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TEMPERATURE STUDIES ON A CHINESE STRAIN OF *BACTROCERA CUCURBITAE* (COQUILLETT) (DIPTERA: TEPHRITIDAE)

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Abstract.—We examined preadult and adult survival, development and fecundity of *Bactrocera cucurbitae* (Coquillett) from China at six constant temperatures between 19° and 36° C. Development of immature stages and ovaries was inversely related to temperature. Preadult mortality was greatest at 36° C. Average female longevity was inversely related to temperature but male longevity was not. The intrinsic rate of increase was greatest at 25° C. No eggs or larvae survived exposure to constant temperatures of 2° to 3° C for longer than seven days.

Key Words.—Insecta, *Bactrocera cucurbitae,* commodity treatment, demographic parameters

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Bactrocera cucurbitae (Coquillett) (Diptera: Tephritidae) is a cucurbit pest found in Kenya, Mauritius, Sri Lanka, India, China, Malaya, Indonesia, and the Philippines (White & Elson-Harris 1992). In the last century, it has expanded its range to a number of Pacific islands including Hawaii. It has been detected in California on two occasions. Each of these California infestations, along with those on several Pacific islands, have been eradicated (Dowell & Gill 1989; Shiga 1989; RVD, unpublished data).

Bactrocera cucurbitae is one of five species of economically important fruit flies found in mainland China, and one of two species attacking cucurbits; the other is *Bactrocera tau* (Walker). Recent efforts by the Chinese to expand agricultural exports have increased the importance of developing information about the bionomics of *B. cucurbitae* in China, because the fly is quarantined by a number of countries including the United States (Yang et al. in press).

Temperature is an important environmental factor influencing fruit fly population dynamics. Data on the effects of temperature on fruit fly development and survival are critical: to developing models that predict fly phenology, to estimate the age structure of field populations, to the timing of control activities, and to developing quarantine compliance protocols (Smith 1977, Carey 1993). We studied the effect of temperature on the development, survival and reproduction of the immature and adult stages of a Chinese strain of *B. cucurbitae.* We also evaluated the survival of *B. cucurbitae* eggs and larvae when they were subjected to cold treatments similar to those used to meet USDA quarantine regulations for *Ceratitis capitata* (Wiedemann) (Fiskaali 1991).

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Table 1. Average developmental time and survival of immature *B. cucurbitae* reared at six constant temperatures.

Stage	Temperature (° C)					
	19°	22°	25°	28°	30°	36°
Developmental time[a,b]						
Egg	3.00	2.00	2.00	1.50	1.00	1.00
	(1.1)	(0.5)	(0.7)	(0.4)	(0.1)	(0.1)
Larva	7.31	6.42	5.56	3.41	3.26	4.42
	(1.4)	(1.7)	(2.5)	(0.9)	(0.9)	(1.5)
Pupa	14.80	14.30	10.20	9.00	7.90	6.50
	(0.5)	(0.5)	(1.5)	(0.6)	(0.2)	(0.8)
Percent mortality						
Egg	5	4	4	5	5	12
Larva	15	16	19	9	14	7
Pupa	3	1	5	8	9	22
Total	23	21	28	22	28	41

[a] Days, mean ± (SD).
[b] Three replicates, $n = 30$ eggs and 50 larvae or pupae per replicate.

Materials and Methods

Effect of Temperature on Growth and Survival.—*Bactrocera cucurbitae* were collected from the Parcel Islands, in the South China Sea, and maintained in a colony for several generations at the Guangzhou Animal and Plant Quarantine Service prior to use. Tests were conducted at 12:12 L:D cycle and 80% to 90% RH. Immature stages and adults were held at test temperatures (± 0.5° C) of 19°, 22°, 25°, 28°, 30°, or 36° C. All trials were replicated three times.

Duration and survival of immature stages were determined as follows. Thirty newly-laid eggs were placed on a piece of wet black cloth in a petri dish and checked for hatch every eight hours. Fifty neonate larvae were placed on pieces

Table 2. Adult longevity and reproduction of *B. cucurbitae* held at six constant temperatures.

