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不同地理种群棉蚜对温度和光周期的生态适应性

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摘要: 实验室研究了采自越南胡志明市、我国海南三亚市、北京市和新疆石河子市 4 个棉蚜地理种群对温度和光周期的适应性分化特征。在 18 C配合光周期 $L:D=8:16$ 和 $L:D=10:14$ 的条件下, 越南和中国海南种群无性蚜分化现象, 而北京和新疆种群则产生大量性蚜并产下受精卵, 表明短光照已不能诱导低纬度热带地区种群产生性蚜。应用实验种群生命表技术研究了 35 C、30 C、25 C、20 C、15 C 五个温度下新疆种群、北京种群和越南种群的存活、生长发育、繁殖及内禀增长率的差异, 结果表明, 在 20 C～30 C 的温度区间内, 各种群间生命参数差异不显著, 而在低温下(15 C), 差异则比较显著, 成蚜寿命和产蚜量均为新疆种群>北京种群>越南种群, 表现为高纬度种群大于低纬度种群, 其内禀增长率也随纬度升高逐渐增大, 而来自热带地区的越南种群对高温则比较适应, 其在 30 C下种群的成蚜历期和产蚜量均高于其它种群。

关键词: 棉蚜; 温度; 光周期; 生态适应性

The ecological adaptability of *Aphis gossypii* collected from different climate zones to temperature and photoperiod

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Abstract: Cotton aphid *Aphis gossypii* (Homoptera: Aphididae), an important agricultural pest, its distribution extends from 60°N to 40°S in the world. This insect is capable to survive under different climatic conditions due to its wider adaptability. In summer, this insect reproduces parthenogenetically from generation to generation, after the late autumn it produces sexual aphids to lay eggs to over-winter. This paper presents studies on ecological adaptability of *Aphis gossypii* under different temperature and photoperiod ranges in the laboratory.

Adults of *Aphis gossypii* were collected from cotton plants in Ho Chi Minh city of Vietnam (106.42° E, 10.45°N), Beijing (116.5°E, 39.9°N), Shihezi city of Xinjiang Municipality (85°E, 45°N) and Sanya city of Hainan Province (109.5°E, 18.2°N) in 2001 and these adult populations were named as YN, BJ, XJ and HN respectively. Each aphid culture was maintained on cotton seedlings at 22 C, 70%RH, and a photoperiod of 14:10 ($L:D$). The relationship between emergence of sexual morphs and photoperiod ($L:D=8:16$ and $L:D=10:14$) at 18 C as well as the life parameters of these populations at different

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temperatures were evaluated.

In the 1st part of the study with asexual aphids (collected from cotton plants), forty 4th instar aphids (G_0)were transferred into environment chamber and allowed to breed using Leaf Wafer Method. After 24 hours, the G_0 adult aphids were removed, and forty new nymph (G_1) from G_0 generation were introduced to breed until generation (G_3). The G_2 nymphs were kept on feeding, which were produced at the 2nd, 7th, 12th and 17th day separately. During the growth period, the number of apteral and alate aphids was checked and the alate ones were transferred to cotton plants having 3 to 4 leaves to get G_3 generation. The cotton plants were enclosed with transparent plastic sleeves, which were covered at the top with gauze. The rates of development of three types of aphids [(1) virginoparae cotton aphid in G_3 with reproductive potential, (2) male alate aphid with genetalia without reproductive potential and, (3) female apteral aphid having eggs] were observed.

In the 2nd part of the study, fifty aphids from each of the 3 populations (i.e. YN, BJ and XJ) were placed at various temperatures (15, 20, 25, 30 and 35℃ respectively) maintaining 70%RH, and photoperiod $L:D=16:8$. Each aphid from respective population was fed on cotton cotyledon in 25ml glass beaker with 10ml-dissolved medium at the bottom. The newly produced aphids were transferred on cotyledon, and the cotton cotyledon was put on the surface of culture medium tightly. The newly produced nymphs were picked out everyday, but the adults were allowed to remain in the same container with replacement of fresh cotyledon and medium as and when required. Ecdysis, reproduction and death of aphid were observed everyday until all aphid adults died.

