Population Dynamics of the House Dust Mites *Dermatophagoides farinae*, *D. pteronyssinus*, and *Euroglyphus maynei* (Acari: Pyroglyphidae) at Specific Relative Humidities

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ABSTRACT Experiments were conducted to determine the effects of relative humidity on the population dynamics of single and mixed species of *Dermatophagoides farinae* Hughes, *D. pteronyssinus* (Trouessart), and *Euroglyphus maynei* (Cooreman) at specific relative humidities maintained at 20°C, with unlimited food. The population density of single and mixed species (*D. farinae* and *D. pteronyssinus*) increased exponentially when cultured at 65, 70, and 75% RH. The mean population growth rates were 17.3 ± 4.4 SD and 32.5% ± 4.7/wk for *D. farinae* and *D. pteronyssinus*, respectively. Mean population doubling times were 2.2 ± 0.3 and 4.2 ± 1.3 wk for *D. pteronyssinus* and *D. farinae*, respectively. Mixed species cultures, started with equal numbers of *D. farinae* and *D. pteronyssinus*, resulted in higher percentages of *D. farinae* than *D. pteronyssinus*. In cultures started with 75% of one species and 25% of the other, the more numerous species remained dominant and in similar ratios throughout the experiment. Both *D. farinae* and *D. pteronyssinus* population densities maintained at 85% RH declined over a 12-wk culture period because of mold growth. *E. maynei* were unable to survive at 65, 70, 75, and 85% RH, which indicated that their climatic requirements were different from those of *D. farinae* and *D. pteronyssinus*. Population densities of *D. farinae* and *D. pteronyssinus* cultures declined when held at 21–22°C and relative humidities of ≤50%; however, at 50% RH, significant proportions of the populations survived for 10 wk. Half-life for desiccation of *D. farinae* and *D. pteronyssinus* at 45% RH was 11.5 and 1.2 wk, respectively, but at 50% RH was 86.3 and 4.0 wk, respectively. The data indicated that a ≤50% RH would have to be maintained for long periods to reduce both *D. farinae* and *D. pteronyssinus* by desiccation procedures. The results of this study show that *D. farinae* and *D. pteronyssinus* have high reproductive potentials and population growth rates, which indicate that mite reduction procedures must be thorough or mite densities will return to high levels quickly following remediation if adequate food and suitable microclimatic conditions exist.

KEY WORDS *Dermatophagoides farinae*, *Dermatophagoides pteronyssinus*, *Euroglyphus maynei*, house dust mites, population dynamics, relative humidity

THE ALLERGY CAUSING mites most commonly found in dwellings worldwide are *Dermatophagoides farinae* Hughes, *D. pteronyssinus* (Trouessart), *Euroglyphus maynei* (Cooreman), and *Blomia tropicalis* Bronswijk, Cook & Oshima (Hurtado and Parini 1987, Arlian 1989, Arruda et al. 1991, Arlian et al. 1992, Stanaland et al. 1994). These mites are the sources of multiple potent allergens in house dust. Mites are most often found in high use areas where shed skin scales collect and serve as a food source and the relative humidity is above the critical levels for sufficient time to satisfy their water requirements (Arlian 1992). All 4 mite species occur in homes in the United States, but *D. farinae* and *D. pteronyssinus* are the predominant species and occur over a wider geographical range than *E. maynei* and *B. tropicalis* (Mulla et al. 1975; Lang and Mulla 1977a, b; Arlian et al. 1982, 1992; Smith et al. 1985; Klein et al. 1986; Fernandez-Caldas et al. 1990). *E. maynei* occur in subtropical areas of the United States and may be the predominant species in some homes (Smith et al. 1985, Arlian et al. 1992).

Most United States homes are co-inhabited by *D. farinae* and *D. pteronyssinus* and in some regions by *D. farinae*, *D. pteronyssinus*, *E. maynei*, and *B. tropicalis*, whereas some homes may contain only 1 species (Arlian et al. 1992). In homes co-inhabited by multiple species, 1 species usually predominates and makes up >70% of the total mite population. However, the dominant or only species present may vary between homes within a geographical area and between homes in different geographical locations (Lang and Mulla 1977b). The factors that favor population growth of 1 species so that it becomes

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more numerous than the others are unknown but different temperature and relative humidity requirements of the various species play a key role.