	Temperature (° C)					
	19°	22°	25°	28°	30°	36°
Longevity[a,b,c]						
Female	103.0	100.8	97.8	72.2	69.0	31.7
	(45.7)	(62.1)	(45.3)	(51.9)	(49.5)	(21.5)
Male	95.9	107.8	111.4	80.9	71.1	29.7
	(50.8)	(66.2)	50.8)	(51.5)	(48.9)	(16.0)
Reproduction						
Preoviposition period	33.0	19.0	16.0	12.0	11.0	9.0
Gross fecundity[b,d]	317.9	644.5	509.8	452.0	468.2	434.7
Net fecundity[b,d]	171.8	317.6	249.7	201.9	191.2	86.2
Eggs/day/female	1.7	3.2	2.6	2.9	2.8	2.7

[a] Average number of days.
[b] Three replicates with 50 pairs of flies per replicate.
[c] Mean ± (SD).
[d] Eggs per female.

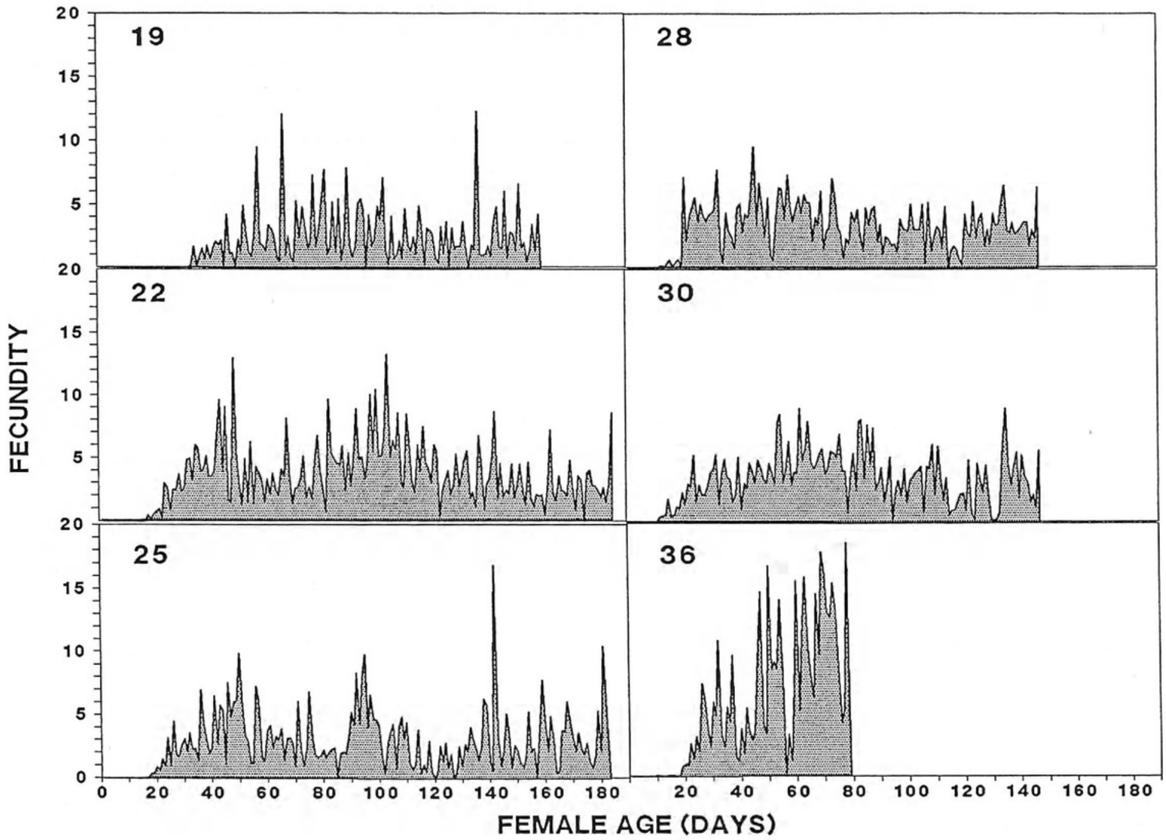

Figure 1. Daily gross egg production for *B. cucurbitae* female reared at six constant temperatures (19°, 22°, 25°, 28°, 30°, 36° C), given at left top of each graph.

of cucumber (*Cucumis sativus* L.) held in glass bottles (10 cm dia × 10 cm high) containing a layer of moist sand. The larvae were checked daily and food was added as needed. The sand was sifted daily to recover pupae. Fifty newly formed pupae were held in petri dishes and checked daily for emergence.

