东棉田。在本实验室用米蛾 *Corcyra cephalonica* 卵持续保种 20 余代。实验开始前 3 代，用新鲜米蛾卵在 25±1℃，*RH*：70%～80%，光照：16L：8D 条件下繁育，接蜂时间为 24h，种群数量维持在10 000～15 000头。随机选取羽化 0～24h、已交配且无产卵经历的同代雌蜂供试。

供试寄主为米蛾卵，取自本实验室用麦麸＋大豆粉饲养的米蛾实验种群。每日收集当日新产的米蛾卵，置于 4℃下贮藏，0～2d内供试待用。使用前距 30W 紫外灯 40cm 照射 40min，杀死其胚胎。

1.2　供试花粉

供试花粉于 2004 年 8 月 28 日采自河北省石家庄市农科院马兰农场实验田。棉花品种为常规棉石远 321（以下简称常规棉）和转 *Bt+CpTI* 双价转基因抗虫棉 SGK321（转入的基因为 *Cry1Ac+CpTI*，以下简称 Bt 棉）。石远 321 为 SGK321 的受体棉。采集期前 2 周内未施用任何杀虫剂。选取当日开放的花倒转至于塑料容器上方，用手指弹震使花粉落入容器内，每品种共采集约 100 朵。将花粉带回室内后，去除杂质，用硫酸纸包装成小份，置于－20℃保存 20d 内待用。

1.3　饲喂处理

共设计 7 个饲喂处理，即不饲喂、水、水＋常规棉花粉、水＋Bt 棉花粉、10%蜂蜜水、10%蜂蜜水＋常规棉花粉和 10%蜂蜜水＋转 Bt 棉花粉，分别简记为 UNFED、W、W＋P、W＋BtP、H、H＋P 和 H＋BtP。其中 W＋P、W＋BtP、H＋P 和 H＋BtP 处理方法为：称取 20mg 花粉与 1ml 水或 10%蜂蜜水配成悬浮液。对寿命的测定分供卵和不供卵两种形式进行。

1.4　测试方法

单蜂引入试管（2cm×8cm）中，以黑色棉布封口。供以一方形纸片（1.1cm×2.1cm），其上用双面胶带（宽 2 mm）平行间距 0.5cm 粘米蛾卵约 200 粒和一小片方形（0.3cm×1.2cm）滤纸（作为供给食物的底物）。用微量移液器吸取每日新鲜配制的上述食物 5μl，均匀点涂于上述滤纸上。预备试验观察得出，5μl 的食物量可使食物充分浸润滤纸且不至于粘死成蜂；5μl 花粉＋水悬浮液或花粉＋10%蜂蜜水悬浮液所含花粉粒数约为 500～1 000 粒。24h 更换一次纸片，观察并记录每头雌蜂的寿命，不足 1d 按 1d 记。将更换下的纸片置于相同试验条件下培养。5d 后，当被寄生卵变黑时，记录寄生卵数。14d 后，用乙醚麻醉致死残余羽化的活蜂，记录子代羽化数和子代雌、雄蜂数。

试验条件为：温度 25±1℃，RH70%～80%，光照 16L：8D。每一处理起始观察头数为 40。试验过程中舍去个别雌蜂丢失和米蛾卵孵化幼虫取食寄生卵的重复，并将实际重复数列于试验结果中。

1.5　数据分析

采用 Kolmogorov-Simirov 法对各处理寿命、子代羽化数和性比进行观测量的正态分布检验。当不呈正态分布的数据进行相应转换使之呈正态分布后，进行独立样本的方差分析 Duncan's 多重比较；对数据转换方法也不能使数据实现正态分布时，采用多个独立样本的非参数检验（Kruskal Wallis H）和两个独立样本的非参数检验。以上数据分析用统计软件 SPSS 进行[27]，数值采用平均值±标准误（mean±SE）。

2　结果

2.1　不同饲喂处理对拟澳洲赤眼蜂寿命和存活的影响

不同食物饲喂处理的拟澳洲赤眼蜂雌蜂寿命测试结果绘成图 1。在不供卵条件下，W＋P 和 W＋BtP 处理的雌蜂平均寿命分别为 1.50±0.08d 和 1.35±0.08d，两处理间无显著差异，且分别与 UNFED 处理（1.55±0.08d）和 W 处理（1.48±0.08d）间

