

EAACI/DGAI Symposium Reviews

Domestic mites from an acarologic perspective

Spieksma FThM. Domestic mites from an acarologic perspective.
Allergy 1997; 52: 360–368. © Munksgaard 1997.

Knowledge of the taxonomic, physiologic, biologic, and ecologic characteristics of allergenic domestic mites contributes to the understanding of the causation of many cases of allergic asthma, and to the measures to be taken to control excessive mite occurrence in homes. Domestic mites, i.e., the combined group of storage mites living in the home environment and of pyroglyphid house-dust mites, belong to the subclass of the acari. This comprises also many other mites of medical and economic importance, together with thousands of free-living mites. Because of some species-specific properties of their allergenic products, it is important that the producing mite is always correctly identified. In spite of their small size (approx. 0.5 mm), domestic mites have well-developed and elaborate systems of respiration, digestion, and water balance, enabling them to live and survive in the various habitats of the home environment. Knowledge of the effects of the various and changing ecologic conditions in the home environment is helpful in developing strategies to prevent the establishment and growth of large populations of allergenic domestic mites.

F. Th. M. Spieksma

Laboratory of Aerobiology, Department of
Pneumology, University Hospital Leiden, Leiden,
The Netherlands

Key words: allergenic; domestic; house dust;
mites; storage.

F. Th. M. Spieksma
Laboratory of Aerobiology
Department of Pneumology
University Hospital Leiden
PO Box 9600
NL-2300 RC Leiden
The Netherlands

Accepted for publication 29 November 1996

The first records of cases of allergic sensitization to mites date from the 1920s (1, 2). In the last 30 years, we have learnt that mites which live in the direct environment of man (3–5) can sensitize predisposed patients (6–10). These so-called domestic mites (11) have adapted their ecologic requirements to the human habitat, living and multiplying successfully in our homes, where they play a beneficial role as biologic recyclers and reducers of our waste products.

Some species, particularly some pyroglyphid house-dust mites, are so exclusively bound to the home environment that they can be considered typical dwellers of the human nest (12). Slowly, we have realized that we are not alone in our beds and sofas. It is time that we learn a little more of the almost invisible, sometimes very numerous, but always intriguing coinhabitants of our homes.

Taxonomy, morphology, identification

Mites and ticks

The taxonomic subclass of acari (mites and ticks) comprises tens of thousands of species, grouped in many families and several orders. They belong to the

very heterogeneous phylum of arthropods (joint-legged animals), and for the nonacarologist their main morphologic characteristics are the possession of four pairs of legs, like spiders and scorpions (insects have three pairs; crustaceans have five pairs), and the relative smallness of their bodies. With a length of almost always less than 1 mm, they are often invisible to the naked eye and easily escape notice. Only ticks engorged after a blood meal become as large as 10 mm or more. A general outline of the taxonomic division of the acari is given in Table 1.

The vast majority of mites are free-living in all biologic habitats, and are mostly useful in the biologic recycling process as scavengers, or as saprophageous or parasitic mites. A few mite species live in close association with warm-blooded animals, including man, the best known of which cause health problems or economic damage, such as ticks, scabies mites, house-dust mites, storage mites, and spider mites (Table 2).

Domestic mites

House-dust mites were recognized as the major source of the allergens in house dust about 35 years

Table 1. Simplified outline of taxonomic division of acari

		Orders		Some families
Arthropoda	Crustacea			
	Insecta			
	Arachnida	Scorpiones		
		Opiliones ("long legs")		
		Aranea (true spiders)		
	Acari (mites and ticks)	Anactinotrichida (parasitiformes)	Notostigmata Holothyrida Ixodida Mesostigmata	Opilioacaridae Holothyridae Ixodidae Argasidae Dermanyssidae Parasitidae
		Actinotrichida (acariformes)	Oribatida Prostigmata Astigmata	Oribatidae Tarsonimidae Pyemotidae Trombiculidae Tetranychidae Demodicidae Cheyletidae Glycyphagidae Acaridae Pyroglyphidae Sarcoptidae

Table 2. Best-known mites of medical or economic importance

Genus		Common name	
Storage mites	<i>Ixodes</i>	Hard tick	
	<i>Argas</i>	Soft tick	
	<i>Dermanyssus</i>	Chicken mite	
	<i>Pyemotes</i>	Grain itch mite	
	<i>Trombicula</i>	Chigger, harvest mite	
	<i>Tetranychus</i>	Spider mite	
	<i>Demodex</i>	Hair follicle mite	
	<i>Cheyletus</i>	Predatory mite	
	<i>Acarus</i>	Flour mite	Domestic mites
	<i>Tyrophagus</i>	Copra mite	
	<i>Lepidoglyphus</i>	Hay mite	
	<i>Glycyphagus</i>	House mite	
	<i>Blomia</i>	Tropical house mite	
	<i>Dermatophagoides</i>	House-dust mite	
	<i>Sarcoptes</i>	Scabies mite	

ago (6, 13). They are members of the family Pyroglyphidae, which are typical inhabitants of

animal nests, including man's nest, i.e., furniture, textile floor covers, and bedding. House-dust mites

and several species of storage mites living in homes, together with accompanying predatory mites, are designated as domestic mites, the most important of which are listed in Table 2. Generally speaking, all mite products should be considered potentially allergenic (14), sensitizing predisposed patients if certain thresholds of exposure, both in intensity and duration, are passed. Allergenic products of taxonomically related species show a certain degree of cross-reactivity; e.g., between *Lepidoglyphus* spp. and *Glycyphagus* spp., or between *Dermatophagoides farinae* and *D. microceras*. But there is also species specificity of allergens (9, 14), making a correct taxonomic identification of the mite species under allergenic investigation necessary.