The results showed: Sexual aphids of *Aphis gossypii* from BJ and XJ could be induced successfully at 18℃ and photoperiod ($L:D=8:16$ or $L:D=10:14$). An increasing trend in percentage of sexual aphids with enhancement of reproductive duration was observed in BJ and XJ populations, whereas sexual aphids of *Aphis gossypii* from YN could not be reproduced. The cotton aphid was found to survive normally at temperature ranging from 15℃ to 30℃, but they died quickly in nymph stage at 35℃. There were also observed significant differences in adult duration among YN, BJ and XJ populations. Adult duration of the aphid in YN was much longer than those of the other two populations at 30℃. The duration showed an increasing trend with the increase in latitude of location at 15℃, and fecundity of the aphid also showed a similar trend.

Sexual morphs of aphids collected from temperate regions could be reproduced under artificial conditions, whereas the aphids collected from tropical regions could not be reproduced. Significant differences were also observed in life parameters of cotton aphid among the populations obtained from different agro-ecological zones. All these results indicated that *Aphis gossypii* collected from different climate zones had the different ecological adaptabilities.

Key words: cotton aphid (*Aphis gossypii*); temperature; photoperiod; ecological adaptability

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棉蚜(*Aphis gossypii* Glover)广泛分布于北纬 60°至南纬 40°地区[1],它是棉花、瓜类等农作物的重要害虫。在植物生长季里,棉蚜一般营孤雌生殖,而在秋末冬初营一代有性生殖,存在明显的世代交替现象。棉蚜有性世代方面,丁锦华、傅强对棉蚜性蚜的交配和产卵习性进行了观察[2];孟玲、冯德江等在不同温度下对棉蚜越冬卵的孵化和干母的存活率进行了研究[3];赵惠燕、汪世泽等对棉蚜性蚜的种群动态及性母、性雄、性雌内外生殖系统进行了解剖观察与描述,同时在性雌产卵习性、产卵量以及交配习性方面也做了大量工作[4]。但有棉蚜性蚜的人工诱导方面,国内仅见龚鹏、张孝羲的报道[5]。有关棉蚜生命参数的研究,国内也已有过一些报道[6,7]。

昆虫对不同气候带环境的适应必然导致种内的遗传分化。在华北自然环境中,棉蚜到秋末冬初会进行有性繁殖,但如果在温室中则可以一直以孤雌胎生方式繁殖后代[1]。调查虽表明棉蚜在我国有着不同的生活史类型,但实验室方面的证据则比较缺乏。为了明确棉蚜在我国热带、亚热带和温带地区遗传分化特征和生境适应性的关系,本文研究了不同气候带棉蚜对温度和光周期的适应性特征。

1　材料与方法

1.1　供试虫源

供试棉蚜于2001年分别采自越南胡志明市(106.42°E,10.45°N)、北京市(116.5°E;39.9°N)、新疆石河子市(85°E,45°N)和海南省三亚市(109.5°E,18.2°N),寄主植物为棉花。采回的棉蚜在棉苗上繁殖,环境温度22℃,相对湿度70%,光周期$L:D=14:10$。棉苗用人工配制的培养液培养[8]。

1.2　试验方法

1.2.1　棉蚜的性蚜诱导研究　4个棉蚜地理种群,温度18℃,$L:D$为8:6和10:14两短光照周期,共组成8个处理,每个处理40头棉蚜。实验过程如下:将上述备用的4龄棉蚜40头(G_0)放入培养箱内,叶子圆片法[7,9]单头饲养。24h后取其1龄若蚜(G_1)40头(尽可能为不同克隆)继续饲养,同时将成蚜G_0淘汰,待G_1成熟并开始产仔,分别接取第2、7、12、17d所产若蚜(G_2)养至成蚜,记录无翅蚜和有翅蚜的比例,将有翅蚜转移到具有3~4片叶的棉苗上,放在自制笼罩中饲养至G_3代长至成蚜,判断各种蚜型。G_3代中凡可产仔的蚜虫为孤雌胎生蚜,不产仔而具雄性外生殖器的有翅蚜为雄蚜,不产仔而怀有蚜卵的无翅蚜为雌蚜。观察并记录G_3代中各蚜型的比例。实验方法参考相关文献[5]。

