第 24 卷第 12 期
2004 年 12 月

生 态 学 报
ACTA ECOLOGICA SINICA

Vol. 24, No. 12
Dec., 2004

温度对传粉甲虫——棉露尾甲生长发育、存活及繁殖的影响

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摘要：在光照周期为 12L：12D、土壤含水量为 15%的 5 种恒温条件下（15℃、20℃、25℃、30℃和 35℃），以丝瓜花为饲料研究了棉露尾甲未成熟期（卵期、幼虫期和蛹期）的生长发育和存活情况；同时，在同样的光照和温度、棉球保湿的条件下，研究了温度对成虫寿命及繁殖的影响情况。结果表明，未成熟期各虫态发育速率随温度呈抛物线变化，30℃时发育速率最大；15℃时卵孵化率最高，20～30℃时，幼虫存活率、蛹羽化率显著高于低温（15℃）和高温（30℃），平均分别可达 96.3%和 93.2%，低温和高温对其有明显的抑制作用；成虫寿命同温度之间呈负的线性关系，雌虫寿命普遍长于雄虫，30℃时雌虫的产卵期最长，繁殖力最大，最高可达 146 粒/雌，产卵期和产卵量与温度之间呈抛物线关系。

关键词：棉露尾甲；温度；发育；繁殖力

Influence of temperature on development, survival and fecundity of Pollination Beetle: *Haptoncus luteolus* (Erichson)

LUO Feng, XIONG Qiang, WANG Jian, LEI Chao-Liang (*Institute of Insects Resources, Huazhong Agricultural University, Wuhan*, 430070, *China*). ***Acta Ecologica Sinica*, 2004, 24(12): 2789～2793.**

Abstract: Beetles are one of the oldest pollinators and many have evolved fixed pollination relationship with flowers. Nitidulids (Coleoptera: Nitidulidae) were reported as pollinators long ago and are important pollinators of plants such as Annonaceae, Arecaceae, Dipterocarpaceae, Ebenaceae, Icacinaceae, Moraceae, Myristicaceae, Palmae, etc. *Haptoncus luteolus* (Erichson) can pollinate commercially grown sugar apples (*Annona squamosa* L.) and atemoyas (*A. squamosa* X *A. cherimola* P. Miller) in Florida. In domestic studies, nitidulids were recorded as pests in storages, cotton and rape. Luo Feng et al. have carried out research on the distribution and diffusion of *H. luteolus* in cotton field. They considered a valuable pollinator because it has a strong ability to diffuse and its range of host plants pollinated is very wide. Since this early research of nitidulids pollinators in China, there have been few reports about their biological and ecological traits. In this study we investigate the development, survival and fecundity of *H. luteolus* at different temperatures.

H. luteolus used in our experiments were taken from the towel gourd field of Huazhong Agricultural University. They were housed and raised in the Institute of Insects Resources of Huazhong Agricultural University. We kept the adults at a constant temperature (27±2℃) and used the flowers of towel gourd to feed them. Every day we changed their foods, kept a tampon wet to maintain the humidity in the the bottles used to house the beetles, and collected eggs from petals.

Five temperature were used in the experiments (15℃, 20℃, 25℃, 30℃ and 35℃) one level of water-content in soil (15%) and illumination cycle of 12 hours light and 12 hours dark. The temperatures and illumination cycle were controlled by JKDP-2 type Eternal Temperature boxes. Intensity of illumination was equal to that found 15cm away from a 10W lightbulb in normal daylight. We took the soil from the field and removed stones and roots of grass. The soil was then dried in an oven and its

基金项目：湖北省自然科学基金资助项目（2003ABA103）

收稿日期：2003-05-11；**修订日期**：2004-03-10

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Foundation item: Hubei Natural Science Foundation (No. 2003ABA103)

Received date: 2003-05-11; **Accepted date**: 2004-03-10

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weight stabilised. When the soil was cooled to room temperature, we added water to make the water-content of thesoil 15% (comparative water-content in soil).