Morphology

The general structure of the mite body consists of three main parts: the gnathosoma, carrying the mouth-parts; the propodosoma, carrying the forelegs; and the hysterosoma, carrying the hindlegs and the external sexual organs in the adult. Both the body and the legs very often bear many hairs (setae) of various sizes, structures, and functions.

The identification of mite species is almost entirely based upon external morphologic characters, such as type and construction of mouth-parts, arrangement and shape of legs, number and arrangement of body setae, etc. Microscopic inspection of preferably intact specimens, sometimes by phase-contrast or scanning electron microscopes, is the keystone of the identification procedure. Very often, before the light microscopic inspection, the mite body is made transparent by treatment with lactic acid, optically dissolving all soft internal organs, but making all sclerotized, mostly external characters clearly visible (Fig. 1).

Many acarologic handbooks (15, 16) list taxonomic considerations and identification keys to families, genera, and species (17). Pictorial identification keys, especially for domestic mites of allergenic importance, have also been published (18, 19).

Physiology

Respiration

Most of the domestic mites of allergenic importance belong to the order Astigmata (Table 1), indicating that they lack special body openings leading to a tracheal tube system for gas exchange. Their body size is so small that they do not need transportation or conducting systems for breathing. In these

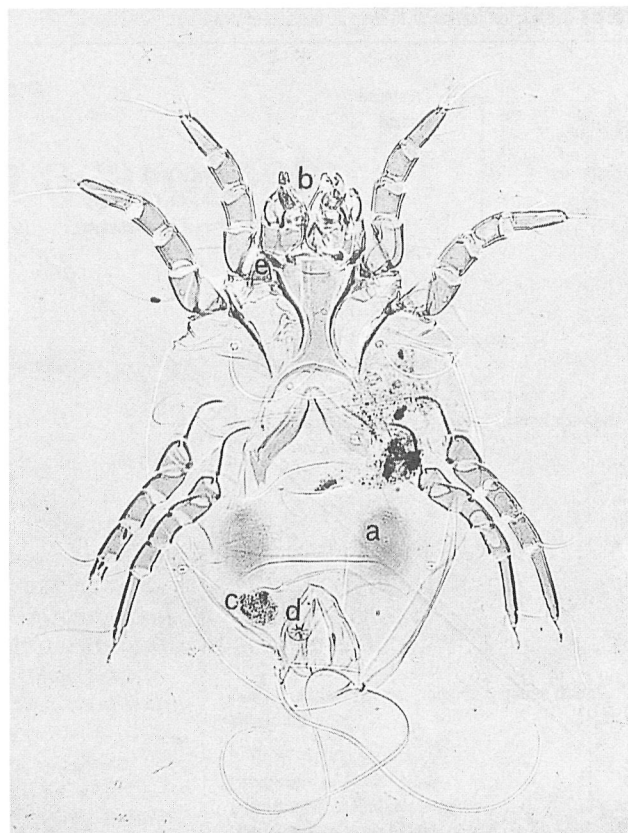


Fig. 1. Light microscopic photograph of female of *Dermatophagoides pteronyssinus* (Trt, 1897). Body length: 350 μ m. a) Abdominal gland; b) chelicera; c) fecal ball in hindgut; d) internal opening to receptaculum seminis; e) position of supra-coxal seta (at dorsal side).

small animals, the ratio between body surface area and content allows efficient gas exchange by a combination of diffusion and random body fluid flow. To keep the cuticle skin of the mite body in the optimal state for gas transmission, these mites have two lateroabdominal glands producing a conditioning secretion (Fig. 1, a).

Digestion

Mites have a well-developed digestive tract, including an elaborate system of mouth-parts (chelicerae and pedipalps) (Fig. 1, b), salivary glands, and a duct consisting of esophagus, midgut with a large cecum, hindgut, and slit-formed anus (20) (Fig. 2). In the usual preparative lactic acid treatment of mite specimens for identification purposes or morphologic studies, this digestive tract becomes invisible, except for the content of the hindgut. Very often, the dark filling of the hindgut, where it is wrapped in the so-called peritrophic membrane, is clearly visible within the transparent mite body (Fig. 1, c), as the future fecal ball. In storage mites, the content of the hindgut is also often