也无显著差异。以上各处理均显著短于H处理(3.98±0.32d)、H+P处理(6.74±0.47d)和H+BtP处理(6.92±0.55d)。其中H+P处理和H+BtP处理间差异不显著,但均与H处理差异显著。

在供卵条件下,W+P和W+BtP处理的雌蜂平均寿命分别为1.75±0.13d和1.70±0.11d,两处理间无显著差异,且分别与UNFED处理(1.87±0.09d)和W处理(1.86±0.10d)间也无显著差异。上述两处理寿命均显著短于H处理(7.02±0.69d)、H+P处理(11.68±0.76d)和H+BtP处理(11.63±0.79d)。其中H+P处理和H+BtP处理间差异不显著,并且均与H处理差异显著。

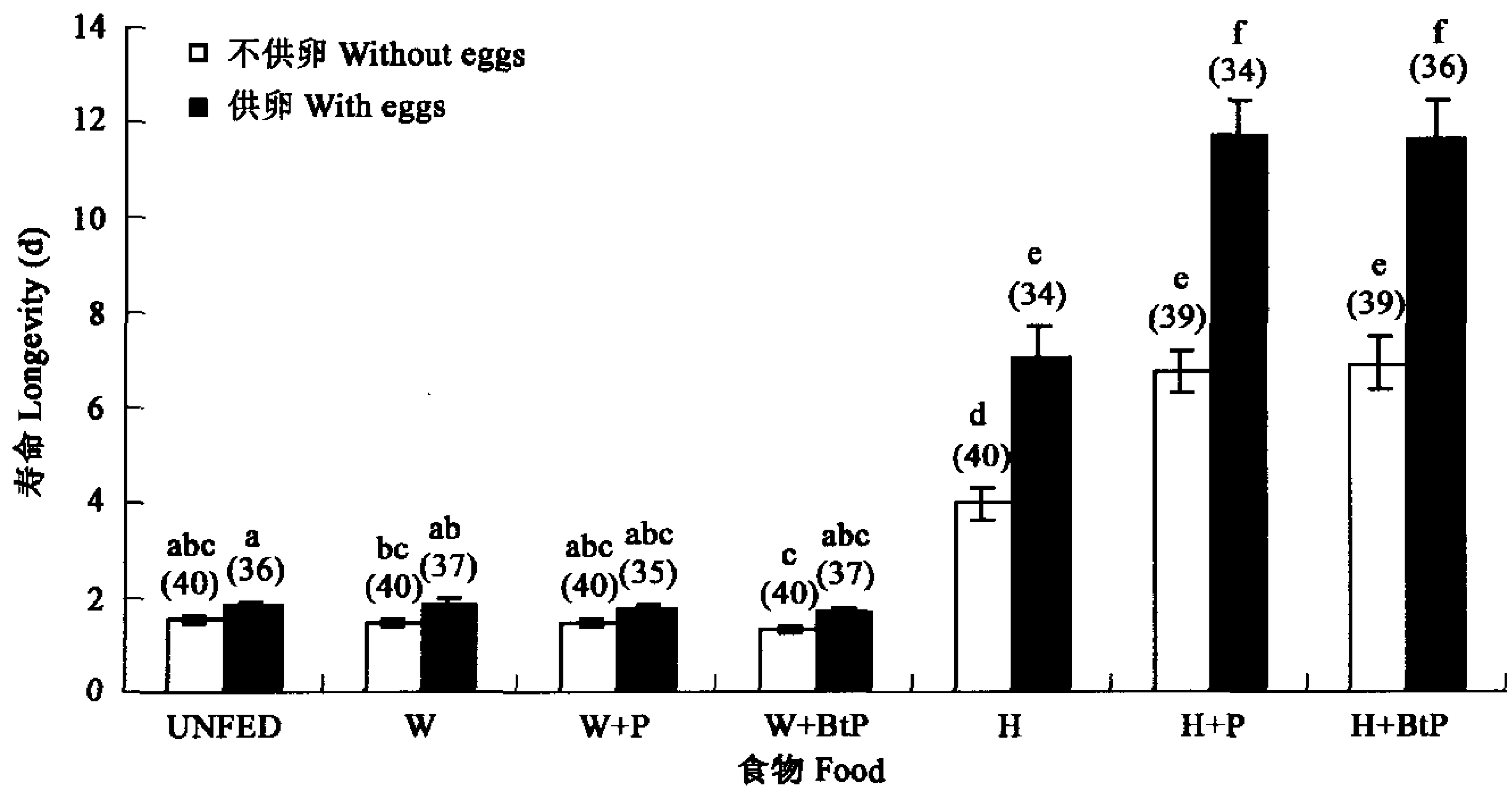

图1 供卵和不供卵条件下不同饲喂处理拟澳洲赤眼蜂的寿命(±标准误)

Fig.1 Longevity(±SE) of *Trichogramma confusum* females provided with different diets in the presence or absence of host eggs

括号内数字为重复数;柱上字母为Kruskal Wallis检验比较结果,字母不同表示差异显著($p\leqslant 0.05$)Numbers in bracket are sample sizes; Columms with different letters indicate significant difference at $p\leqslant 0.05$ by Kruskal Wallis.

供卵条件下H、H+P和H+BtP处理的雌蜂平均寿命均显著长于不供卵条件。逐日存活率数据(图2)表明,饲喂H、H+P和H+BtP处理的雌蜂存活时间均长于其它处理,其中H+P和H+BtP处理逐日存活率变化趋势近似,下降较平缓,且存活时间均长于H处理。

2.2 不同饲喂处理对拟澳洲赤眼蜂繁殖特征指标的影响

不同食物饲喂条件下拟澳洲赤眼蜂雌蜂寄生卵数、子代羽化数和性比等繁殖特征数据列于表1。比较平均每雌寄生卵数来看,可将各处理明显分为3类,即UNFED、W(44.00±2.23粒)、W+P(37.67±2.10粒)和W+BtP(40.41±2.15粒)为最低,H(93.74±9.14粒)为居中,H+P(141.09±8.58粒)和H+BtP(154.53±10.32粒)为最高,且同一类中不同处理间无显著差异,不同类别间差异显著。从逐日寄生卵量(图3)来看,各处理雌蜂均在羽化当日就达到其产卵高峰,之后随雌蜂年龄的增加急剧波动性下降。其中,UNFED、W、W+P和W+BtP下降趋势相似,H+P和H+BtP下降趋势也相似。