Under the conditions of each combination of temperatures, water-content in soil and illumination cycle, we got data from at least 10 replicates containing immature stages including of eggs, larvae and pupae which were kept in a culture dish ($\Phi \times h =$ 6.5×1.5cm). We repeated the same experiment three times. Every day we observed the beetles 3 times (08:00, 14:00 and 20:00). Each time we not only made observations and recorded the developmental periods of instars at different ages but also paid attention to the developmental process and how well they grew. At the last observation (20:00) of each day, we measured the weight of each cultural dish and added water to maintain the water-content at 15% but only after taking the records.

When dealing with the adults, we use the same temperatures and illumination cycle as in the immature stages. We placed one female and one male, eclosing in 12h, into a finger tube (1.5cm×6.0cm) and used a water-soaked tampon to maintain humidity instead of controlling water-content in soil. The coupled adults were fed petals of towel gourd covered in pollens. Petals were changed daily and the number of number of eggs laid by the female laid in 24h counted. Counting ended when the female died. We recorded the pre-oviposition duration, fecundity and longevity of females. If the male died first, we maintained our observation. If the female died first, we ceased our observation. Our results show that temperature has a significant effect to development, survival and fecundity of *H. luteolus*. The relationship between temperatures and rate of developmental immature stages (egg, larva and pupae) changes as a parabola model and the rate of developmental was highest at 30℃ are most rapid. The hatchability rate of eggs was highest at 15℃ (96.7%). Under conditions of 20～30℃, the survivability of larvae and the rate of eclosion averaged 93.2% and peaked at 96.3%. These values are significantly higher than under lower (15℃) and higher (35℃) temperatures. With increasing temperature, the longevity of adults declined as a model of negative linearity. At the same time, oviposition duration and fecundity of females change as model parabola. Generally, longevity of females is higher than that of male. 30℃ is a suitable condition for oviposition duration and fecundity of adults which peaked at 16.85d and 146 grain per female respectively.

Key words: *Haptoncus luteolus*; temperature; development; fecundity

文章编号:1000-0933(2004)12-2789-05 **中图分类号**:Q968 **文献标识码**:A

甲虫是地质史上出现最早的传粉昆虫[1]，在漫长的进化过程中，很多甲虫形成了与植物花相互密切联系的专一性的特征，并与之建立起了固定的传粉关系，是很重要的传粉昆虫[2]。

棉露尾甲 *Haptoncus luteolus*(Erichson)属于鞘翅目(Coleoptera)露尾甲科(Nitidulidae)。国外很早就有露尾甲科昆虫作为传粉昆虫的研究报道[3]，并且露尾甲科传粉甲虫传粉的植物范围很广，主要有番荔枝科(Annonaceae)、槟榔科(Arecaceae)、龙脑香科(Dipterocarpaceae)、柿科(Ebenaceae)、茶茱萸科(Icacinaceae)、桑科(Moraceae)、肉豆蔻科(Myristicaceae)、棕榈科(Palmae)等[4]，棉露尾甲则是番荔枝科植物上的一种重要的传粉昆虫[5]；国内研究主要记载为仓储害虫[6]、棉花害虫[7]和油菜害虫[8]，罗峰对棉露尾甲在棉花上的分布、扩散和寄主范围进行了调查研究，发现该种露尾甲有较强的活动扩散能力和较广的寄主分布范围，认为其是一种极具利用前景的传粉昆虫[9]。

我国对传粉露尾甲的研究尚处于起始阶段，有关其生态学特性等各方面的研究少见报道，为此，本文报道了在实验室不同恒温条件下棉露尾甲的生长发育、存活及繁殖情况。

1 材料与方法

1.1 供试虫源

棉露尾甲成虫采自华中农业大学校园丝瓜菜地，采回后置于罐头瓶中以新鲜的丝瓜花为饲料，用蘸水的脱脂棉保湿，放置于室内恒温下(27±2℃)饲养。每天更换丝瓜花，并从换下的花瓣中挑取当日所产的卵备用。

1.2 实验方法

1.2.1 温度、土壤含水量及光照的设置 试验共设置了 5 个温度为 15℃、20℃、25℃、30℃和 35℃，温度误差幅度控制在±0.5℃范围以内；土壤含水量为 15%；光照周期 L:D=12:12，其中温度和光照周期通过人工气候箱设置。