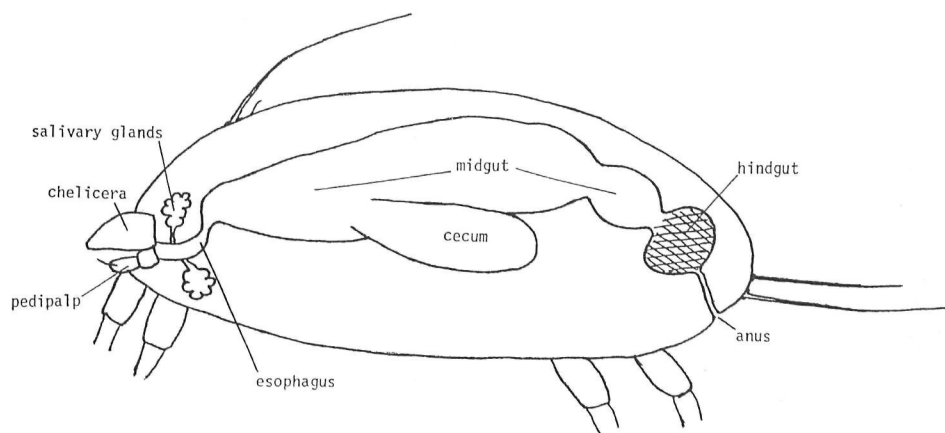


Fig. 2. Schematic presentation of digestive tract of domestic mite. After Mumcuoglu (20).

visible. Under natural conditions, house-dust mites probably take human skin scales as their main food, giving the hindgut content a dark-grayish appearance, but in laboratory cultures this color depends on the kind of food presented. Allergochemical studies (21, 22) have shown clearly that these fecal balls are extremely rich in allergens, which probably are digestive enzymes or their derivatives.

Water balance

Among domestic mites, the water balance in house-dust mites has been studied most extensively (23). The principle of this water balance seems to be rather simply based upon water uptake from environmental water vapor when relative humidity is around 65% or more, and water loss by evaporation when surrounding relative humidity drops below approx. 55%, and also by excretion of feces. Mites do not drink or urinate. There are, however, a number of biophysical mechanisms which allow them to survive periods of drought. Firstly, mites can excrete a hyperosmotic, hygroscopic substance by the supracoxal gland situated at the base of the first leg (Fig. 1, e), which attracts water even when the surrounding relative humidity is under 55%. Secondly, digestion of food results in the production of metabolic water, the quantity of which is probably enough to compensate for water loss by fecal excretion. Finally, when the (dry) surrounding air in direct contact with the mite body is still, the mite can create a protective shield of humid air around its body by limited evaporation. Water loss by diffusion from this protective humid air shield is probably so low that the mite can survive a period of drought. This effect can be enhanced by clustering of several mite bodies, as is often seen in house-dust mite cultures when exposed for educational demonstration.

Biology and ecology

Life cycle and reproduction

Most domestic mites of the Astigmata order have a sequence of developmental stages consisting of egg, larva (six-legged), protonymph, deutonymph (sometimes absent, sometimes as resting or survival stage), tritonymph, and adult male or female. The duration of the nonadult stages is temperature (and humidity) dependent, taking 5–6 days under optimal conditions (13, 23) (Fig. 3), for *D. pteronyssinus* and *D. farinae*. In house-dust mites, no deutonymphal stage is observed. Some storage mites, such as *Acarus* spp. and *Glycyphagus* spp., do have a deutonymphal stage which is highly specialized to survive unfavorable conditions: the hypopus. The life time of the adult stages is from some weeks to several months, again depending on temperature and humidity conditions (24). Adult males and females have complete and elaborate sexual organs (25), the sclerotized, mostly external elements of which are often helpful as identification characteristics (17). Mating may take place immediately after molting of the adults from the tritonymphal stage. In *D. pteronyssinus*, adult males attach themselves with their adanal suckers to tritonymphs which always become female adults after molting. This behavior might be particularly useful to improve the chances of encountering a female in a sparse mite population.

Ecology

The three main abiotic ecologic factors determining the presence and size of a mite population in a certain place are food, temperature, and humidity. Domestic mites feed on a wide variety of material, but do prefer protein-rich substances. Cereals, cheese, and dried fruit are some of the main nutrients for many storage mites, while some species like moldy