Laboratory studies have shown that temperature and relative humidity directly influence the biotic potential of these mites because of their effects on the duration of the life cycle, fecundity, survival, rate of feeding, and allergen production (Arlian 1975, 1977, 1992; Brandt and Arlian 1976; Arlian et al. 1990, unpublished data; Arlian and Dippold 1996). These climatic factors can affect species differently. Active life stages of *D. farinae* and *D. pteronyssinus* are able to extract enough water from unsaturated air to replace the water lost during body processes and transpiration when the relative humidity is above the critical equilibrium humidity (Larson 1969; Arlian and Wharton 1974; Arlian 1975, 1977). The critical equilibrium humidities for fasting female *D. farinae* and *D. pteronyssinus* are 70 and 73% RH, respectively, at 25°C (Larson 1969, Arlian 1975). The mites begin to desiccate and are unable to survive for long periods when constantly exposed to relative humidities below these critical equilibrium humidities. The critical equilibrium humidity is temperature dependent (Arlian and Veselica 1981). Mites survive only a short time at temperatures >45°C (unpublished data).

Surveys have shown that relative humidity is an important factor that affects house dust mite reproduction and survival and thus mite prevalence in homes (Larson 1969; van Bronswijk et al. 1971; Arlian and Wharton 1974; Arlian 1975, 1977, 1992; Brandt and Arlian 1976; Korsgaard 1983). Homes in dry climates contain few house dust mites (Lang and Mulla 1977b; Arlian et al. 1983, 1992; Moyer et al. 1985; Nelson and Fernandez-Caldas 1995; de Andrade et al. 1995), whereas virtually all homes in humid climates contain thriving dust mite populations (Lang and Mulla 1977b, Arlian et al. 1982, Smith et al. 1985, Fernandez-Caldas et al. 1990). Mite densities in homes in temperate regions exhibit seasonal fluctuations that parallel outdoor relative humidity with the highest mite levels occurring during periods of high relative humidity (van Bronswijk and Sinha 1971; van Bronswijk et al. 1971; Dusbabek 1975; Charlet et al. 1977; Lang and Mulla 1977, 1978; Furumizo 1978; Murray and Zuk 1979; Arlian et al. 1982, 1983; Arlian 1989, 1992). During dry periods (the heating season), mite levels decline because of desiccation of active life stages.

Clearly, temperature and fluctuations in relative humidity in mite microhabitats directly influence the survival and population dynamics of house dust mites and therefore the concentration of mite allergens in indoor environments. It may be possible to control mite levels in homes by maintaining the appropriate temperature and relative humidity in their microhabitat (Arlian 1977, 1992; unpublished data). Likewise, a key aspect of controlling these mites and the allergies they cause is understanding how rapidly mite populations can increase when given specific climatic conditions at which they can reproduce. Understanding population dynamics is important in developing new strategies for control of house dust mites by managing indoor climatic conditions. However, the relationship of temperature and relative humidity on mite population dynamics has not been reported. The purpose of this study was to determine the effect of ranges of 65–85% RH on the population dynamics of single and mixed populations of *D. farinae*, *D. pteronyssinus*, and *E. maynei* at 20°C. In addition, the survival of thriving populations of *D. farinae*, *D. pteronyssinus*, and *E. maynei* was determined at 20–65% RH and 21–22°C.

Materials and Methods

Source of Mites. *D. farinae*, *D. pteronyssinus*, and *E. maynei* were obtained from laboratory cultures maintained in the laboratory of L.G.A. at Wright State University.

Population Growth. Specific numbers of adult female mites were selected randomly from thriving cultures and placed into culture jars along with enough growth medium to feed the resulting mite populations for 12 wk. The culture jars consisted of 15-ml glass vials (Wheaton, Millville, NJ) closed with plastic snap-on ventilated (35 μm pore size nylon monofilament) lids that allowed gas exchange but prevented mite escape. The cultures were held in humidity chambers at 65, 70, 75, or 85% RH and 20°C. The numbers of females of each species initially placed in each culture were 40 *D. farinae*, 20 *D. farinae*, 40 *D. pteronyssinus*, 20 *D. pteronyssinus*, 40 *E. maynei*, 20 *E. maynei*, 20 *D. farinae* + 20 *D. pteronyssinus*, 20 *D. farinae* + 20 *E. maynei*, 20 *D. pteronyssinus* + 20 *E. maynei*, 15 *D. farinae* + 15 *D. pteronyssinus* + 15 *E. maynei*, 30 *D. farinae* + 10 *D. pteronyssinus*, and 10 *D. farniae* + 30 *D. pteronyssinus*. Twelve experimental culture jars were started for each combination of mites at each different humidity. The 12 cultures for each mite combination were divided equally among 4 humidity chambers for each relative humidity. For each test relative humidity at 4, 8, and 12 wk, 1 culture was removed from 3 different humidity chambers and the population density was determined. If aberrant counts or unusual conditions (mold growth) were observed, a 4th and sometimes additional cultures were analyzed for that particular sample time and test set. The number of replicates analyzed at each time ranged from 3 to 6. All 4 humidity chambers for each relative humidity were held in the same incubator at 20°C for the 12-wk test period.