表1 不同饲喂条件下拟澳洲赤眼蜂的寄生卵数、子代羽化数和子代性比

Table 1 Number of eggs parasitized and number and sex ratio of progeny emerged of *Trichogramma confusum* given different food sources

饲喂处理 Treatment	n	寄生卵数(粒) Number of parasitized eggs	子代羽化数(头) Number of progeny emerged	性比(雌∶雄) Sex ratio (female/male)
UNFED	36	40.95±1.82a	37.00±1.78a	3.78±0.43a
W	37	44.00±2.23a	41.86±2.13a	3.49±0.34a
W+P	35	37.67±2.10a	36.20±2.13a	2.22±0.26bc
W+BtP	37	40.41±2.15a	35.68±2.13a	2.75±0.30ab
H	34	93.74±9.14b	86.32±8.39b	1.54±0.17c
H+P	34	141.09±8.58c	127.74±7.76c	1.06±0.15d
H+BtP	36	154.53±10.32c	138.97±9.26c	1.64±0.33d

表中数据为平均值±标准误,同列数字后字母为Duncan's新复极差比较的结果,字母相同表示差异不显著,字母不同表示差异显著($p<0.05$)Data are Mean±SE; Means in a column followed by the same letter are not significantly different at $p<0.05$ by ANOVA

比较平均每雌子代羽化数来看,也可将各处理明显分为3类,即UNFED(37.00±1.78粒)、W(41.86±2.13粒)、W+P(36.20±2.13粒)和W+BtP(35.68±2.13粒)为最低,H(86.32±8.39粒)为居中,H+P(127.74±7.76粒)和H+BtP