Adult life history traits were determined by placing 50 pairs of newly emerged adults in cages 25 cm on a side. Water was provided and fresh orange juice was used as adult food. A small piece of cucumber was placed daily in each cage for egg collection. Mortality was recorded daily until the last female died. Life history data were analyzed using the methods of Carey (1993).

Effect of Cold Temperatures on Egg and Larval Survival.—The survival of *B. cucurbitae* larvae held in four host plants at low temperatures was determined by placing newly molted second instar larvae in bottles (10 cm dia × 10 cm high) with cut pieces of each plant (Table 4). The bottles were then held at 2° C for one to five days to simulate quarantine treatment conditions. Each day one-fifth of the bottles were removed and the number of living and dead larvae was determined. All subsequent tests were run using cucumber as larvae feeding on it took the longest time to reach 100% mortality. Another series of tests was run as above holding third instars at 2° C, and eggs, first and third instars at 3° C for eight to ten days.

Results

Preadult Development and Survival.—Developmental times for *B. cucurbitae* eggs and larvae were inversely related to temperature from 19° to 30° C (eggs: *r*

Table 3. Demographic parameters for *B. cucurbitae* reared at six constant temperatures.

Parameter	Temperature (° C)					
	19°	22°	25°	28°	30°	36°
Intrinsic rate of increase[a]	0.044	0.065	0.069	0.064	0.066	0.053
Mean generation time[b]	95.7	65.2	65.2	65.4	62.8	51.8
Doubling time[b]	16.9	10.7	10.1	10.9	4.7	5.7

[a] Per day.
[b] Days.

= −0.92, F = 20.49, $P = 0.01$, $n = 5$; larvae: $r = -0.98$, F = 71.23, $P = 0.004$, $n = 4$). The duration of the egg stage did not change at 36° C, but that of the larval stage increased. The duration of the pupal stage and total preadult development time were inversely related to temperature at all test temperatures (pupae: $r = -0.95$, F = 38.85, $P = 0.003$, $n = 5$; preadult: $r = -0.95$, F = 35, $P = 0.004$, $n = 5$) (Table 1).

Egg mortality was relatively uniform between 19° and 30° C, but it increased

Table 4. Mortality of second instar *B. cucurbitae* larvae reared at 2° C in four hosts.

Host/days exposed	Number alive	Number dead	Total	Percent mortality
Sponge Gourd[a]				
1	13	40	53	75.4
2	3	8	11	72.7
3	1	15	16	93.8
4	0	21	21	100.0
5	0	15	15	100.0
Balsam Pear[b]				
1	9	39	48	81.3
2	7	35	42	83.3
3	1	88	89	98.9
4	0	54	54	100.0
5	0	26	26	100.0
Cucumber[c]				
1	14	7	21	33.3
2	8	58	66	87.9
3	4	80	84	95.2
4	1	19	20	95.0
5	0	15	15	100.0
Wax Gourd[d]				
1	49	4	53	7.6
2	5	18	23	78.3
3	0	27	27	100.0
4	0	43	43	100.0
5	0	21	21	100.0

[a] *Luffa aegyptiaca* Miller.
[b] *Momordica charantia* L.
[c] *Cucumis sativus* L.
[d] *Benincasa hisida* (Thunberg).

Table 5. Mortality of immature stages of *B. cucurbitae* in cucumber held at cold temperatures.