To maintain 65, 70, 75, or 85% RH, 1 liter of the appropriate concentration of glycerol solution (Segur 1953) was placed in the bottom of each humidity chamber. The humidity chambers measured 34 by 25 by 9 cm (Anchor Hocking St. Paul, MN) (7.5 l) with airtight lids. At the appropriate sampling times the numbers of live mites in each culture replicate were counted using a stereomicroscope. The mean number of live mites per sample time was calculated

from the replicate cultures. Regression analysis was used to determine the rate constants for population growth. After counting, random portions of the mites from each mixed-species culture were mounted on microscope slides and adults were identified to species. In total, 100,220 mites were mounted of which 23,564 were adults and were identified to species. Those not identified were immatures. The percentage of each species in mixed populations was determined based on adults.

Effect of Low Relative Humidities on Thriving Populations. Thriving cultures of *D. farinae*, *D. pteronyssinus*, and *E. maynei* were subjected to 20, 30, 40, 45, 50, 60, and 65% RH and 21–22°C for 10 wk. Glycerol solutions to maintain the desired relative humidity and humidity chambers were prepared as described above. Thriving cultures containing 70 g of each species were held at each test relative humidity. Population densities of the thriving cultures were determined when they were removed from the colony before they were placed into the test relative humidity conditions. At 2, 4, 6, and 10 wk the density of live mites (all active life stages) was again determined by counting the numbers of live mites in 63 mg of culture material. Specifically, 100 mg of culture material was removed randomly from each experimental culture and evenly spread (visually) in a gridded petri plate. The number of live mites in 10 randomly selected grids (63 mg of culture material) was counted.

Data Analysis. Means and standard deviations for all replicates read at each sampling time were calculated and plotted against time. Because food was not limiting and population growth patterns best fit an exponential model, population growth rates and correlation coefficients were calculated by regression analysis using the 1st order relationship as follows:

$$P_t = P_o e^{kt},$$

where P_t was the population density at any time t, P_o was the initial population density at time 0, k was the rate constant for increase ($k > 0$) and decrease ($k < 0$) in population density, and t was time. Accordingly, times for the population to double (t_2) or decline by half ($t_{1/2}$) were equal to $ln\ 2/k$ and $ln\ 0.5/-k$, respectively. The natural logs (ln) of 2 and 0.5 are 0.69 and −0.69, respectively.

Results

Population Growth. Single species population densities of *D. farinae* and *D. pteronyssinus* increased exponentially when cultured at 20°C and 65, 70, and 75% RH (Fig. 1 A and B) with growth rates that ranged from 10.9 to 22.3 and 26.8 to 40.2%/wk for *D. farinae* and *D. pteronyssinus*, respectively (Table 1). The population growth rate constants were significantly ($P < 0.005$) higher for *D. pteronyssinus* than *D. farinae*. Growth rates for both species were independent of relative humidity over the range of 65–75%. The mean growth rates were 17.3 ± 4.4 (mean ± SD) and 32.5 ± 4.7%/wk for *D. farinae* and *D. pteronyssinus*, respectively, for all relative humidities. The mean times for populations to double ranged from 1.7 to 2.6 and 3.1 to 6.3 wk for *D. pteronyssinus* and *D. farinae*, respectively (Table 1). Mean population doubling times were 2.2 ± 0.3 and 4.2 ± 1.3 wk for *D. pteronyssinus* and *D. farinae*, respectively. Single species cultures of *D. farinae* and *D. pteronyssinus* increased some during the first 4 wk and then declined during the subsequent 8 wk when held at 85% RH and 20°C (Fig. 1). Under these same conditions, mixed species cultures of *D. farinae*, *D. pteronyssinus*, and *E. maynei* all declined from the start (Fig. 1). Most cultures held at 85% RH developed visible mold growth, which was likely responsible for inhibiting mite survival and reproduction. The mold was identified as *Aspergillus* spp. and *Penicillium* spp. In contrast to *D. farinae* and *D. pteronyssinus*, single species populations of *E. maynei* declined when cultured at 65, 70, 75, and 85% RH over the 12-wk test period (Table 1).