土壤含水量的设定为将丝瓜菜地中取回的土壤除去石块、草根等杂质，放入烘箱中烘干至恒重，冷却至室温后，用精确度为 0.01 的电子天平称取烘干土壤，加水分别配置成试验所需的含水量。含水量＝加入的水量/(土壤重量＋加入的水量)。

光照强度为 10W 的日光灯管距培养皿 15cm 照射。

1.2.2 未成熟期的发育观察试验 将每天采下的卵放在小片丝瓜花瓣上置于土壤含水量为 15%、直径 Φ×高 h 为 6.5cm×

1.5cm 的培养皿中,皿口覆上保鲜膜并加盖,每天定时观察 3 次(8:00、14:00 和 20:00),将每次得到的发育状况一致的同龄幼虫小心挑到相同条件的培养皿(放有处理过的丝瓜花瓣)中继续培养。得到的蛹置于调好土壤含水量的培养皿中直接培养,同时标记并详细记录各虫态发育历期,预蛹期是指末龄幼虫颜色变深,体形不再增加,不吃不动的这段时间;蛹期是指从蛹到成虫羽化的这段时间;幼虫历期不包括预蛹期。各虫态历期的倒数即为发育速率。每虫态获取至少 10 个数据,重复 3 次,并且计算出卵孵化率、幼虫存活率和蛹羽化率。每天最后一次观察后,对每个培养皿称重,并补充相应重量的水分,以保持土壤含水量的稳定。

1.2.3 成虫产卵前期、产卵量和寿命的观察试验　取 $\Phi \times h$ 为 1.5cm×6cm 的指形管,底部垫上少许脱脂棉并盖上一层滤纸,加水用以保湿。取 12h 内羽化的成虫雌雄配对,用带有花粉的丝瓜花瓣作为产卵垫,管口盖上一层打有小孔的滤纸进行饲养。每天定时观察并更换丝瓜花瓣,注意保持脱脂棉的湿润,同时检查成虫是否在花上产卵及产卵的数量。记载雌虫第 1 次产卵的时间、产卵持续的时间及以后各次的产卵量,直至雌雄虫均死亡为止,记载死亡时间。如每对成虫中雄虫先死而雌虫未死,则继续观察;如果雌虫死亡则停止观察。

2　结果与分析

2.1　温度对棉露尾甲未成熟期发育速率的影响

从表 1 可以看出,未成熟期各虫态随温度的升高,历期缩短,发育速率明显加快,到 30℃时达到最大,在此温度下卵、幼虫、预蛹、蛹的发育历期依次为 1.21d、1.94d、3.67d 和 2.28d,对应的发育速率分别为 0.8264、0.5155、0.2725 和 0.4386;当温度继续升高时(到 35℃),发育速率反而降低,各虫态发育速率同温度之间呈抛物线变化(图 1,表 2)。