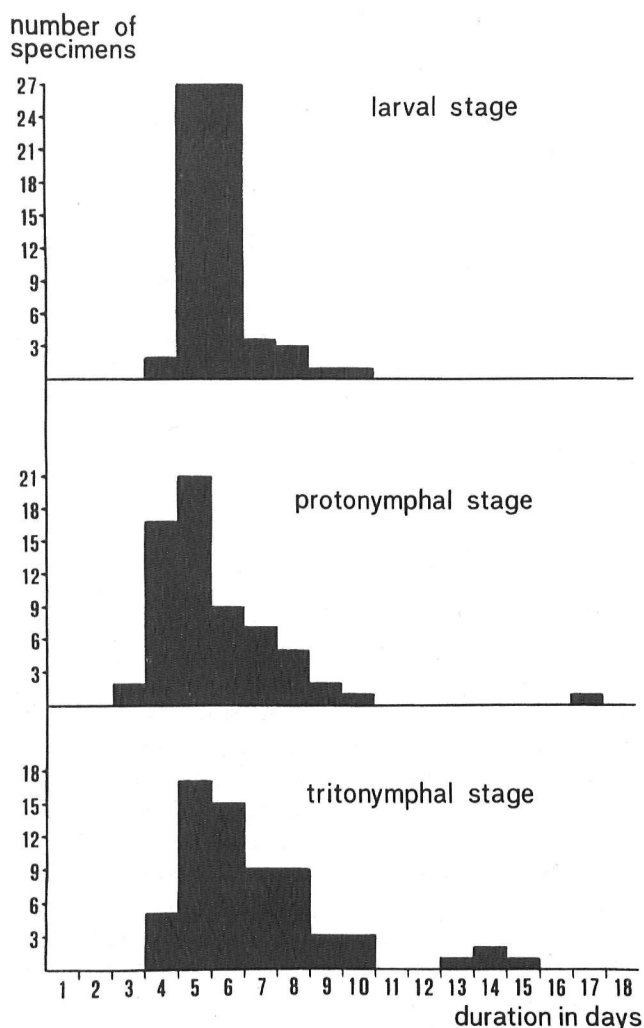


Fig. 3. Duration (in days) of three active developmental stages, determined for 65 specimens of *D. pteronyssinus*.

substrates. House-dust mites appear to prefer animal skin scales (13) (Fig. 4), but also many other elements from the mite's living place can be found inside the intestinal tract; e.g., fungal spores (26). Most probably, food is seldom a limiting factor for the development of populations of house-dust mites in the home environment, as it may be for some storage mites.

Nor are temperature requirements critical within the limits of home conditions. Most domestic mites can stand rather low temperatures, and house-dust mites survive freezing conditions for short periods of time (27). Of course, metabolic, reproductive, and other biologic activities, slow down at lower temperatures. For the great majority of domestic mites, temperatures of 20–30°C are optimal (13, 24, 28, 29) (Fig. 5); over 35°C is too high for an established population. Effective and quick killing of a domestic mite population, including eggs and resting stages, requires temperatures of over 60°C for several hours.

The level of environmental humidity is of great influence on the presence and development of a mite population. For purposes of measuring humidity conditions in physioclimatic studies, it is necessary to express humidity in absolute values (e.g., gram of water vapor per kilogram of air). But the effect on both individual mites and mite populations is regulated by the level of relative humidity, which is highly temperature dependent (23). Optimal values of relative air humidity lie between 70 and 90% (13, 23, 29). Humidity conditions higher than 90% may affect mite populations secondarily by the more rapid development of other microorganisms in the mites' living place, such as fungi and bacteria. When humidity levels drop below 55% relative humidity, depending on temperature, mites start losing more water by evaporation than they can absorb from the environment. But some mites have efficient methods of protection against desiccation, such as clustering or (hypopal) resting stages. It appears that several species of domestic mites, including house-dust mites, can survive surprisingly long periods of drought (30). Still, it is thought that humidity conditions indoors are the main ecologic factor for the presence and distribution particularly of pyroglyphid house-dust mites (31–34), as shown by their relative scarcity in cold and alpine climates (34–37) with dry indoor climates. Humidity is also thought to be the main determining factor (13, 38, 39) of the seasonal fluctuations in house-dust-mite populations in moderate and continental climate zones, with growing mite populations in summer and decreasing populations in winter.

Control

The clinical effectiveness of the various techniques of mite control in homes lies outside the scope of this "acarologic perspective". Reports are continually published on these aspects, and for a more extensive review, the reader is referred to a British Society for Allergy and Clinical Immunology working group position paper (40). Still, a few biologic aspects of control measures might be mentioned here. Five main methods for controlling or reducing mite infestations may be distinguished: *mechanical removal*, *impermeable barriers*, *humidity reduction*, *temperature treatment*, and *chemical control*.

Mechanical removal

Removal of heavily infested objects, such as an old kapok mattress, is always helpful in reducing domestic mite numbers. However, vacuum-cleaning floors, carpets, and beds is not very effective in lowering the numbers of mites (40). Still, by careful vacuum-cleaning not only is a portion of