Mite populations that contained both *D. farinae* and *D. pteronyssinus* exhibited total population growth rates that were similar to growth rates of segregated single species populations at 65, 70, and 75% RH (Table 1; Fig. 1 A and B). However, cultures started with equal numbers of *D. farinae* and *D. pteronyssinus* always resulted in higher percentages of adult *D. farinae* than adult *D. pteronyssinnus* (Table 2). In contrast, for cultures that were started using unequal numbers of *D. farinae* and *D. pteronyssinus* (30 *D. farinae* + 10 *D. pteronyssinus* and vice versa) the more numerous species initially remained the predominant species after 12 wk and maintained approximately the same percentages of adults of each species as were present at the start (Table 2). Except in 1 case (*D. farinae* at 65% RH), the population growth of cultures containing *E. maynei* and *D. pteronyssinus* or *E. maynei* and *D. farinae* increased at slower rates than the populations containing *D. pteronyssinus* or *D. farinae* alone (Table 1).

Effect of Low Relative Humidities on Thriving Populations. As part of this study, we also determined the effect of low relative humidities on already thriving populations of mites in continuous culture. Population densities of *D. farinae* held at 45 and 50% RH initially increased for 4 and 6 wk, respectively, then declined (Fig. 2A). Population densities of live *D. pteronyssinus* and *E. maynei* (all life stages) in thriving cultures declined when each was held at relative humidity of ≤50% (Table 3; Fig. 2 B and C). In contrast, population densities of thriving cultures of *D. farinae* and *D. pteronyssinus* remained stable or increased when they were held at RH of ≤60%. At 20, 30, 40, and 45% RH, the half-lives for desiccation (decline) of thriving populations were 0.6–11.5 and 0.7–1.3 wk for *D. farinae* and *D. pteronyssinus*, respectively (Table 3). At relative humidities between 30 and 50%, *D. pteronys-*

