ENVIRONMENTAL ASPECTS OF THE SURVIVAL AND REPRODUCTION OF ORIENTAL COCKROACHES (*BLATTA ORIENTALIS* L.).

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Abstract—The ability of mobile stages of oriental cockroaches to survive at −5°C increased with acclimation at 10°C. Fully acclimated insects had LT50s (time) of 1.3–4.1 days, depending on stage. A minimum of 8 days at −5°C or 1 days t −10°C was required to kill all stages; insects could survive for more than 6 weeks at 2°C. The critical temperature for continued oothecal production by females and for hatch of oothecae lay between 15° and 20°. Females prevented from depositing oothecae by cold exposure rapidly resumed production when returned to a preferred temperature (28°C). Incubation times for oothecae were independent of relative humidity (RH) over the range 20–28°C; mean times to hatch were 42.7 days, 60.7 days and 89.3 days at 28°, 24° and 20° respectively. The mean number of nymphs emerging from oothecae decreased with RH within this temperature range.

INTRODUCTION

When Oriental cockroaches are displaced from preferred harbourages they can live for long periods under conditions which are sub-optimal for reproduction and population growth. Survivors of pesticide treatments and immigrants into pest-free environments may harbour in areas not normally associated with infestation before they locate optimal sites within buildings. The temperature limits for survival and for the various components of reproduction are therefore of interest in the context of pest exclusion and control strategies. For example, introduction of cockroaches into premises on packaging can potentially be prevented (or sensitive equipment and fittings disinsected) by chilling for a sufficient period, although no data is currently available on the times and temperatures required; population growth in an infested environment can be arrested by allowing temperatures to fall below the critical level for mating and reproduction (for example, when apartments are left vacant between tenancies), and such static populations may be easier to control or eradicate using conventional treatments; the possibility of insects establishing outdoor populations which serve as a focus for re-infestation of building needs to be considered when interpreting trap catches in treated areas.

This paper is a preliminary report of recent work on the effect of environmental conditions on survival and reproduction by Oriental cockroaches. Full results will be published elsewhere.

EXPERIMENTAL METHODS

The population of *B. orientalis* was obtained in 1989 from Rentokill Ltd. and has been subsequently reared at 28°C on laboratory mouse food pellets. Culture cages contain insects which have hatched over a period of 7 days, and under these conditions adult females deposit their first oothecae approximately 6 months after emergence as first instar nymphs.

Cold tolerance of mobile stages

Nymphs of instars 1–5 and adult males and females were cold-adapted and exposed to low temperatures in constant temperature rooms or cabinets maintaining required temperatures to within 0.5°C. Following exposure, insects were returned to 28°C for a period of 10 days prior to determining mortality. A proportion of immobilised insects made an apparently complete recovery during this period, although some were cannibalised. Regressions of probit (mortality) on log (exposure time) were used to estimate LT50 (time) and associated statistics.

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Oothecal production by mated and virgin females

Batches of mated or virgin adult females were taken when the fist oothecae had started to protrude, held at 20°, 15° or 10° for a period of 5 weeks (7 weeks for unmated females) and then returned to 28° to determine the reversibility of inhibition of oothecal production. Oothecae were counted weekly and production rates corrected for any mortality. Batches in which more than 40% mortality occurred were discarded.

Oothecal hatch as a function of temperature and humidity

Oothecae were collected daily from cultures and batches transferred to sealed containers with saturated salt solutions maintaining RH in the range 40–100% at temperatures of 15°, 20°, 24° and 28°. Following incubation, the number of nymphs emerging/batch was monitored daily until no further emergence occurred.

RESULTS

Cold-tolerance of 5th instar nymphs at −5° increased as the time of acclimation at 10° increased; fully-acclimated insects (as defined by this exposure regime) were obtained after 11 days at 10°. The time required to kill all individuals in a test population and corresponding LT50 (time) values are shown for acclimated and non-acclimated insects in Table 1, from which it is seen that there was comparatively little difference between the cold-tolerance of the mobile stages tested. Prior acclimation at 10° increased LT50 (time) values at −5° by factors of between 6 and 10. All stages were relatively tolerant of long-term exposure at 2°C.

Oothecal production by both mated and unmated females was effectively halted at 15° and below, and although it resumed when the insects were returned to 28° there was a lag period of 2–3 weeks before it recovered to a value close to that of uncooled insects (Table 2).

Mean incubation periods were 42.7, 60.7 and 89.3 days for oothecae held at 28°, 24° and 20° respectively, and did not vary significantly with RH (Table 3). No nymphs emerged from oothecae stored at 15° over a period of 6 months. The mean number of nymphs emerging from oothecae increased with temperature and with RH.