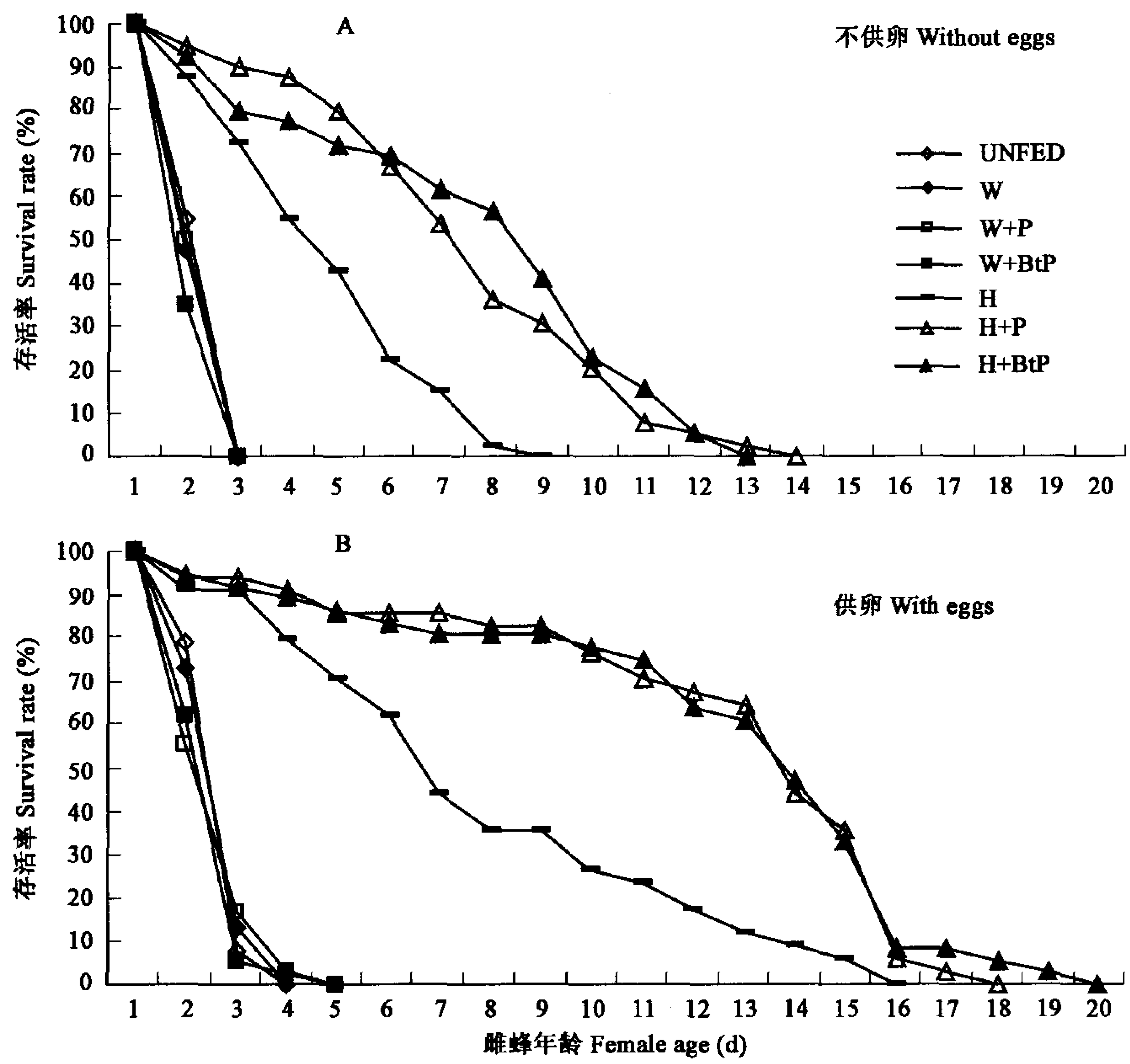

图 2　供卵和不供卵条件下不同饲喂处理拟澳洲赤眼蜂雌蜂的逐日存活率

Fig. 2　Daily survival rate of *Trichogramma confusum* females provided with different foods with and without eggs