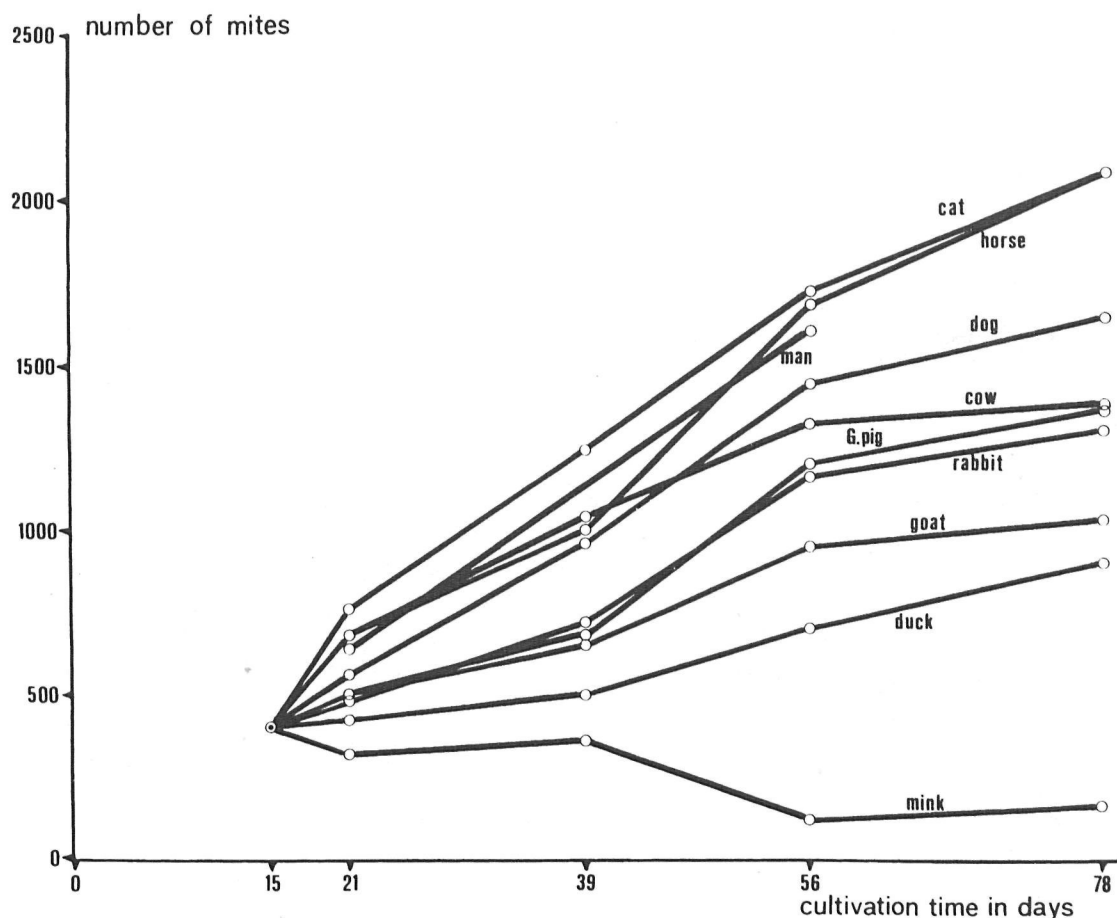


Fig. 4. Growth of laboratory populations of *D. pteronyssinus* on various types of skin scales. Starting density of populations was adjusted at 450 per cultivation cup.

the allergen-producing mites removed, but also a part of the settled reservoir of allergen-carrying particles, which may become airborne after disturbance. Therefore, vacuum-cleaning should have a place in a complete control package.

Impermeable barriers

The application of particle-impermeable, dust- and mite-tight covers on mattresses, pillows, and duvets serves several purposes (41, 42). It should prevent mites from colonizing and settling inside the bedding, and it should confine mites present inside the bedding. The covers should also be impermeable to small particles to prevent allergen-carrying dust particles from emanating from the mattress or pillow; and they should keep the mites' main food, skin scales, outside.

Particularly with a new foam mattress, the application of a mite- and dust-tight cover may keep the bedding free of mites and allergen for a long time. It should be realized that colonization by mites of the covers themselves is very likely, so that regular cleaning, e.g., every 2–3 months, by

warm washing is necessary to achieve an optimal effect.

Humidity reduction

Substantial and prolonged reduction of humidity indoors, on a meso- and microclimatic scale, is probably the most effective method to decrease domestic mite infestation (31, 32, 43–49). However, the outdoor macroclimatic conditions under which this can be achieved occur only in (semi-) alpine, moderate to cold, and continental climates. In tropical, subtropical, and humid climates (50–52), the outdoor temperature does not drop for periods of months to levels at which, at room temperature, indoor humidity becomes lower than 50%.

Temperature treatment

Two types of temperature treatment for controlling mite infestations in smaller objects are possible: cooling to deep-freeze ($<-20^{\circ}\text{C}$) temperature (53, 54), and heating (55–57) to at least 50°C , under