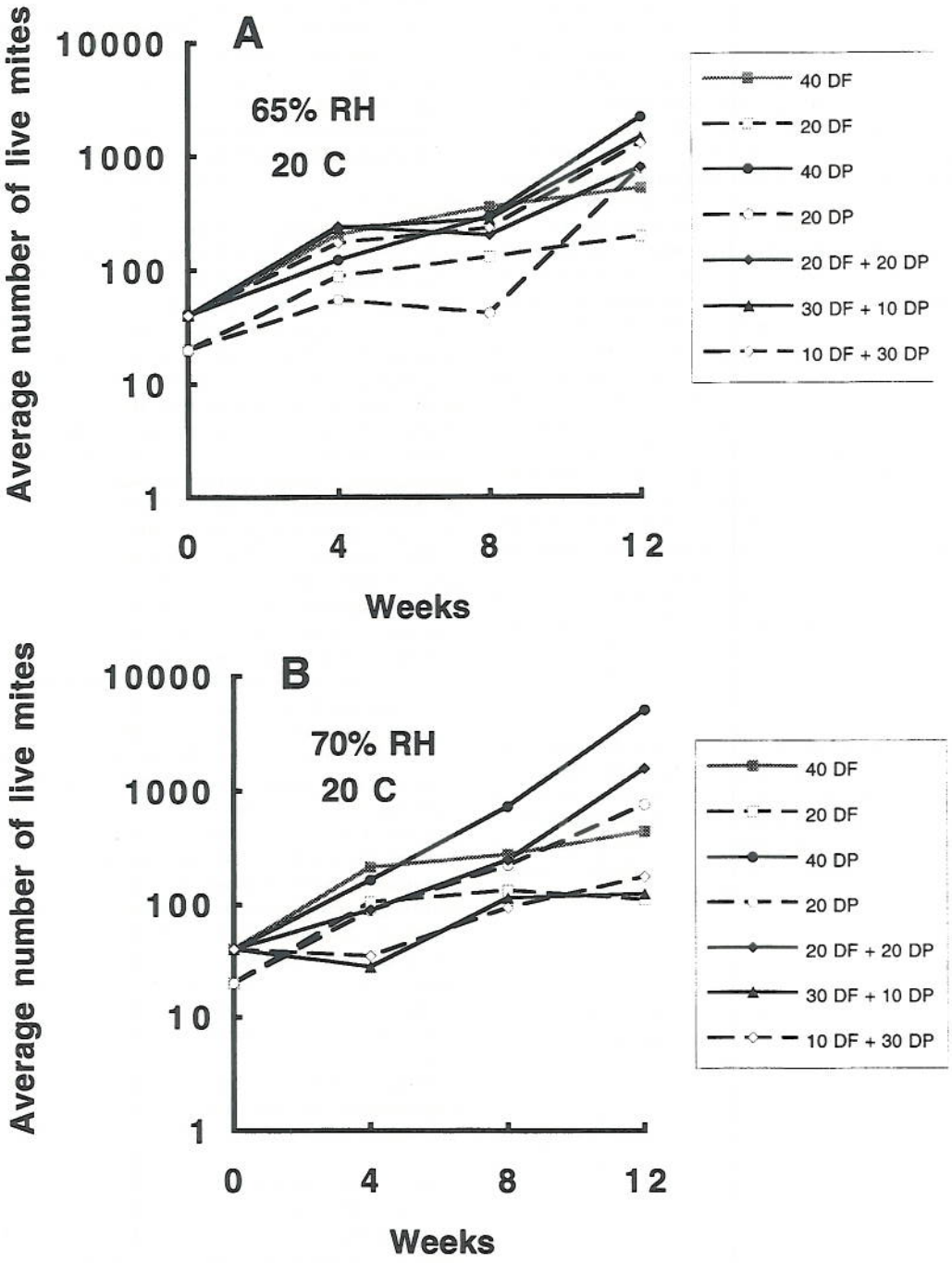

Fig. 1. Population dynamics of single and mixed species of *D. farinae* and *D. pteronyssinus* held at 20°C for 12 wk and (A) 65% RH, (B) 70% RH. Initial populations consisted of the specific numbers of females as indicated in the figure legend.

sinus was more susceptible to desiccation than *D. farinae*. At 50% RH the half-life for desiccation of *D. farinae* was 86 wk, whereas for *D. pteronyssinus* it was 4 wk. Significant portions of the populations of *D. farinae* survived for 10 wk at 45 and 50% RH but populations survived only at 50% RH for *D. pteronyssinus*. Except at 45 and 50% RH for *D. farinae* and *D. pteronyssinus*, the half-life for die out caused by desiccation was correlated with relative humidity. Compared with *D. farinae* and *D. pteronyssinus*, *E. maynei* populations died out quickly because of desiccation when held at relative humidity of 20–50%.

Table 1. Total population growth rate constants (k), correlation coefficients (r^2), and doubling times (t_2) for *D. farinae* (DF), *D. pteronyssinus* (DP), and *E. maynei* (EM) in single or mixed species cultures held at 20°C and 65, 70, and 75% RH for 10–12 wk

Starting population (females)	65% RH			70% RH			75% RH		
	r^2	k (wk^{-1})	t_2 (wk)	r^2	k (wk^{-1})	t_2 (wk)	r^2	k (wk^{-1})	t_2 (wk)
40 DF	0.887	0.206	3.35	0.847	0.187	3.69	0.906	0.223	3.09
20 DF	0.883	0.181	3.81	0.613	0.134	5.15	0.531	0.109	6.33
40 DP	0.965	0.323	2.14	0.994	0.402	1.72	0.927	0.351	1.97
20 DP	0.750	0.268	2.57	0.992	0.297	2.32	0.839	0.308	2.24
40 EM	0.692	−0.073	—	0.983	−0.153	—	0.972	−0.172	—
20 EM	0.917	−0.087	—	0.847	−0.180	—	0.409	−0.125	—
20 DF + 20 DP	0.852	0.220	3.14	0.962	0.302	2.28	0.519	0.100	6.90
20 DF + 20 EM	0.921	0.229	3.01	0.726	0.089	7.75	0.727	0.078	8.85
20 DP + 20 EM	0.940	0.219	3.15	0.935	0.167	4.13	0.036	−0.010	—
30 DF + 10 DP	0.927	0.275	2.51	0.688	0.121	5.70	0.069	0.036	19.17
10 DF + 30 DP	0.944	0.269	2.57	0.853	0.137	5.04	0.049	0.015	46.00
15 DF + 15 DP + 15 EM	0.944	0.281	2.46	0.967	0.142	4.86	0.856	0.158	4.37

Discussion

This study systematically examined the population dynamics of *D. farinae*, *D. pteronyssinus*, and *E. maynei* during both constant hydrating and dehydrating conditions. Understanding the population dynamics of these mites under static hydrating and dehydrating conditions when adequate food is available and temperature is in the optimal range provides valuable ecological information about their survival in human dwellings where their survival depends on the relative humidity in the microenvironment where they breed (Arlian 1992). Because of the health problems associated with these mites, these data also provide a basis for developing guidelines to make recommendations to remediate mites in human dwellings. Predicting population growth rates and densities during mite growing seasons and repopulation of dwellings after reductions of mites are important aspects of managing mite-induced asthma, allergic rhinitis, and atopic dermatitis.