(138.97±9.26 粒)为最高，且分类格局、差异性比较结果与上相同。逐日子代羽化数(图 3)变化趋势也与上相似。

从平均每雌子代性比来看，饲喂 W+P 和 W+BtP 处理的性比分别为 2.22±0.26 和 2.75±0.30，两处理间无显著差异，但均显著低于与 UNFED 处理(3.78±0.43)和 W 处理(3.49±0.34)，而 UNFED 处理和 W 处理(3.49±0.34)间差异不显著。饲喂 H+P 和 H+BtP 处理的性比分别为 1.06±0.15 和 1.64±0.33，两处理间无显著差异，但均分别显著低于 H 处理(1.54±0.17)及其它处理(表 1)。从逐日子代性比(图 3)来看，各处理子代性比均在母代雌蜂羽化当日为最高，之后随母代雌蜂年龄的增加急剧波动性下降。其中，UNFED、W、W+P 和 W+BtP 下降趋势相似，H+P 和 H+BtP 下降趋势近似。

3　讨论

许多寄生蜂成虫通过取食花粉、花蜜或同时取食二者来获取营养[9,13,28]。花粉一般含有复杂的小分子营养组分，并且许多花粉含有高水平的游离氨基酸[12]。富含碳水化合物的花蜜一般提供能量，而通常与花蜜一同被取食的花粉一般提供体内卵成熟所需养分[28]。Zhang 研究表明甘蓝夜蛾赤眼蜂饲喂玉米花粉+水与只饲喂水相比可显著提高其寿命和生殖力，饲喂花粉+蜂蜜混合物与只饲喂蜂蜜相比则对寿命和生殖力无显著提高[21]。研究表明，拟澳洲赤眼蜂雌成蜂饲喂棉花(常规棉和 Bt 棉)花粉+水悬浮液与不饲喂和只饲喂水相比，对其寿命和寄生卵数(可近似作为生殖力的估计)无显著影响，但饲喂棉花花粉+10%蜂蜜水悬浮液可显著提高其寿命和寄生卵数。两研究上述结果间的差异除与研究材料的本质差异(如蜂种、花粉营养组分和蜂蜜浓度不同等)有关外，还与棉花花粉需与蜂蜜组合才能成为拟澳洲赤眼蜂实现其最大存活和繁殖力的食物有关。田间蜜源的存在，如植物花蜜或外花蜜(extrafloral nectar)、昆虫(如蚜虫)分泌的蜜露等，可提高赤眼蜂寿命和对靶标害虫的寄生率[11,19,20,29]。在室内，通常以蜂蜜或蔗糖来替代上述自然食物源，通过大量研究也已表明蜜源对提高赤眼蜂成虫寿命和生殖力及其它生物学指标的价值[14~18]。针对花粉作为食物源对赤眼蜂存活和繁殖的影响的室内研究结果则提示：田间散落的花粉也是不容忽视的影响其生防效能及自然控制作用的重要因子之一。寄主卵也是赤眼蜂的潜在食物源之一。一般认为取食寄主对寄生蜂体产卵有利，而非寄主食物对维持存活和繁殖有利[16]。Roberson 等报道，短管赤眼蜂 *T. pretiosum* 通过取食寄主致死 3.0%～6.6%的寄主卵[30]。Hasen 等报道，在 30℃下，土耳其斯坦赤眼蜂 *T. turkestanica* 逐日取食 1.7%～7.0%的地中海粉斑螟 *Ephestia Kuehniella* 卵[16]。研究结果表明，供卵条件下 H、H+P 和 H+BtP 处理的拟澳洲赤眼蜂雌蜂平均寿命均显著长于不