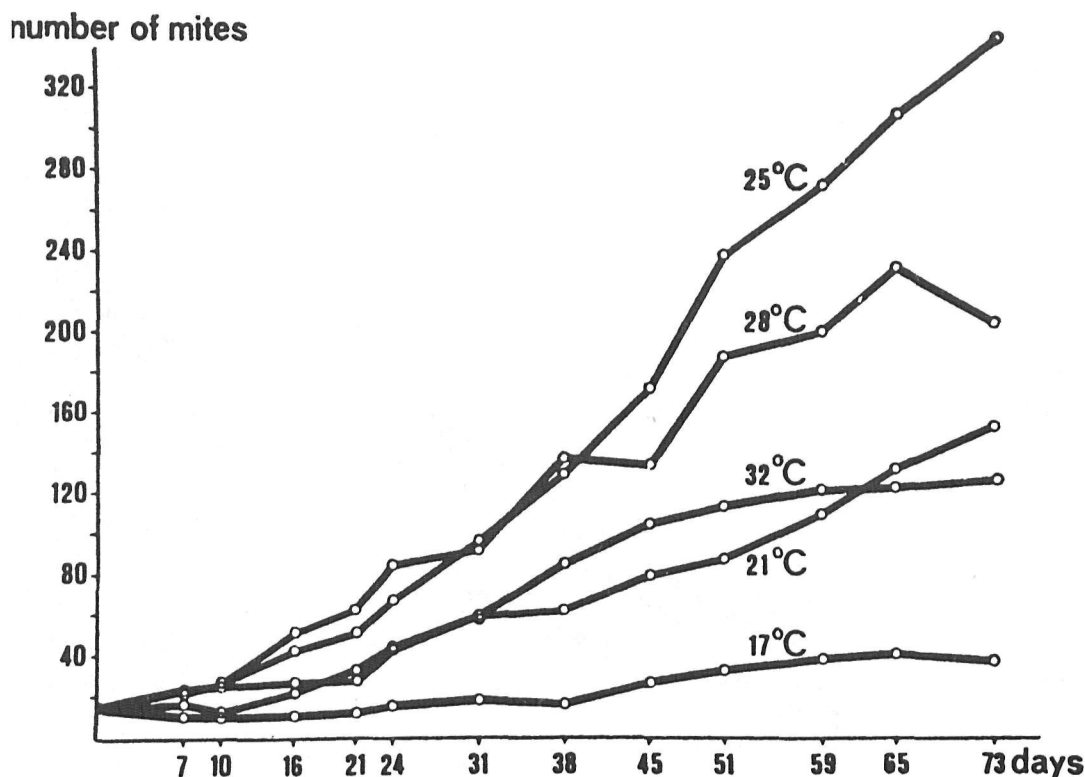


Fig. 5. Growth of laboratory populations of *D. pteronyssinus* at different temperatures.

both dry and wet conditions. The advantage of heating under wet conditions, i.e., washing (58–61), is that not only are mites killed, but also allergen is removed. For larger objects, furniture, and carpets, steam cleaning seems an effective treatment (57).

Chemical control

The discussion of the clinical effectiveness and the pros and cons of chemical control with acaricides has not yet ended (14, 40, 42, 62–71). Effective killing of mites deep inside mattresses and textile floor coverings appears to be difficult. Moreover, recolonization, some time after treatment, restricts the persistence of the effect.

References

1. Ancona G. Asma epidemica da *Pediculoides ventricosus*. Policlinica Sez Med 1923;30:45-70.
2. Storm van Leeuwen W, Bien Z, Varekamp H. Experimentele allergische Krankheiten (Asthma bronchiale, Rhinitis vasomotoria). Z Immunol Fortschr Exp Ther 1924;40:552-69.
3. Voorhorst R, Spieksma-Boezeman MIA, Spieksma FThM. Is a mite (*Dermatophagoides* sp.) the producer of the house-dust allergen? Allergie Asthma 1964;10:329-34.
4. Oshima S. Observations of floor mites in Yokohama. I. On the mites found in several schools in summer. Jpn J Sanit Zool 1964;15:233-44.
5. Spieksma FThM, Spieksma-Boezeman MIA. The mite fauna of house dust with particular reference to the house-dust mite *Dermatophagoides pteronyssinus*. Acarologia 1976;9:226-41.
6. Voorhorst R, Spieksma FThM, Varekamp H, Leupen M, Lyklema AW. The house-dust mite (*Dermatophagoides pteronyssinus*) and the allergens it produces. Identity with the house-dust allergen. J Allergy 1967;39:325-39.
7. Miyamoto T, Oshima S, Ishizaki T, Sato S. Allergenic identity between the common floor mite (*Dermatophagoides farinae*) and house dust as a causative antigen in bronchial asthma. J Allergy 1968;42:14-28.
8. Pepys J, Chan M, Hargreave FE. Mites and house-dust allergy. Lancet 1968;1:1270-2.
9. Spieksma FThM, Voorhorst R. Comparison of skin reactions to extracts of house dust, mites, and human skin scales. Acta Allergol 1969;24:124-46.
10. Miyamoto T, Oshima S, Mizuno K, Sasa M, Ishizaki T. Cross-antigenicity among six species of dust mites and house dust antigens. J Allergy 1969;44:228-38.
11. Spieksma FThM. Domestic mites: their role in respiratory allergy [Review]. Clin Exp Allergy 1991;21:655-60.
12. Spieksma FThM. Mite biology. Clin Rev Allergy 1990;8:31-49.
13. Voorhorst R, Spieksma FThM, Varekamp H. House-dust atopy and the house-dust mite *Dermatophagoides pteronyssinus*. Leiden: Stafleu, 1969.
14. Platts-Mills TAE, Thomas WR, Aalberse RC, Vervloet D, Chapman MD. Dust mite allergens and asthma: report of a second international workshop. J Allergy Clin Immunol 1992;89:1046-60.
15. Evans GO. Principles of acarology. Wallingford: CAB International, 1992.
16. Hughes AM. The mites of stored food and houses. London: HMSO, 1976.
17. Fain A, Guérin B, Hart BJ. Mites and allergic disease. Varennes: Allerbio, 1990.