It was shown that *D. farinae* and *D. pteronyssinus* have very high reproductive potentials and population growth rates. *D. pteronyssinus* had greater population growth rates than *D. farinae* at the static

Table 2. Percentage of the population (live and dead) of each species (*D. farinae* [DF] and *D. pteronyssinus* [DP]) in mixed species cultured at specific relative humidities, 20°C

% RH	No. females in initial population	% total population of adults					
		Week 0			Week 12[a]		
		DF	DP	n	DF	DP	n
65							
	20 DF + 20 DP	50	50	40	63	37	754
	30 DF + 10 DP	75	25	40	76	24	1,203
	10 DF + 30 DP	25	75	40	21	79	1,401
70							
	20 DF + 20 DP	50	50	40	53	47	562
	30 DF + 10 DP	75	25	40	76	24	201
	10 DF + 30 DP	25	75	40	24	76	218
75							
	20 DF + 20 DP	50	50	40	64	36	252
	30 DF + 10 DP	75	25	40	78	22	114
	10 DF + 30 DP	25	75	40	27	73	135

[a] Males and females.

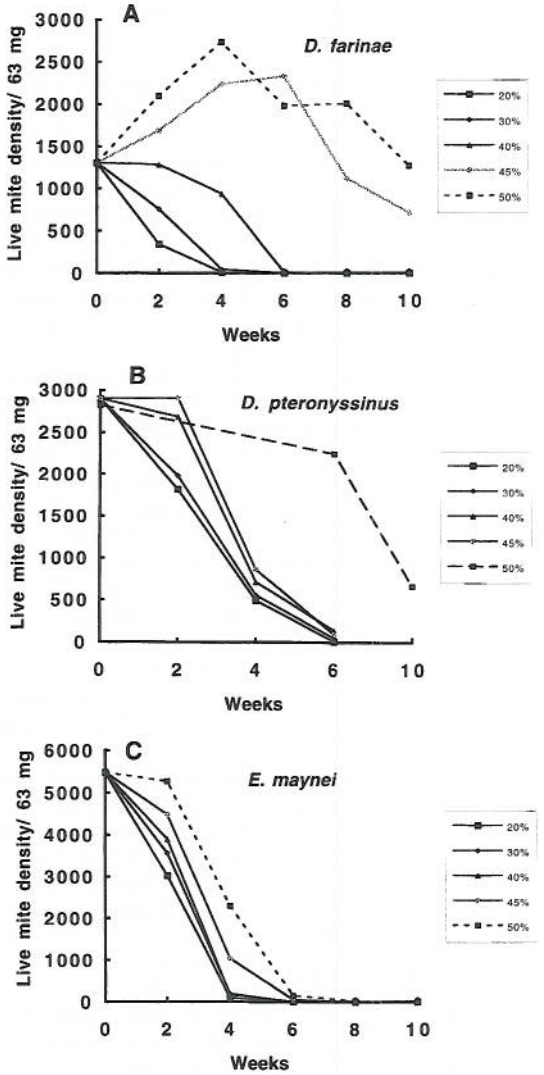

Fig. 2. Live mite densities of thriving cultures of (A) *D. farinae*, (B) *D. pteronyssinus*, and (C) *E. maynei* when held at 21–22°C and 20, 30, 40, 45, and 50% RH for 10 wk.

