

Development of *Dermatophagoides pteronyssinus* (Acari: Pyroglyphidae) at Constant and Simultaneously Fluctuating Temperature and Humidity Conditions

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ABSTRACT House dust mites are found in almost all dwellings in New Zealand and are a major risk factor in the development of asthma and perennial allergic rhinitis. We studied the longevity, life stage length, and fecundity of a New Zealand strain of European house dust mite, *Dermatophagoides pteronyssinus* (Trouessart), at constant (23°C, 75% RH) and the fluctuating conditions typically found in dry (18–25°C, 60–38% RH) and damp (18–23°C, 70–55% RH) New Zealand dust mite microhabitats in carpets. All the adult mites placed in the “dry” conditions died within 18 d. Mites in the “damp” conditions had developmental times, oviposition, and death rates that were not significantly different from constant conditions. These mites are tolerant of fluctuating temperatures, but they are more susceptible to environments that strongly fluctuate in humidity.

KEY WORDS *Dermatophagoides pteronyssinus*, temperature, humidity, survival, fecundity

HOUSE DUST MITES ARE known to be a major risk factor in the development of asthma and perennial allergic rhinitis (Platts-Mills et al. 1989, Colloff et al. 1992, Sporik et al. 1992, Korsgaard 1998). Abiotic conditions strongly influence mite population dynamics (Arlian et al. 1990, de Boer 1998). There is no liquid water in the environments where dust mites are found (Arlian et al. 1998, de Boer 1998), and mites are reliant on the moisture in the air and in their food to maintain water balance (Arlian 1976).

There have been several studies that on the life cycle and fecundity of house dust mites over a range of temperatures and humidities (Colloff 1987, Arlian et al. 1990). Most studies have been carried out in North America and Europe, and they do not cover the full range of conditions that are found in New Zealand houses. Bedrooms are often unheated in New Zealand and thus tend to be cooler in winter than those in the Northern Hemisphere: floor temperatures of 10°C are not uncommon (Cunningham et al. 2001). Low temperatures markedly increase time for mites to complete their life cycle and reduce the relative humidity at which the mites can survive (Colloff 1987, Arlian et al. 1990). Furthermore, diurnal temperature and humidity conditions vary sinusoidally and inversely in New Zealand dust mite habitats (Cunningham et al. 2001), and it is not known how dust mites respond.

In New Zealand, the most abundant house dust mite is the European house dust mite, *Dermatophagoides*

pteronyssinus (Trouessart) (Cornere 1972, Wickens et al. 1997). They are found in almost all dwellings (Cornere 1972, Andrews et al. 1992, Wickens et al. 1997). Our principal aim in this study was to determine how dust mites respond to the simultaneous diurnal sinusoidal fluctuations of temperature and relative humidity typical in New Zealand.

Materials and Methods

The time for *D. pteronyssinus* to complete its life cycle was documented in constant and variable temperature and humidity combinations. The constant conditions were 23°C, with 75% relative humidity maintained in 500-ml jars with saturated salt or glycerol solution (O'Brien 1948). The variable condition experiments were set up in a Contherm 190 RHS precision environmental chamber (Contherm Scientific, Lower Hutt, New Zealand). These simulated two microclimates within the base of a New Zealand carpet (Cunningham 1998). The “dry” summer conditions had temperatures ranging sinusoidally from 18 to 25°C and relative humidity ranging sinusoidally from 60 to 38% RH, whereas “damp” summer conditions ranged from 18 to 23°C and 70 to 55% RH (Fig. 1). Humidity was monitored with HOB0 H8 temperature and humidity data loggers (Onset Computer Corporation, Bourne, ME).

The mite culture originated from a house in Christchurch, New Zealand, in March 2001. Experiments were begun ≈2 yr after collection. Voucher specimens of these mites were lodged with the insect collection at the Museum of Te Papa Tongarewa, Wellington, New Zealand. Mites were maintained on

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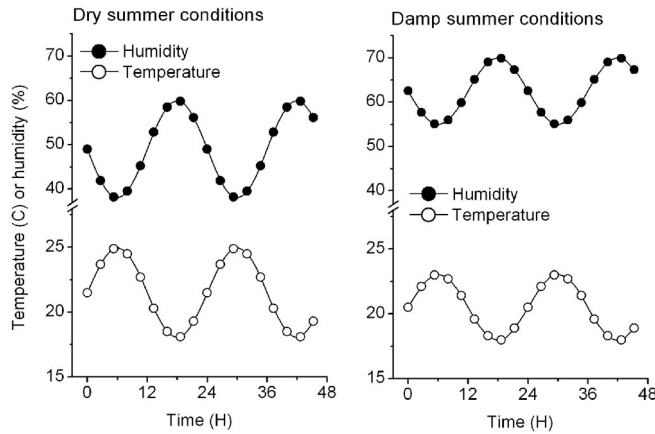