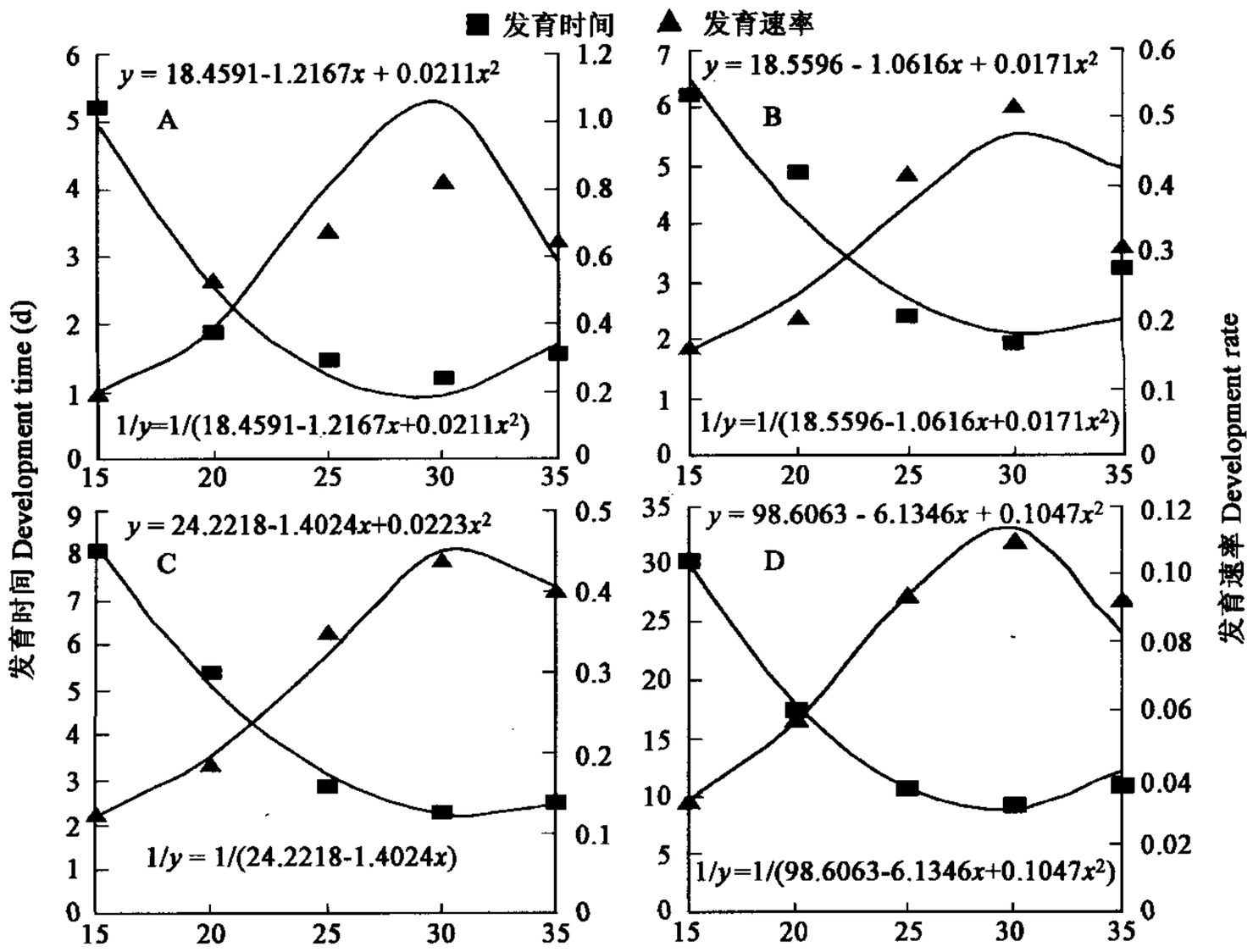

图 1　温度与未成熟期发育的关系

Fig. 1　Relationship of development to temperature for immature stages of *H. luteolus*

A　卵期 Egg;B　幼虫期 Larva;C　蛹期 Pupae;D　整个未成熟期 Whole immature stages

表 1　不同温度下棉露尾甲未成熟期发育历期

Table 1　Development time of immature stages of *H. luteolus* under different temperatures

温度(℃) Temperature	卵期(d) Egg	幼虫期(d) Larva	预蛹期(d) Prepupa	蛹期(d) Pupa	总和(d) Immature stages
15	5.21±0.076	6.23±0.046	10.74±0.096	8.12±0.15	30.30±0.28
20	1.88±0.059	4.90±0.11	5.39±0.060	5.37±0.16	17.45±0.27
25	1.48±0.034	2.40±0.07	3.96±0.057	2.87±0.12	10.71±0.18
30	1.21±0.050	1.94±0.05	3.67±0.081	2.28±0.05	9.09±0.11
35	1.55±0.055	3.23±0.11	3.69±0.36	2.49±0.28	10.79±0.42

卵的生长发育受温度的影响较为显著,发育历期从 15℃的 5.21d 缩短到 30℃的 1.21d,20℃到 35℃各温度之间相差不大,约 0.5d,说明此温度范围内比较适合于卵的生长发育,卵的发育速率最大;低温(15～20℃)条件下,幼虫、预蛹和蛹的发育进度较慢,适温(25～30℃)和高温(35℃)条件下,各虫态发育进度明显加快,不同温度之间历期差异不大,约 1d 左右,说明在