18. van Bronswijk JEMH, Sinha RN. Pyroglyphid mites and house dust allergy: a review. *J Allergy* 1971;47:31-52.
19. Colloff MJ, Spieksma FThM. Pictorial keys for the identification of domestic mites. *Clin Exp Allergy* 1992;22:823-30.
20. Mumcuoglu YK. Biologie und Ökologie der Hausstaubmilben. *Allergologie* 1988;11:223-8.
21. Tovey ER, Chapman MK, Platts-Mills TAE. Mite faeces are a major source of house dust allergens. *Nature* 1981;289:592-3.
22. Stewart GA, Bird CA, Krska KD, Colloff MJ, Thompson PJ. A comparative study of allergenic and potentially allergenic enzymes from *Dermatophagoides pteronyssinus*, *D. farinae* and *Euroglyphus maynei*. *Exp Appl Acarol* 1992;16:165-80.
23. Arlian LG. Water balance and humidity requirements of house dust mites. *Exp Appl Acarol* 1992;16:15-35.
24. Colloff MJ. Age structure and dynamics of house dust mite populations. *Exp Appl Acarol* 1992;16:49-74.
25. Walz MG. Ultrastructure of the reproductive system of the house dust mites *Dermatophagoides farinae* and *D. pteronyssinus* with remarks on spermatogenesis and oogenesis. *Exp Appl Acarol* 1992;16:85-116.
26. van Bronswijk JEMH. Hausstaub-Ökosystem und Hausstaub-allergen(e). *Acta Allergol* 1972;27:219-28.
27. van Bronswijk JEMH, Koekkoek HHM. Effects of low temperatures on the survival of house-dust mites of the family Pyroglyphidae. *Neth J Zool* 1972;22:207-12.
28. Barker PS. Bionomics of *Lepidoglyphus destructor*, a pest of stored cereals. *Can J Zool* 1983;61:355-8.
29. Colloff MJ. Effects of temperature and relative humidity on development times and mortality of eggs from laboratory and wild populations of the European house-dust mite *Dermatophagoides pteronyssinus*. *Exp Appl Acarol* 1987;3:279-89.
30. de Boer R, Kuller K. Winter survival of house dust mites (*Dermatophagoides* spp.) on the ground floor of Dutch houses. *Proc Exp Appl Entomol* 1995;6:47-51.
31. Korsgaard J. House dust mites and absolute indoor humidity. *Allergy* 1983;38:85-92.
32. Charpin D, Vervloet D. Dampness, mites and respiratory allergy. *Aerobiologia* 1990;6:82-6.
33. Harving H, Korsgaard J, Dahl R. House-dust mites and associated environmental conditions in Danish homes. *Allergy* 1993;48:106-9.
34. Wickman M, Nordvall L, Pershagen G, Korsgaard J, Johansen N. Sensitization to domestic mites in a cold temperature region. *Am Rev Respir Dis* 1993;148:58-62.
35. Spieksma FThM, Zuidema P, Leupen MJ. High altitude and house-dust mites. *BMJ* 1971;1:82-4.
36. Vervloet D, Penaud A, Razzouk H, et al. Altitude and house dust mites. *J Allergy Clin Immunol* 1982;69:290-6.
37. von Auer H, Demetz H, Frank A, Janetschek H. Untersuchung über das Vorkommen der Hausstaubmilbe in Tal- und Hochlagen Tirols als Voraussetzung einer Allergenkarrenz Empfehlung. *Allergologie* 1985;8:123-7.
38. Murray AB, Zuk P. The seasonal variation in a population of house dust mites in a North American city. *J Allergy Clin Immunol* 1979;64:266-9.
39. Lintner TJ, Brame KA. The effects of season, climate and air conditioning on the prevalence of *Dermatophagoides* mite allergens in household dust. *J Allergy Clin Immunol* 1993;93:862-7.
40. Colloff MJ, Ayres J, Carswell F, et al. The control of allergens of dust mites and domestic pets: a position paper. *Clin Exp Allergy* 1992;22 Suppl 2:1-28.
41. Ehnert B, Lau-Schadendorf S, Weber A, Buettner P, Schou C, Wahn U. Reducing domestic exposure to dust mite allergen reduces bronchial hyperreactivity in sensitive children with asthma. *J Allergy Clin Immunol* 1992;90:135-8.
42. Weeks J, Oliver J, Birmingham K, Crewes A, Carswell F. A combined approach to reduce mite allergen in the bedroom. *Clin Exp Allergy* 1995;25:1179-83.
43. Wickman M, Emenius G, Egmar AC, Axelsson G, Pershagen G. Reduced mite allergen levels in dwellings with mechanical exhaust and supply ventilation. *Clin Exp Allergy* 1994;24:109-14.
44. Harving H, Korsgaard J, Dahl R. House-dust mite exposure reduction in specially designed, mechanically ventilated "healthy" homes. *Allergy* 1994;49:713-18.
45. Custovic A, Taggart SCO, Kennaugh JH, Woolcock A. Portable dehumidifiers in the control of house dust mites and mite allergens. *Clin Exp Allergy* 1995;25:312-16.
46. Sundell J, Wickman M, Pershagen G, Nordvall SL. Ventilation in homes infested with house-dust mites. *Allergy* 1995;50:106-12.
47. Munir AKM, Björkstén B, Einarsson R, et al. Mite allergens in relation to home conditions and sensitization of asthmatic children from three climatic regions. *Allergy* 1995;50:55-64.
48. Fletcher AM, Pickering CAC, Custovic A, Simpson J, Kennaugh J, Woolcock A. Reduction in humidity as a method of controlling mites and mite allergens: the use of mechanical ventilation in British domestic dwellings. *Clin Exp Allergy* 1996;26:1051-6.
49. de Boer R, Kuller K. Mattresses as a winter refuge for house-dust mite populations. *Allergy* 1997;52:299-305.
50. Colloff MJ. Dust mite control and mechanical ventilation: when the climate is right. *Clin Exp Allergy* 1994;24:94-6.
51. Dornelas de Andrade A, Birnbaum J, Lanteaume A, et al. Housing and house-dust mites. *Allergy* 1995;50:142-6.
52. Plácido JL, Cuesta C, Delgado L, et al. Indoor mite allergens in patients with respiratory allergy living in Porto, Portugal. *Allergy* 1996;51:633-9.
53. Colloff MJ. Use of liquid nitrogen in the control of house dust mite populations. *Clin Allergy* 1986;16:411-17.
54. Tsunoda T, Mori H, Shimada K. Studies on supercooling and cold-hardiness in house dust mite *Dermatophagoides pteronyssinus*. *Jpn J Appl Entomol* 1992;36:1-4.
55. Mosbech H, Korsgaard J, Lind P. Control of house dust mites by electrical heating blankets. *J Allergy Clin Immunol* 1988;81:706-10.
56. Shibasaki M, Takita H. Effect of electric heating carpet on house dust mites. *Ann Allergy* 1995;72:541-5.
57. Colloff MJ, Taylor C, Merrett TG. The use of domestic steam cleaning for the control of house dust mites. *Clin Exp Allergy* 1995;25:1061-6.
58. McDonald LG, Tovey E. The role of water temperature and laundry procedures in reducing house dust mite populations and allergen content of bedding. *J Allergy Clin Immunol* 1992;90:599-608.
59. de Boer R, van der Hoeven WAD, Kuller K. The control of house dust mites in rugs through wet cleaning. *J Allergy Clin Immunol* 1996;97:1214-17.
60. Nagakura T, Yasueda H, Obata T, et al. Major *Dermatophagoides* mite allergen, Der 1, in soft toys. *Clin Exp Allergy* 1996;26:585-9.
61. Bischoff ERC, Fischer A, Liebenberg B, Kniest FM. Mite control with low temperature washing. I. Elimination of living mites on carpet pieces. *Clin Exp Allergy* 1996;26:945-52.
62. Reiser J, Ingram D, Mitchell EB, Warner JO. House dust mite allergen levels and an anti-mite mattress spray (na-