Fig. 1. Cycle of variable temperature and humidity conditions simulating conditions in the base of carpets during a New Zealand dry or damp summer, based upon actual recordings from a New Zealand house (Cunningham 1998). The circles mark the set points programmed into the environmental chamber.

wheat germ, deactivated yeast, and fish food in a Contherm 190 RHS precision environmental chamber at 26°C and 76% RH. Mites were housed separately in glass cages following the methods described by Brandt and Arlian (1976) and Arlian et al. (1990). The cages measured 20 mm in length, had a 5-mm external and 3-mm internal diameter, and were plugged with a hollow plastic tube wrapped in 50-µm Nybolt nylon mesh to allow air exchange. The mesh was dyed black with Dylon Ebony Black dye to aid detection of the mites and eggs. Several adult female mites of variable age were randomly taken from the colony and placed in a cage (26°C and 76% RH) until an egg was produced. Cages were checked once daily. After an egg was produced, the adult mites were removed from the cage, which was placed in a glass jar at the required temperature and humidity. The mites were feed one flake of wheat germ and a deactivated yeast pellet. Cages were checked once per day for developmental changes, production of eggs, or mite death.

The procedure of Arlian et al. (1990) was used to measure fecundity separately. Several tritonymphs were placed in glass cages at 23°C and 75% RH, until one molted into an adult female. At this point, the other tritonymphs were removed, a single male was

added, and the number of eggs laid by the female was recorded. Twenty-five replicates were subjected to damp summer conditions and constant conditions of 23°C and 75% RH. Female mites that produced eggs for more than the first 10-d period were used in the statistical analysis ($n = 16$ for both damp summer and the constant conditions). To measure maximum life span, a cohort of 25 mites was held at 10°C and 75% RH.

Data were analyzed using two sample t -tests, repeated measures analysis of variance (ANOVA), and χ^2 tests, with examination for homoscedasticity by plots of residuals. Significance was assumed at $\alpha = 0.05$, and a Bonferroni adjustment was applied to analyses of different aspects of data gathered from the same treatment. Mite mortality rates through time (without transformation) were compared using the slopes of linear regression analyses (Zar 1984).

Results

At constant 23°C and 75% RH, 27% of mites survived to the adult stage (Table 1). Male and female mites developed to adults in the same time ($t = 0.509$, $df = 11$, Bonferroni adjusted $P = 1.00$) and had a similar life span ($t = 1.381$, $df = 11$, Bonferroni adjusted $P =$

Table 1. Survival and developmental times of *D. pteronyssinus* under constant and variable temperature and humidity conditions observed in New Zealand

Condition	Sex ^a	n ^b	Eggs	Larvae	Nymphs	Adult-days
Constant (n = 48)	U	3, 23, 9	9.3 ± 0.2	13.4 ± 1.0		
	F	6	8.8 ± 0.4	11.8 ± 0.5	30.5 ± 7.9	100.8 ± 16.1
	M	7	8.9 ± 0.3	11.3 ± 0.7	35.6 ± 4.9	111.0 ± 2.1
Dry (n = 49)	U	32, 17, 0	10.4 ± 2.3			
	F	0				
	M	0				
Damp (n = 43)	U	9, 9, 7	10.0 ± 0.7	20.7 ± 3.5		
	F	7	10.5 ± 1.0	14.9 ± 1.3	72.5 ± 17.7	119.8 ± 24.8
	M	11	10.6 ± 0.8	15.6 ± 2.0	42.3 ± 7.3	103.1 ± 11.5

Constant, 23°C, 75% RH; dry, 18–25°C, 60–38% RH; damp, 18–23°C, 55–70% RH.

^a Sex of the mites was male (M), female (F), or the mite died before development to an adult (U).

^b For those mites that died before becoming adults, the number is shown for egg, larval, and nymphal stages.

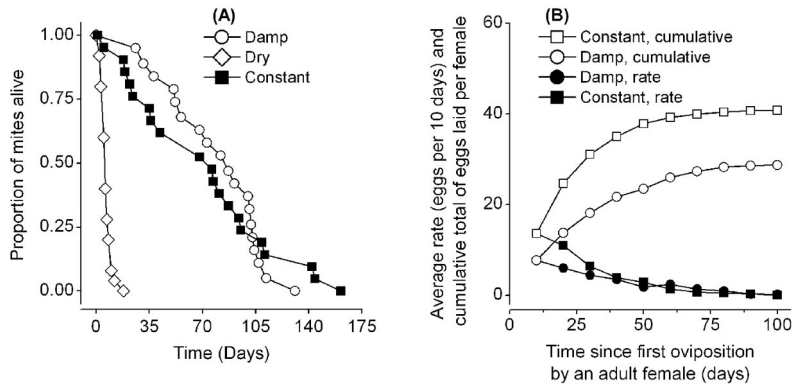


Fig. 2. (A) Longevity of adult female mites under the constant and variable conditions simulating dry summer and damp summer in the base of carpets in a New Zealand house (see Fig. 1). (B) Fecundity and longevity of adult female mites by using juvenile mites cultured at 23°C and 75% RH until molting into adults.