1.2.2　棉蚜生命参数的研究　利用人工气候箱控制湿度($RH70\%$)和光周期($L:D=16:8$)。设置35℃、30℃、25℃、20℃、15℃ 5个温度,棉蚜种群为越南种群(YN)、北京种群(BJ)、新疆种群(XJ)3个种群,共15个处理,每个处理50头棉蚜,以琼脂为原料配成培养基,倒入25ml平口烧杯中,每烧杯约10ml,待其凝固后,将1片棉苗子叶贴于培养基表面,接入1头新产棉蚜[7,9]。自虫体接入起,每日进行观察,记录其蜕皮情况、产蚜量、死亡数,虫体养至成蚜后,每日挑出所产若蚜,保留母蚜,直至全部死亡。试验过程中,及时更换叶片。

内禀增长率的计算应用公式$r_m=\ln R_0/T$,其中T为种群经历一个世代的生长周期;$R_0=N_T/N_0$,N_T为经过一个世代的虫量,N_0为世代开始时的虫量[10]。

1.3　统计分析

利用SAS软件对棉蚜种群各生命参数进行多重比较(LSD法)。棉蚜在35℃不能正常发育并很快死亡,所得相关指标未参加统计分析。

2　结果与分析

2.1　棉蚜的性蚜诱导

2.1.1　不同地理种群棉蚜性蚜的诱导　由表1可以看出:在实验的条件下,BJ、XJ棉蚜均能产生性蚜;而HN、YN棉蚜G_2代中有翅蚜率为0,G_3代中性蚜率也为0,即没有性蚜的产生。表明短光照已不能诱导低纬度热带地区种群性蚜的分化。

2.1.2　棉蚜性蚜的产生与产仔天数的关系　由表2、表3可以看出:实验条件下,BJ、XJ的棉蚜第2天、第7天所产的后代中只能产生性雌蚜,而没有雄蚜的出现;第12天、第17天所产的后代则既出现雌蚜又出现雄蚜。性母代的有翅蚜、性雌蚜的产生与否同产仔天数关系不大,而总性蚜率有随产仔天数的增加而增长的趋势。

2.2　棉蚜的生命参数

2.2.1　存活率　由表4可知:各地理种群棉蚜在15~30℃,成蚜期存活率均在80%以上,而在35℃各种群棉蚜成虫期存活率均为0,即棉蚜在35℃高温下不能正常存活。

2.2.2　存活率曲线　由图2、图3可知,3种群棉蚜在25℃和20℃存活曲线基本一致,差异性不大。30℃,前8d曲线基本一致,后一阶段呈现一定的变化,表现为越南种群存活曲线斜率最大,即单位时间内死亡率最低(图1)。15℃,前11d曲线基本一致,后一阶段斜率表现为新疆种群>北京种群>越南种群,即单位

表 1 棉蚜各代蚜型百分比(18℃)

Table 1 Percentages of various morphs in G2 and G3 generation of cotton aphid(18℃)

光周期(h) Photoperiod	地理种群 Population	G_2 代中各型蚜(%) Percentages of various morphs in G_2		有翅 G_2 的 G_3 后代中各型蚜(%) Percentages of various morphs in G_3 from alate G_2			
		无翅蚜 Aptera	有翅蚜 Alate	孤雌 Virginoparae	雄蚜♂ Male	性雌蚜♀ Ovipara	性蚜♂+♀ Sexual morphs
8	YN	100	0	0	0	0	0
	HN	100	0	0	0	0	0
	BJ	91.93	8.07	58.78	7.43	33.79	41.22
	XJ	41.83	58.17	49.67	7.32	43.01	50.33
10	YN	100	0	0	0	0	0
	HN	100	0	0	0	0	0
	BJ	54.62	45.38	51.95	7.47	40.58	48.05
	XJ	40.11	59.89	48.64	13.92	37.44	51.36