DISCUSSION

Outdoor populations of Oriental cockroaches, often associated with tips, animal houses or other building, are not uncommon in the United Kingdom (Alexander *et al.*, 1991). Taken in conjunction with winter mean daily temperatures (Thran and Broekhuizen, 1965), results obtained in the present study suggest that cold-adapted Oriental cockroaches should be able to overwinter outdoors over much of Western Europe provided by are able to locate harbourages which protect them from severe ground frosts. The factors limiting population development in such circumstances appear to be the deposition, development and hatch of oothecae, all of which are arrested between 15° and 20°C. Although it takes approximately 3 months for oothecae to hatch at 20°C it should be possible during a warm summer in the United Kingdom for females which have overwintered as late instar nymphs to mature, mate and deposit oothecae, and for those oothecae to hatch. A slight increase in mean Summer temperatures would presumably make outdoor populations much more common.

Like many other insects, Oriental cockroaches are considerably more vulnerable to cold-exposure if they are transferred directly into the cold than if they are given the opportunity to adapt for a period at an intermediate temperature. This is an important consideration if cold exposure were to be used to disinfest equipment and furnishing or to prevent immigration of cockroaches into food-processing or other sensitive environments on packaging. Mobile stages harbouring in boxes or cartons in an infested area could acclimate during transport and intermediate storage, so that a temperature of −5°C throughout the material for at least 8 days would be required to ensure no survivors. On the other hand, infested equipment or fittings transferred directly from a warm environment to a cold-room could be disinsected within a shorter period.

Females, whether mated or unmated, do not produce oothecae in environments where the temperature is too low for the oothecae to hatch (15°). Oothecal production is reversible with

Table 1. Cold-tolerance of mobile stages of *B. orientalis*

Acclimation at 10° (weeks)	Instar	Exposure Temp. (°C)	LT50 (days	time for 100% kill (days)
0	1	−5	0.33	1
	3		0.21	1
	5		0.42	2
	adult f		0.43	2
	adult m		0.41	2
2	1	−5	2.8	5
	3		1.3	8
	5		4.1	8
	adult f		3.1	8
	adult m		3.8	6
2	1	2	16.1	35
	4		25.3	>42
	5		>42	>42
	adult f		12.3	38
	adut m		27.2	>42

Table 2. Mean oothecal production at sub-optmal temperatures and following return to 28°C

Temp. (°C)	Mean oothecae/ female/week*	Weeks**	Temp. (°C)	Mean oothecae/ female/week	Weeks**
		mated females			
28	1.22	0-5	28	0.96	5-11
20	0.68	0-5	28	0.99	5-11
15	0.09	0-5	28	0.78	5-11
10	0.04	0-5	28	0.52	5-11
		unmated females			
28	0.74	0-7	28	0.88	7-11
20	0.42	0-7	28	0.66	7-11
15	0.03	0.7	28	0.54	7-11
10	0.01	0.7	28	0.36	7-11

*5 batches of 10 females at each temperature.
**timed from emergence of first ootheca.

Table 3. Effect of RH and temperature on mean number of nymphs emerging from oothecae

Temperature (°C)	RH (%)	Mean nymphs per ootheca*	incubation period (days)
15	75	0.0	—
20	43	0.7	89
	75	6.6	90
	93	6.2	90
24	43	1.3	61
	75	9.3	61
	93	10.0	57
28	43	8.6	44
	75	12.3	43
	93	11.5	42

*50 oothecae at each temperature/humidity.

temperature, although females maintained at low temperatures (e.g. 10°) take 2–3 weeks to recover deposition rates similar to those of uncooled insects when returned to a preferred temperature (28°C). Preliminary studies indicate that oothecae rapidly lose viability when exposed to temperatures of 0° and below, although data is needed on the relationship between exposure time, temperature and viability at temperatures between 0° and 15°, with cold-exposure occurring at various points during the incubation period.

The mean number of nymphs emerging from oothecae, and thus population growth, is dependent on relative humidity as well as temperature. Mean incubation time did not vary significantly with RH, implying that a proportion of eggs can complete development even under low RH conditions. Roth and Willis (1955) found that the water content of oothcae of *B. orientalis* remained constant between formation and egg hatch (unstated RH) despite gaseous exchange via aeropyles in the keel of the ootheca (Lawson, 1952). The reduction in mean numbers of nymphs emerging from oothecae as the RH is lowered may be due to an increasing proportion of eggs failing to hatch as a result of premature hardening of the chorion (Hinton, 1981), and possibly also to desiccation of the oothecal walls leading to an increase in the force required to open the keel.

While kitchens and bathrooms are high humidity environments, other areas of heated building generally have quite low humidities (40–50% RH). Reproduction rates of oriental cockroaches displaced from preferred high humidity environments by modification of fittings or insecticidal treatment may be limited by low oothecal viability.

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