25～35℃范围内，幼虫、预蛹和蛹的发育进度最快。

表 2 各虫态历期(y)依温度(x)变化的回归模型

Table 2 Regression equations of various stages of *H. luteolus* between development time(y) and temperature(x)

虫态 Life stages	回归式 Regression equation	相关系数 Correlation coefficient
卵 Egg	$y=18.4591-1.2167x+0.0211x^2$	$R=0.9076^{**}$
幼虫 Larva	$y=18.5596-1.0616x+0.0171x^2$	$R=0.9004^{**}$
蛹 Pupa	$y=24.2218-1.4024x+0.0223x^2$	$R=0.9230^{**}$
未成熟期总和 Immature stages	$y=98.6063-6.1346x+0.1047x^2$	$R=0.9811^{**}$

** 表示在显著水平为 0.01 means significant level is 0.01

同一温度下，卵的发育进度最快，其次是幼虫和蛹；预蛹期的发育时间最长，各温度下分别为 10.74d、5.39d、3.96d、3.67d 和 3.69d，约占各自未成熟期总和的 30%～40%。

2.2 温度对各虫态存活率的影响

温度对未成熟期各虫态的存活率有着显著的影响(表 3)。卵在 15℃和 30℃条件下，孵化率均达到 90%以上，其中 15℃时达 96.7%；幼虫存活率和蛹羽化率在 20～30℃温度范围内变化不大，并且均在 90%以上，其中幼虫平均存活率达到 96.3%，蛹期平均存活率达 93.2%，高温和低温条件下明显不适合幼虫及蛹的发育，其中幼虫在 35℃下存活率仅为 16.7%，而蛹羽化率仅为 60%。

表 3 不同温度下各虫态的存活率(%)

Table 3 Survival rate of various stages of *H. luteolus* under different temperatures

温度 Temperature(℃)	卵 Egg	幼虫 Larva	蛹 Pupa
15	96.7	58.6	76.5
20	83.3	96.0	95.8
25	66.7	96.7	93.1
30	90.0	96.3	90.8
35	85.7	16.7	60.0

2.3 温度对成虫寿命及繁殖的影响

温度对成虫寿命、产卵期和产卵量有显著的影响(表 4)。雌雄成虫的平均寿命(y)与温度(x)之间呈显著的线性关系(图 2，3)，与雌虫寿命关系式为：$y=65.0520-1.8000x$ ($R=0.9931^{**}$)，与雄虫寿命关系式为：$y=58.7430-1.6130x$ ($R=0.9919^{**}$)，15℃时雌雄成虫的寿命最长，分别为 34.29d 和 39.93d，其变幅均在 9～62d 范围之内，35℃时寿命最短，最长不超过 3d，总的趋势，雌虫寿命普遍长于雄虫。

产卵期(y)与温度(x)之间呈开口向下的抛物线变化关系(图 4)：$y=-57.5291+6.1466x-0.1304x^2$ ($R=0.9649^{**}$)，其中 20～30℃时产卵期显著长于其它条件，其间差异仅为1～5d，说明此温度范围比较适合成虫产卵，20℃时产卵期最长为 15.86d，35℃时最短仅为 1d。

每雌的平均产卵量(y)与温度(x)之间呈开口向下的抛物线变化(图 4)：$y=-161.0760+15.1542x-0.2950x^2$ ($R=0.8471^{**}$)，其中，30℃时平均产卵量最高，为 42.00 粒，产卵量变化范围在 4～146 粒之间，即单雌最高产卵量为 146 粒；35℃时产卵量最低，仅为 1～3 粒。