Table 3. Total population growth rate constants (k), half life ($t_{1/2}$), and correlation coefficients (r^2) for thriving populations of *D. farinae*, *D. pteronyssinus*, and *E. maynei* when held for 10 wk at specific relative humidities, 21–22°C

Species	% RH	r^2	k (% wk^{-1})	$t_{1/2}$ (wk)
D. farinae	20	0.941	−117.2	0.589
	30	0.867	−84.1	0.821
	40	0.783	−8.3	8.313
	45	0.248	−6.0	11.50
	50	0.011	−0.8	86.25
D. pteronyssinus	20	0.839	−93.1	0.741
	30	0.893	−68.1	1.013
	40	0.893	−52.2	1.322
	45	0.843	−57.3	1.204
	50	0.711	−17.1	4.035
E. maynei	20	0.858	−101.9	0.677
	30	0.845	−83.9	0.822
	40	0.823	−88.2	0.782
	45	0.904	−101.4	0.681
	50	0.886	−73.5	0.939

conditions of this study. These high population growth rates indicate that mite reduction procedures must be thorough or mite densities can return to high levels quickly after remediation when adequate food and suitable microclimatic conditions exist. For example, allowing for variations between patients, as a reference 100 mites per gram of dust is sometimes used as the theoretical threshold that induces sensitization and allergic reactions (Platts-Mills et al. 1990). A long-term study of 252 homes located in 8 different geographical areas of the United States reported that 92% of the homes had at least 1 sample site with average mite densities >100 mites per gram of dust for the duration of the study (July 1986–September 1990) (Arlian et al. 1992). Using the rate constants for population growth from this study, if the mite populations were reduced to 50 mites per gram of dust the mite densities could return to 100 mites per gram within 1 wk even when using the slowest doubling time (1.97 wk) observed in this study. Therefore, products or appliances recommended for the control of mites in carpets and furniture must be near 100% efficiency or their use must be repeated within short time intervals when suitable climatic conditions exist in mite breeding locations in dwellings.

The fact that both *D. farinae* and *D. pteronyssinus* thrived at 65% RH indicated that the critical equilibrium humidities determined for fasting females at 25°C and constant relative humidity (70 and 73% for *D. farinae* and *D. pteronyssinus*, respectively) in laboratory conditions (feeding and lower temperature conditions) are lower than may actually exist in mite microhabitats in dwellings. These results are consistent with previous findings that the critical equilibrium humidity was temperature dependent (Arlian and Veselica 1981). Mite populations are found in homes where ambient relative humidity periodically fluctuates much below 65% for extended periods of time during a 24-h period. This suggests that fluctuating relative humidity that is periodically >65% for a crucial period of time is key to mite survival when the relative humidity is dehydrating most of the time. It may be that mites are able to survive because they obtain sufficient water from unsaturated air during a few hours at hydrating conditions to sustain them during longer periods of dehydrating conditions. Therefore, "time of wetness" may be key to mite survival under these dehydrating conditions and an important consideration when regulating relative humidity to control these mites. However, we also found that laboratory population growth was not sustained and declined after 4 wk at 85% RH. This high relative humidity promoted mold growth in the cultures that appeared to be responsible for inhibiting mite survival. Noticeable growth did not occur in cultures at ≤75% RH. These results suggest that when relative humidity is high (e.g., 85%) significant mold growth occurs but fluctuations in relative humidity to levels below the critical equilibrium humidity may reduce or inhibit this mold growth. In homes where mites are found, relative humidity is often above 85% during some seasons. Low relative humidity periodically may reduce the mold growth and thus reduce the negative influence of mold on mite reproduction and survival, but short periods of high relative humidity would provide the necessary water for maintenance of the mites' water balance. Thus, fluctuations in relative humidity that are at times both dehydrating and hydrating to the mites are key to mite survival over a wide range of both hydrating and dehydrating relative humidity. Therefore, mite populations may thrive better over a wider range of relative humidity when relative humidity conditions are dynamic rather than static as they were in our experiments.

We found that both *D. farinae* and *D. pteronyssinus* thrived at 20°C and sustained 65, 70, and 75% RH, but *D. pteronyssinus* reproduced more rapidly than *D. farinae*. Yet, in the same geographical area, some homes contain predominantly *D. farinae*, whereas others contain predominantly *D. pteronyssinus* (Lang and Mulla 1977b, Arlian et al. 1992). If the proportions of each species in mixed populations were dependent only on the population growth rates of each species, then all mixed populations should contain higher proportions of *D. pteronyssinus*, which had an average growth rate 1.87 times greater than that for *D. farinae* under the constant conditions of these experiments. Differences in the success of the 2 species must be influenced by subtle differences in climatic conditions in the different homes and how these conditions influence survival and reproduction of each species. Life cycle studies have already shown that different temperatures greatly affect the developmental rates of both *D. farinae* and *D. pteronyssinus* and that the developmental success of *D. pteronyssinus* is greater over a wider temperature range than it is for *D. farinae* (Arlian et al. 1990, Arlian and Dippold 1996). Direct comparisons of the kinetics of water uptake and loss for *D. farinae* and *D. pteronyssinus* have not

been conducted. However, species differences in rate constants for water loss under dehydrating conditions and the rate of water uptake under hydrating conditions may further explain why in the same geographical areas some homes contained predominantly *D. farinae* whereas others contained predominantly *D. pteronyssinus*.