0.389). The dry summer conditions were unsuitable for the mites, which all died either in the egg or larval stage (Table 1; Fig. 2A). Mites that were kept in damp summer conditions tended to survive better than in the constant condition with 42% of the mites surviving to the adult stage (Table 1), although differences were not a significant ($\chi^2 = 2.205$, $df = 1$, $P = 0.138$). Under damp summer conditions, male and female mites developed to adults in the same time ($t = 1.451$, $df = 16$, Bonferroni adjusted $P = 0.332$) and had similar total life span ($t = 1.362$, $df = 16$, Bonferroni adjusted $P = 0.384$). The mortality rate was similar and not significantly different between damp summer (mean = 0.9% mite population death d^{-1}) and constant conditions of 23°C and 75% RH (mean = 0.7% mite population death d^{-1}) ($t = 0.509$, $df = 39$, Bonferroni adjusted $P > 0.10$). However, the death rate under dry summer conditions was significantly higher than both the damp summer ($t = 3.770$, $df = 38$, Bonferroni adjusted $P < 0.05$) and constant conditions ($t = 3.548$, $df = 39$, Bonferroni adjusted $P < 0.05$).

Only six of the 25 mites in the dry summer conditions produced eggs, for an average of 2.33 ± 0.97 eggs during the first 10-d period. The one mite that survived to 18 d under these conditions produced no further eggs. Because of the large number of zero values, this treatment was not subsequently included in the repeated measures ANOVA. No significant difference was observed in the oviposition rate of mites in constant and damp summer conditions ($F = 3.04$; $df = 1, 28$; $P = 0.092$), although the oviposition rate declined significantly with increasing adult age ($F = 158.67$; $df = 9, 252$; $P < 0.001$). A significant treatment \times age interaction indicated that the mean oviposition rate significantly differed in the first two time periods, but was similar for the others ($F = 13.84$; $df = 1, 28$; $P < 0.001$) (Fig. 2B). Although the mean total cumulative number of eggs produced by mites in constant conditions was higher than that in damp summer conditions, differences between these treatments were not significant due to a high amount of variation in the samples ($t = 0.334$, $df = 30$, Bonferroni adjusted $P = 0.334$).

As of 5 January 2005, one female mite in a separate treatment at 10°C and 75% RH was still alive after 839 d in these conditions, which to our knowledge is the longest documented duration for this species.

Discussion

D. pteronyssinus prefers conditions of $\approx 23^\circ\text{C}$ and 75% RH (Wharton 1976, Arlian et al. 1990, Colloff 1991). Both our study and that of Arlian et al. (1990) observed high mortality rates ($\approx 75\%$) in the preadult stages even at supposedly optimum conditions. However, many aspects of the development and fecundity in our strain of mites at steady conditions were somewhat different from a North American strain (Arlian et al. 1990). Most importantly, the New Zealand mites tended to live approximately twice as long, but laid less than half the number of eggs. This could be due to several factors, including a different diet or slightly different experimental methods, and especially mite strains (Wharton 1976, Colloff 1987).

New Zealand house temperatures in dust mite microhabitats fluctuate widely (Cunningham 1998, Cunningham et al. 2001), which has a strong influence on mite population dynamics. Under conditions simulating the base of carpets during a dry summer, mites would die quickly. Arlian (1975) estimated the lethal time to achieve 100% *D. pteronyssinus* mortality to be 10 d at 50% RH and 28°C. Our study indicated that such a constant exposure to low humidity is not necessary to kill these mite populations. Rather, conditions varying between 60 and 38% RH were sufficient to inhibit mites from developing, although there may be some refuges of more humid conditions in some areas of a house.

Mites kept at varying conditions of a damp summer had much better survival than those in dry summer conditions. Although statistically similar, damp summer mites had 42% survive to the adult stage versus 25% at the constant conditions 23°C and 75% RH. Several other authors have noted that insects and mites kept in fluctuating conditions have lower mortality, faster developmental rates, and higher fecun-

dity than was predicted from data gathered under average but static conditions (Hogg 1985, Taylor and Shields 1990, Allen et al. 1995). Our results show that population dynamics for mites under realistically fluctuating sinusoidal conditions are similar to a constant environment of 23°C and 75% RH for a range of life history parameters. However, tolerance of variable conditions is important. Mites can tolerate and do well in fluctuating conditions, surviving even for years at 10°C, so long as humidity is maintained.

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