表 4 不同温度对成虫繁殖力和寿命的影响

Table 4 Effects of temperatures on fecundity and longevity of *H. luteolus*

温度 Temperature (℃)	产卵前期 Pre-oviposition duration(d)	产卵期 Oviposition duration(d)	平均每雌每天产卵(粒) Mean fecundity per day per female(g)	平均产卵量(粒/雌) Mean fecundity per female	雄虫寿命 Longevity of male(d)	雌虫寿命 Longevity of female(d)
15	6.18±0.39	3.13±0.69	1.21±0.16	3.75±0.94	34.29±4.59	39.93±4.24
20	4.61±0.35	15.86±2.39	1.17±0.13	18.29±3.10	28.40±1.97	27.47±2.20
25	2.93±0.29	14.23±1.57	1.96±0.21	27.23±3.45	15.87±2.28	18.13±1.56
30	4.40±0.74	10.00±1.09	2.77±0.43	42.00±5.61	10.73±0.78	12.13±0.94
35	1.71±0.00	1.00±0.00	2.00±0.45	2.00±0.45	2.8±0.14	2.6±0.19

3 讨论

3.1 温度对发育历期的影响

不同温度对棉露尾甲发育历期的影响极为显著，其中最适发育温度为 30℃，35℃条件下发育进度虽然与其相差不大，但是死亡率很高，并不适合其生长发育，可以认为是发育的一个极限温度，但是棉露尾甲发生盛期在 7～9 月份，此时武汉地区温度很高(可达 35℃以上)，这可能是自然种群数量限制的一个因素，有待于进一步调查研究。