* YN 和 HN 的 G_2 代的无翅蚜在原条件下继续饲养一代仍无有翅蚜产生 The G_2 apteral aphids still could not produce alate ones, being bred for another generation

表 2 棉蚜性蚜的产生随产仔天数的变化(18℃, $L:D=8:16$)

Table 2 Percentage of sexual morphs of cotton aphid at successive intervals throughout their reproductive period at 18 ℃ and $L:D=8:16$

地理种群 Population	产仔日龄(d) Days in reproductive period	性母代的有翅蚜(%) Alate morphs in G_2	雄蚜♂(%) Male	性雌蚜♀(%) Ovipara	性蚜♂+♀(%) Sexual morphs
BJ	2	6.3	0	31.1	31.1
	7	8.9	0	41.5	41.5
	12	3.3	26.3	31.6	57.9
	17	21.9	42.9	28.6	71.5
XJ	2	50.9	0	44.8	44.8
	7	51.3	0	39.9	39.9
	12	76.7	45.2	43.6	88.8
	17	76.9	45.5	54.5	100

表 3 棉蚜性蚜的产生随产仔天数的变化(18℃, $L:D=10:14$)

Table 3 Percentage of sexual morphs of cotton aphid at successive intervals throughout their reproductive period at 18 ℃ and $L:D=10:14$

地理种群 Population	产仔日龄(d) Days in reproductive period	性母代的有翅蚜(%) Alate morphs in G_2	雄蚜♂(%) Male	性雌蚜♀(%) Ovipara	性蚜♂+♀(%) Sexual morphs
BJ	2	40.6	0	38.1	38.1
	7	39.2	0	65.6	65.6
	12	57.1	42.1	36.8	78.9
	17	56.1	44.1	35.3	79.4
XJ	2	49.3	0	33.8	33.8
	7	50.5	0	43.4	43.4
	12	77.8	31.2	28.4	59.6
	17	86.2	47.3	49.5	96.8

时间内死亡率越南种群>北京种群>新疆种群;新疆种群平均存活时间为 29.38±8.52d,北京种群为 23.5±7.09d,越南种群为 19.35±5.8d(0.05 水平,t 测验,种群间差异显著),随纬度升高种群存活时间逐渐延长(见图 4)。

表 4　棉蚜成蚜期存活率(%)

Table 4　Cotton aphid adult survival rate(%)

地理种群 Population	温度 Temperature(℃)				
	35	30	25	20	15
YN	0	88	90	94	90
BJ	0	86	96	86	90
XJ	0	84	88	94	94

2.2.3　棉蚜若虫和成虫发育历期比较　由表 5 可知:在所设 4 个温度中的任一温度下,若虫历期在种群间变化不大(0.05 水平,t 测验,各种群间差异均不显著);单一地理种群内,棉蚜若虫历期均有随温度降低而增长的趋势(0.05 水平,t 测验,温度间差异显著)。成虫历期,25 ℃、20 ℃种群间差异不大,30 ℃越南种群最长,15 ℃新疆种群>北京种群>越南种群(0.05 水平,t 测验,种群间差异显著),有随纬度增加而增大的趋势。

表 5　棉蚜若虫和成虫发育历期

Table 5　Cotton aphid population duration (larva and adult)

温度(℃) Temperature	地理种群 Population	处理虫数 Number	若虫历期(d) Larval duration	成虫历期(d) Adult duration
30	YN	44	4.14±0.05 a	9.64±0.62 c
	BJ	43	4.12±0.06 a	5.61±0.49 a
	XJ	41	4.12±0.05 a	7.88±0.75 b
25	YN	45	4.93±0.08 a	13.47±0.99 b
	BJ	48	4.85±0.07 a	10.96±0.69 a
	XJ	44	4.71±0.08 a	13.82±0.76 b
20	YN	47	6.51±0.08 a	18.72±1.10 a
	BJ	43	6.58±0.08 a	16.63±1.01 a
	XJ	47	6.81±0.08 a	18.11±1.16 a
15	YN	45	11.29±0.17 a	8.62 ±0.91 a
	BJ	45	11.64±0.14 a	12.76±1.00 b
	XJ	47	11.58±0.09 a	17.77±1.20 c