		Percent mortality		
Days	Eggs[a]	1st instar[a]	2nd instar[a]	3rd instar[b]
1	21.7	14.0	12.4	13.3
2	14.6	43.8	11.1	64.7
3	40.2	41.0	100.0	100.0
4	81.8	35.2	40.3	100.0
5	94.7	79.1	94.4	100.0
6	97.5	90.1	96.9	86.7
7	100.0	100.0	100.0	100.0
8	100.0	100.0	100.0	100.0
9				100.0
10				100.0

[a] Test run at 2° C, n = 15 to 20 larvae per temperature per day.
[b] Test run at 3° C, n = 15 to 20 larvae per temperature per day.

2.4 fold at 36° C. Larval mortality was lowest at 28° and 36° C and varied little among the other test temperatures. Pupal mortality increased 4.4 fold between 25° and 36° C. Preadult mortality was greatest at 36° C (Table 1).

Adult Survival and Reproduction.—Survival of *B. cucurbitae* females was inversely related to temperature ($r = -0.96$, F = 48.41, $P = 0.002$, $n = 5$), but that of the males increased with temperature between 19° and 25° C and decreased with increasing temperature thereafter. The preovipositional period was inversely related to temperature ($r = -0.87$. F = 12.65, $P = 0.02$, $n = 5$). Gross and net fecundity, and eggs per female per day were greatest at 22° C (Table 2) and were not related to temperature ($r = 0.02$, $r = 0.64$, $r = 0.40$ respectively, $P > 0.05$).

Daily egg production fluctuated widely, with no clear trend regardless of rearing temperature. Females continued to lay eggs for at least 140 days at temperatures at or below of 30° C and for up to 180 days at 22° to 25° C (Fig. 1).

The intrinsic rate of population increase was greatest at 25° C, but there was little difference among the values between 22° and 30° C. Mean generation time was shortest at 36° C and there was little difference among the values between 22° and 30° C. Population doubling time was shortest at 30° C, with nearly identical times between 22° and 28° C (Table 3).

Effects of Cold Temperatures on Survival.—No second instar *B. cucurbitae* survived beyond four days when held at a constant 2° C in any of the test plants (Table 4). No third instars survived beyond six days when held at a constant 2° C and no eggs, first or second instars survived beyond six days when held at 3° C (Table 5). Increasing the temperature 1° C, from 2° to 3° C, increased the time needed to kill all second instars from four to six days (Tables 4 and 5).

Discussion

Our preadult developmental times and survivorships of *B. cucurbitae* fall within the range of those from previous studies of wild flies in culture six or fewer generations (Miyatake 1993). Egg and pupal development are mainly dependent upon temperature and larval development upon temperature and host (Tables 1 and 6).

Table 6. Stage specific duration and survival of wild *B. cucurbitae* from previous studies.

Stage[a]	°C	Duration[b]	Host	Reference
Eggs	20	2.0 (73)		Bhatia & Mahto 1970
	25	1.1 (77)		Bhatia & Mahto 1970
	25	1.0 (74)		Carey et al. 1985
Larvae	20	6.7 (85)	pumpkin	Bhatia & Mahto 1970
	25	3.7 (85)	pumpkin	Bhatia & Mahto 1970
	27.5	3.4 (83)	pumpkin	Bhatia & Mahto 1970
	25	4.1 (88)	cucumber	Carey et al. 1985
	25	7.4 (38)	eggplant	Carey et al. 1985
	24	9.8 (90)	papaya	Vargas & Carey 1990
	25	9.0 (na)	media	Miyatake 1993
Pupae	20	15.1 (92)	pumpkin	Bhatia & Mahto 1970
	25	7.8 (91)	pumpkin	Bhatia & Mahto 1970
	28	6.8 (93)	pumpkin	Bhatia & Mahto 1970
	25	13.0 (89)	cucumber	Carey et al. 1985
	24	9.8 (61)	papaya	Vargas & Carey 1990
	25	11.0 (na)	media	Miyatake 1993
Preoviposition	25	16.0	cucumber	Carey et al. 1985
	23.8	14.8	tomato	Keck 1951
	26.7	13.5	tomato	Keck 1951
	25	14.0	unknown	Back Pemberton 1918

[a] Considered wild if in colony six or fewer generations (Miyatake 1993), na = not available.
[b] Percent survival in parentheses.