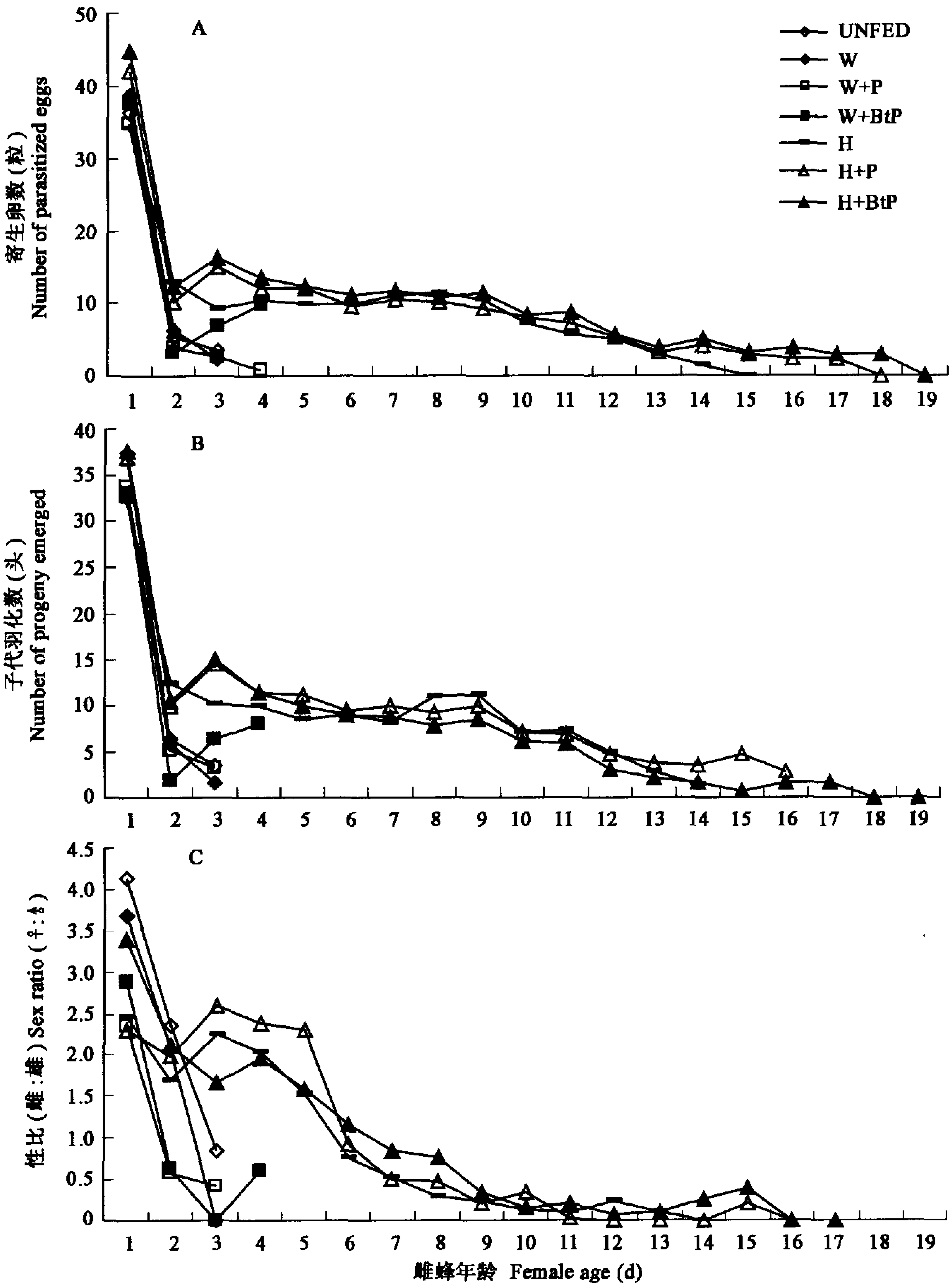

图 3 不同饲喂处理拟澳洲赤眼蜂雌蜂的逐日寄生卵数、子代羽化数和性比

Fig. 3 Daily parasitized eggs and daily numbers and sex ratio of progeny emerged by female *Trichogramma confusum* given diffent foods