As already mentioned, we found that when cultures were held at 85% RH, population growth was not sustained and in fact declined after 4 wk. It was noted that most cultures developed visible mold which likely was responsible for inhibiting mite survival. Mold samples taken from the culture jars were identified as *Aspergillus* spp. and *Penicillium* spp. The mechanism for the inhibition we observed is not known. Toxins produced by the mold or the physical presence of mold, or both, which may alter the mites' food, may inhibit mite survival, reproduction, and population growth.

This study showed that *D. farinae* and *D. pteronyssinus* thrived at 20°C and 65, 70, and 75% RH whereas *E. maynei* did not survive or reproduce. These results indicate that *E. maynei* has different static climatic requirements than *D. farinae* and *D. pteronyssinus*. They also indicate that the microclimatic conditions in homes where the 3 species occur together must not be a constant 20°C and 65–75% RH or *E. maynei* would not be found there. However, the fact that the 3 species do occur together in homes in some geographical areas also indicates that they must have some overlapping microclimatic requirements or they would not co-exist.

It is unclear why mite cultures, started with equal numbers of *D. farinae* and *D. pteronyssinus*, resulted in greater densities of *D. farinae* than *D. pteronyssinus* despite the fact *D. pteronyssinus* population growth rates in single species cultures were greater. Longevity of *D. farinae* females (100 d) is much longer than the longevity of *D. pteronyssinus* females (31 d) (Arlian et al. 1990, Arlian and Dippold 1996). The longer longevity by *D. farinae* females may in part account for the higher numbers of *D. farinae* in these mixed populations. It may be that 12 wk was not long enough for the populations to shift to the species with the higher reproductive potential.

The fact that the population growth rates of mixed cultures of *E. maynei* and *D. pteronyssinus* or *D. farinae* increased at slower rates than populations of *D. pteronyssinus* or *D. farinae* alone suggested that the presence of *E. maynei* in some way inhibited *Dermatophagoides* spp. The mechanisms for this inhibition are unknown at this time particularly because *E. maynei* declined in these mixed populations.

It is possible that the growth rate constants we determined slightly underestimate natural population growth rates. The experimental populations of these studies were started with only gravid females and thus they were synchronized to some degree and had a built-in initial delay. An F_2 generation was not possible until the eggs (F_1) produced by these original females developed to adults. The average developmental times of *D. pteronyssinus* and *D. farinae* are ≈34.0 ± 5.9 and 35.6 ± 4.4 d, respectively, at 23°C (Arlian et al. 1990, Arlian and Dippold 1996). Therefore, in our studies there was an initial delay in population development (35 d) until the F_1 eggs became adults. However, given the wide range of individual developmental times for *D. farinae* and *D. pteronyssinus* and that we monitored population growth for 12 wk to calculate population growth rates, these observed growth rates seem reasonable for predictive purposes. Natural populations have all life stages represented and thus there is no lag period for new adults entering the population so they may grow slightly faster.

Finally, we determined the effect of relative humidity on the desiccation times of already thriving populations of mites in continuous culture to simulate what might happen if relative humidity were lowered in homes with already thriving mite populations. Our results showed that reducing relative humidity to 50% for long periods of time (>4 wk) will eliminate dust mite breeding populations. Thriving populations of *D. farinae*, *D. pteronyssinus*, and *E. maynei* declined in density of living mites when the cultures were continuously held at relative humidities ≤50%. Fifty percent relative humidity was well below the feeding critical equilibrium humidity for all life stages of *D. pteronyssinus*, but it was close to the critical equilibrium humidity for *D. farinae*. Significant portions of the populations of *D. farinae* survived for 10 wk at 45 and 50% RH, whereas significant portions of populations of *D. pteronyssinus* survived only at 50% RH. These results would indicate that relative humidity must be maintained below 50% for long periods to reduce mite densities significantly. It also means that low relative humidity must be sustained for longer periods to control *D. farinae* than to control *D. pteronyssinus*. The slow desiccation time is consistent with *D. farinae* being associated with drier climates. *E. maynei* were most susceptible to desiccation with a population half-life of 0.7–0.9 wk over the relative humidity range of 20–50%.

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