* 用于描述若虫历期和成虫历期的数字为相应的平均数±标准误,相同字母表示种群间差异不显著($p<0.05$; LSD test) Data on larval duration and adult duration were the means ± standard errors. Means followed by the same letter were not statistically different ($p<0.05$; LSD test)

2.2.4　成蚜繁殖力　由表 6 可知,30 ℃越南种群产蚜量最大,25 ℃种群间变化不大,20 ℃新疆种群最大,而 15 ℃新疆种群>北京种群>越南种群(t 测验,0.05 水平,种群间差异显著),即 15 ℃成虫产蚜量有随纬度增加而增大的趋势。由产蚜量曲线(图 5)也可以看出:15 ℃ 产蚜时间和单日产蚜量也为新疆种群最大。

2.2.5　内禀增长率比较　由表 7 可知,YN、BJ、XJ 三个地理种群,在试验所设置的温度梯度(30 ℃、25 ℃、20 ℃、15 ℃)下,内禀增长率均有随温度降低而减小的趋势,而在 15 ℃棉蚜种群的内禀增长率有随纬度升高而增大的趋势。

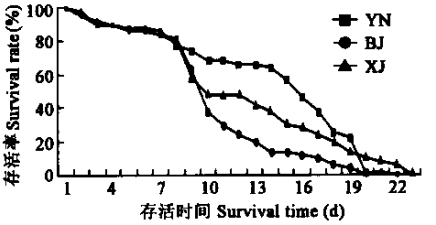

图 1　棉蚜种郡存活曲线 (30 ℃)

Fig. 1　Cotton aphid population survival rate curves

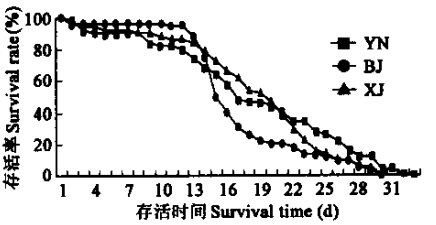

图 2　棉蚜种群存活率曲线(25 ℃)

Fig. 2　Cotton aphid population survival rate curves

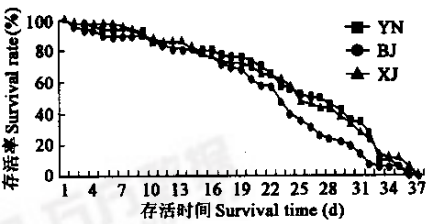

图 3　棉蚜种群存活率曲线 (20 ℃)

Fig. 3　Cotton aphid population survival rate curves

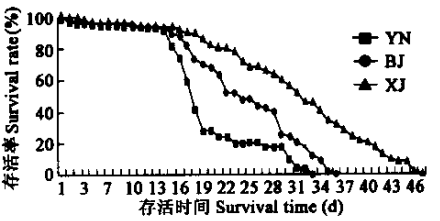

图 4　棉蚜种群存活率曲线 (15 ℃)

Fig. 4　Cotton aphid population survival rate curves

表 6 棉蚜产蚜量(头)

Table 6 Total numbers of cotton aphid larva, produced in the whole life of the aphid (number)

地理种群 Population	温度 Temperature(℃)			
	30	25	20	15
YN	16.52±0.97 b	43.89±2.90 ab	57.47±2.65 b	17.76±2.69 a
BJ	11.93±1.14 a	37.94±2.15 a	40.74±1.93 a	26.96±2.85 b
XJ	9.57 ±0.58 a	47.21±2.13 b	67.21±3.50 c	51.55±3.64 c

* 表中数字为相应的产蚜量的平均数±标准误,相同字母表示种群间差异不显著($p<0.05$; LSD test)Data were the means±standard errors. Means followed by the same letter were not statistically different ($p<0.05$; LSD test)