供卵条件，但尚不能明确这一现象是否直接由拟澳洲赤眼蜂取食寄主导致。

赤眼蜂存活期间可根据寄主供量调节其生殖力，短管赤眼蜂[31]和微小赤眼蜂 *T. minutum*[32]雌成蜂的寿命和生殖力之间呈负相关关系，即寿命越长生殖力越低。相反，螟黄赤眼蜂 *T. chilonis* 却呈正相关关系[31]，对拟澳洲赤眼蜂的试验结果与之相符，即寿命越长生殖力越高。赤眼蜂被认为是前携卵式昆虫[33]，其潜在生殖力不可能由食物的供给而增加，但是存活时间长的赤眼蜂有更多机会产出体内有限的所有成熟卵[15]。试验过程中，多数雌蜂死亡前仍持续产卵寄生寄主卵，仅有个别雌蜂死亡前不持续产卵寄生。此外，还发现不同饲喂处理条件下的拟澳洲赤眼蜂子代性比均在其存活期间首日为最高，之后性比逐渐降低，6d 之后以产雄为主(雌：雄<1)。Leatemia 等研究表明，长寿命的微小赤眼蜂以雌蜂产雄为主(雄性比 50%～62%)，短寿命的以产雌为主(雌性占 74%～82%)[18]，结果与之近似。

种植转基因抗虫植物既要控制靶标害虫，且必须与天敌协调共存，才能融入有害生物综合治理体系[34]。Pilcher 等研究表明 Bt 玉米花粉对斑鞘饰瓢虫 *Coleomegilla maculata*、普通草蛉 *Charysoperla carnea* 和隐伏小花蝽 *Orius insidiosus* 等 3 种捕食性天敌的生长和发育无影响[26]。针对寄生性天敌的大量研究表明，由于转基因抗虫作物对靶标害虫的控制作用，极大地降低了靶标害虫的种群数量，直接影响了寄生性天敌种群的增长，即使是取食转基因抗虫作物存活下来的幼虫，其生长发育也受到很

大的抑制作用，从而影响到体内寄生性天敌的生长发育，必然会导致一些靶标害虫的寄生性天敌的种群数量降低，甚至极显著的降低，但这种影响并不代表转基因抗虫作物本身对寄生性天敌有负面效应[25]。对于赤眼蜂这类卵寄生蜂而言，其幼虫取食寄主卵而完成生长发育；而成虫则取食花粉或花蜜，也可取食寄主卵。这些途径都有可能使转 Bt 基因植物对赤眼蜂产生影响。本试验专注于转 Bt 棉花粉对赤眼蜂雌成蜂的直接负面影响，研究结果初步表明，饲喂 W+BtP 和 H+BtP 对拟澳洲赤眼蜂雌成蜂寿命、寄生卵粒数、子代羽化数和性比均无显著影响。杨益众等报道，无论是棉铃虫哪一个世代、哪一个虫态，常规棉田棉铃虫卵、幼虫的寄生率均显著高于转基因棉，并认为转基因棉田棉铃虫卵的寄生率（以拟澳洲赤眼蜂寄生为主）下降与棉花作物有关，而与棉铃虫卵（寄主）无关[35]。由本研究的结果可推测，Bt 棉花粉的存在不是造成寄生率下降的主要原因，更可能与转基因棉花对棉田寄生物的忌避效应[23]有关。目前，美国、澳大利亚和中国等多个产棉国已大面积推广种植转基因抗虫棉。这些转基因抗虫棉，既有常规的转 Bt 基因、*CpTI* 基因等单一基因的抗虫棉，也有转 API 等多种抗虫基因的抗虫棉。本文仅以转入 Bt+*CpTI* 基因的双价抗虫棉为研究代表，研究 Bt 棉花粉对赤眼蜂繁殖和存活的影响。至于其它转基因棉花品种（系）花粉对赤眼蜂的影响表现如何需要进一步研究。另外，Bt 棉 Bt 毒蛋白含量的时空表达有较大差异。在空间效应上，棉株不同空间组织在同一时期的毒性表达存在差异，其抗虫活性顺序为叶＞蕾＞铃＞花。在苗期，全展功能叶中 Bt 毒蛋白含量最高，根、茎和叶柄 Bt 毒蛋白含量较低；在花铃期，当日开花的花器中 Bt 毒蛋白含量为子房＞雌雄蕊＞花瓣及苞叶[36]。由此，对于 Bt 棉花粉或 Bt 棉对赤眼蜂的影响应从时空角度结合花蜜和外花蜜（由叶、蕾和铃分泌）进一步研究。

试验是在实验室内将试虫局限于狭小的试管中，供以中间寄主而非自然寄主，并且拟澳洲赤眼蜂雌成蜂对寄主和食物的利用在无选择性条件下进行。因而，以上试验结果类推至田间需进一步的田间试验和观察来证实。

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