- tamycin) in the treatment of childhood asthma. *Clin Exp Allergy* 1990;20:561-7.
63. Kniest FM, Young E, van Praag MCG, et al. Clinical evaluation of a double-blind dust-mite avoidance trial with mite-allergic rhinitic patients. *Clin Exp Allergy* 1991;21:39-47.
 64. Brown H, Morrow, Merrett TG. Effectiveness of an acaricide in the management of house dust mite allergy. *Ann Allergy* 1991;67:25-31.
 65. Lau-Schadendorf S, Rusche AF, Weber AK, Buettner P, Wahn U. Short-term effect of solidified benzyl benzoate on mite-allergen concentrations in house dust. *J Allergy Clin Immunol* 1991;87:41-7.
 66. Hayden ML, Rose G, Diduch KB, et al. Benzyl benzoate moist powder: investigation of acaricidal activity in cultures and reduction of dust mite allergens in carpets. *J Allergy Clin Immunol* 1992;89:536-45.
 67. Marks GB, Tovey ER, Green W, Shearer M, Salome CM, Woolcock AJ. House dust mite allergen avoidance: a randomized controlled trial of surface chemical treatment and encasement of bedding. *Clin Exp Allergy* 1994;24:1078-83.
 68. Olsen OT, Jacobsen L, Svendsen UG. Effectiveness of benzyl benzoate in elimination of house dust mites. *Aerobiologia* 1996;12:3-8.
 69. Carswell F, Birmingham K, Oliver J, Crewes A, Weeks J. The respiratory effects of reduction of mite allergen in the bedrooms of asthmatic children – a double blind controlled trial. *Clin Exp Allergy* 1996;26:386-96.
 70. Chang JH, Becker A, Ferguson A, et al. Effect of application of benzyl benzoate on house dust mite allergen levels. *Ann Allergy Asthma Immunol* 1996;77:187-90.
 71. Kalpaklıoğlu AF, Ferizli AG, Mısırlıgil Z, Demirel YS, Gürbüz L. The effectiveness of benzyl benzoate and different chemicals as acaricides. *Allergy* 1996;51:164-70.

This document is a scanned copy of a printed document. No warranty is given about the accuracy of the copy. Users should refer to the original published version of the material.