3 讨论

棉蚜是农业生产上的一种重要害虫,北纬 60°至南纬 40°都有其分布[1]。在这么广泛的分布空间里存在着不同的气候条件,而棉蚜却能在其中很好的生存并使种群得以延续下去,这说明其具有很强的生态适应能力,即对环境具有很强的适应性。华北地区的棉蚜在自然环境中每到秋末冬初会出现有性世代,进行一定时期的有性繁殖,但如果是转到温室里便一直会以孤雌胎生方式繁殖后代[11],可以看出同一种棉蚜对于变化的环境条件,有着其自身的适应对策。本次实验当中,BJ、XJ 棉蚜经诱导产生了性蚜,YN、HN 经人工诱导仍没有性蚜的产生,这可能是生物对环境长期适应的结果。北京、新疆两个地理种群的棉蚜常年生活在高纬度地区,而高纬地区存在明显的四季交替现象,也存在严寒的冬季,这对棉蚜的生存是极其不利的,棉蚜要想在这样的环境中延续种群,必然要采取一定的生态适应对策,也就是产生受精卵以度过寒冷的冬季。越南、海南的两个地理种群的棉蚜生活在低纬度地区,生存环境季节分化不明显常年高温,足以提供生物种群延续的所需条件,在这样的环境中棉蚜通过孤雌生殖足以维持其种群的延续,经过长期的生物进化这一特性可能已在棉蚜的低纬度种群中固定下来,因此经过诱导仍没有性蚜的出现。同时,本次实验也表明 15～30 ℃棉蚜均能正常存活,35 ℃棉蚜成蚜存活率为 0,不能正常存活,这与棉蚜在 18～30 ℃温区内大多数可以发育至成熟的结果基本一致[7]。在 20～30 ℃的温度区间内,各生命参数种群间差异不显著;而在低温 15 ℃,差异则比较显著。这可能是因为就本次实验中昆虫发育的环境条件而言,20～30 ℃是绝大多数昆虫的发育适温区,而限制昆虫生态分布区的主要是抗寒能力[12]。在适温区,各种群均能正常存活;低温 15 ℃,由于各种群抗寒能力的不同,为了维持其种群的延续,相应的表现出各异的生态适应对策,在生命参数上必将呈现一定的差异性。15 ℃成蚜历期和产蚜量均为新疆种群>北京种群>越南种群,表现为高纬度种群大于低纬度种群,其内禀增长力同样也是随纬度升高逐渐增大(见表 7)。这可能是昆虫种群对各自环境长期适应的结果,其中新疆地处温带地区,每年要经历低温的季节,这使得生活在其中的棉蚜对低温相应的产生了一定的适应性;而越南地处热带常年高温,在这样环境中长期生存的棉蚜对低温必将呈现一定的不适应性,对高温则比较适应(30 ℃种群之间,成蚜历期和产蚜量越南种群均相对较长)。

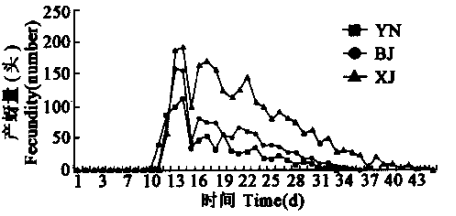

图 5 棉蚜种群产蚜量曲线 (15 ℃)

Fig. 5 Cotton aphid population fecundity curves

表 7 棉蚜内禀增长率

Table 7 Cotton aphid population innate capacity of increase

地理种群 Population	温度 Temperature (℃)			
	30	25	20	15
YN	0.38374	0.32278	0.29067	0.15963
BJ	0.36183	0.35680	0.28284	0.16919
XJ	0.34328	0.34296	0.28740	0.18263

实验中温度及光照均是恒定的,这与自然界的实际情况间存在着一定的差异。在性蚜诱导部分,实验涉及的光温组合相对较少,其它条件下不同地理种群棉蚜间性蚜产出情况有待作进一步的研究。同时,棉蚜生命参数 30 ℃种群间呈现一定的差异性,15 ℃种群间呈现一定的规律性变化,产生这些差异性的原因和机理有待作进一步的研究。

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