The adult reproductive parameters, however, differ considerably among the studies. The gross fecundity of wild *B. cucurbitae* from China is approximately half that of wild *B. cucurbitae* from Hawaii. Wild Chinese *B. cucurbitae* lay one-half to one-third the eggs per day and have population doubling times 1.5 times greater than those from Hawaii. The greater variation in adult responses suggests that this is the stage in which local environmental factors have their greatest influence and, thus, the stage in which the fly adapts to them (Tables 2, 3 and 7). In culture, the response time to selection for a characteristic of adult flies was faster than that for larvae (Miyatake 1993).

Although not definitive, our results suggest that cold treatments may be effective as a disinfestation treatment for produce harboring *B. cucurbitae* eggs and larvae.

Table 7. Adult demographic parameters for wild *B. cucurbitae* from previous studies.

Parameter	Value[a]	Reference
Gross fecundity	1293 eggs	Carey et al. 1985
Net fecundity	709 eggs	Carey et al. 1985
Doubling time	6.9 days	Carey et al. 1985
	12.0 days	Vargas & Carey 1990
Eggs/female/day	7.2 eggs	Carey et al. 1985
	4.7 eggs (21.1° C)	Keck 1951
	8.9 eggs (23.9° C)	Keck 1951
	8.2 eggs (29.4° C)	Keck 1951

[a] Considered wild if in colony for six or fewer generations (Miyatake 1993).

Further, large scale tests will be required before cold treatments of *B. cucurbitae* hosts can be certified for use as a quarantine treatment from countries having the pest.

Literature Cited

Back, E. A. & C. E. Pemberton. 1918. The melon fly. USDA Bull., 643.

Bhatia, S. K. & Y. Mahto. 1970. Influence of temperature on the speed of development of melon-fly, *Dacus cucurbitae* Coquillett (Diptera: Tephritidae). Indian J. Agric. Sci., 40: 821–828.

Carey, J. R. 1993. Applied demography for biologists with special emphasis on insects. Oxford Univ. Press., New York.

Carey, J. R., E. J. Harris & D. O. McInnis. 1985. Demography of a native strain of the melon fly, *Dacus cucurbitae,* from Hawaii. Ent. Exp. Appl., 38: 195–199.

Dowell, R. V. & R. Gill. 1989. Exotic invertebrates and their effects on California. Pan-Pacif. Entomol., 65: 132–145.

Fiskaali, D. A. 1991. Commodity treatment manual, Vol. I. Treatments. Calif. Dept. Food & Agric., Sacramento, California.

Keck, C. B. 1951. Effect of temperature on development and activity of the melon fly. J. Econ. Entomol., 44: 1001–1002.

Miyatake, T. 1993. Difference in the larval and pupal periods between mass-reared and wild strains of the melon fly, *Bactrocera cucurbitae* (Coquillett) (Diptera: Tephritidae). Appl. Entomol. Zool., 28: 577–581.

Nakamori, H. 1987. Variation of reproductive characters in wild and mass-reared melon flies, *Dacus cucurbitae* Coquillett (Diptera: Tephritidae). Jpn. J. Appl. Entomol. Zool., 31: 309–314.

Shiga, M. 1989. Current programme in Japan. Chap. 9.5.2. *In* Robinson, A. S. & G. Hooper (eds.). Fruit flies, their biology, natural enemies and control. Elsevier, New York.

Smith, E. S. C. 1977. Studies on the biology and commodity control of the banana fruit fly *Dacus musae* (Tryon), in Papau New Guinea. Papau New Guinea Agric. J., 28: 47–56.

Vargas, R. I. & J. R. Carey. 1990. Comparative survival and demographic statistics for wild oriental fruit fly, Mediterranean fruit fly, and melon fly (Diptera: Tephritidae) on papaya. J. Econ. Entomol., 83: 1344–1349.

White, I. M. & M. M. Elson-Harris. 1992. Fruit flies of economic significance: their identification and bionomics. C.A.B. Int., London.

Yang, P., J. R. Carey & R. V. Dowel. 1994. Tephritid fruit flies in China: historical perspective and current status. Pan-Pacif. Entomol., 70: 159–167.