3.2 温度对存活率的影响

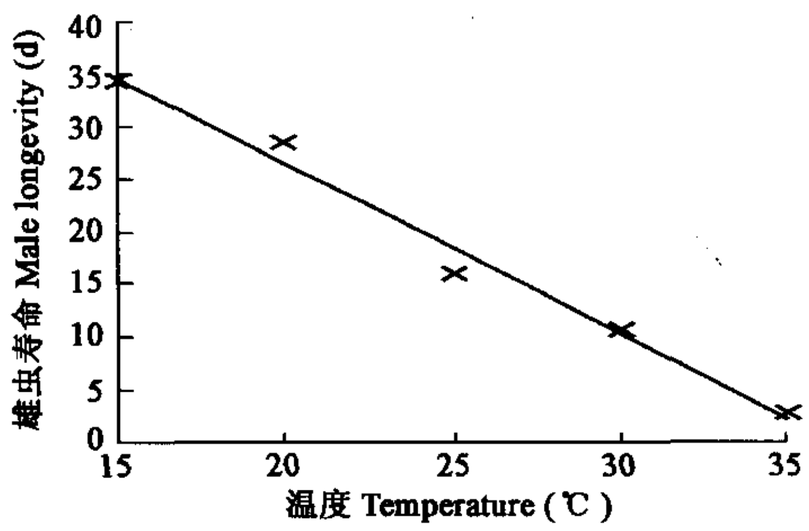

图 2　温度与雄虫寿命的关系

Fig. 2　Relationship of temperature with longeivity of male

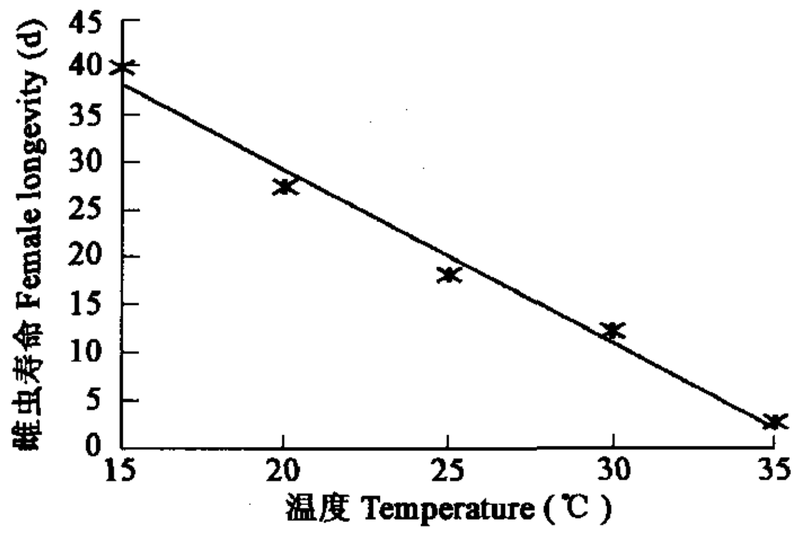

图 3　温度与雌虫寿命的关系

Fig. 3　Relationship of temperature with longeivity of female

温度对幼虫和蛹存活率、羽化率影响较为一致,20～30℃是一个合适的温度范围,高、低温对其有明显的抑制作用;但是卵的孵化率在15℃下却显著高于其它温度,这可能与其生活环境条件有关。卵主要产于花瓣表面,而幼虫和蛹则生活于表层土中,实验过程中,土壤含水量对卵的作用可能是通过调节空气湿度而实现的,而相同的土壤含水量在不同温度条件下所产生的空气湿度存在着一定的差异,故有可能15℃下产生的空气湿度比较适合于卵的孵化;低温条件下,土壤中的水份不易散发,故在培养皿和土壤的相对湿度较大,随着发育时间的延长,幼虫和蛹很容易染病或腐烂;高温条件下,水份散发到空气中较快,土壤中相对较易失水,此时仅空气湿度较大,幼虫和蛹极易干瘪死亡。温度和湿度表现出明显的互作效应,因此有必要对此作进一步研究。

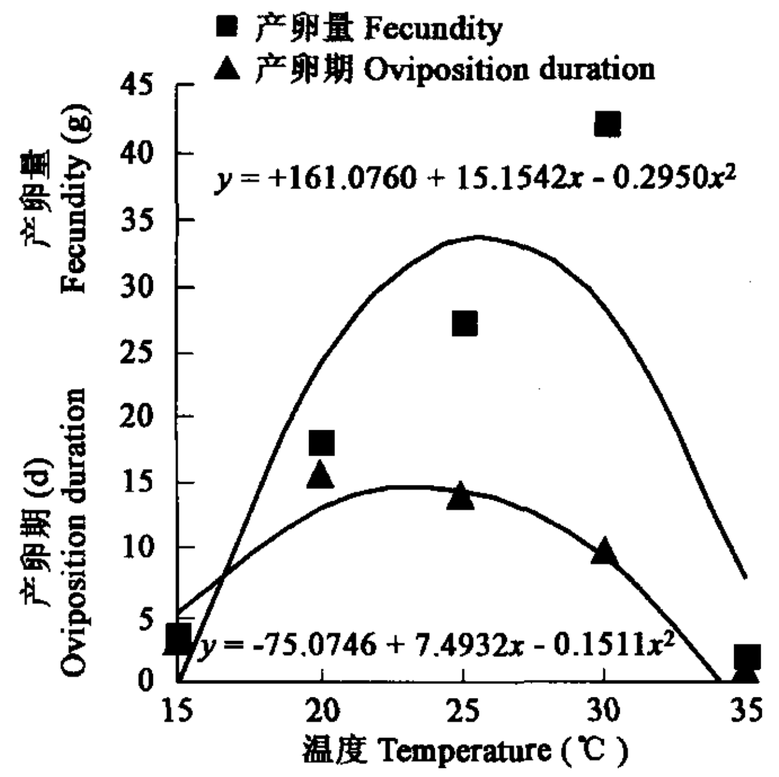

图 4　温度与雌虫产卵期和平均产卵量的关系

Fig. 4　Relationship of temperature with Pre-oviposition duration and Mean fecundity

3.3　温度对成虫寿命和产卵量的影响

高温和低温条件下,温度对成虫交配产卵的抑制影响明显,此时产卵前期较产卵期长。15℃时,产卵前期最长为6.18d,产卵期较短为仅为3.13d,此时,成虫活动交配能力很弱,雌虫一般在产卵期的几天内连续产卵,产卵量也不大,然后停止,此后一般钻到卷曲的花瓣中静止不动或很少活动,表现出明显的休眠现象,室外温度下降后,从田间采回的成虫不在产卵也能证明这一点;35℃高温下对成虫交配产卵有明显的刺激作用,在经过短暂的产卵前期(1.71d)后,即开始产卵;但是此温度是棉露尾甲不适应的极限温度,成虫均在经过短暂的产卵期后死亡。同时,由于是采取棉球保湿,在高温条件下,水分容易蒸发,空气湿度过大可能对其存活影响极大,故温湿度对成虫寿命和繁殖的影响将作进一步研究。

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