

ACARI 637

Storage mites

Marianne van Hage-Hamsten and S.G.O. Johansson

Department of Clinical Immunology, Karolinska Institute, Karolinska Hospital, Stockholm, Sweden

ABSTRACT

van Hage-Hamsten, M. and Johansson, S.G.O., 1992. Storage mites. *Exp. Appl. Acarol.*, 16: 117–128.

The interest in allergy to storage mites has increased over the past few years. Storage mites feed on a variety of substances and they can be found in many different products such as grain, flour, hay and straw, but also in house dust samples. The more common genera are *Lepidoglyphus*, *Tyrophagus*, *Glycyphagus*, *Acarus* and *Blomia*. Several species of storage mites have been shown to cause IgE-mediated sensitization among rural workers, who to a varying extent develop asthma, rhinitis or conjunctivitis when exposed to barn dust. However, a number of studies have reported on sensitization to storage mites also among urban people, indicating that sensitization is not restricted to individuals with occupational exposure. Regarding the allergenic relationship between storage mites and house dust mites, there appears to be a limited allergenic cross-reactivity between the two species. However, both species also possess their own unique allergens. Further research on identification and characterization of storage mite allergens and their cross-reactivity is required to understand the complexity of epitopes and allergens.

INTRODUCTION

Although mites belonging to the genus *Dermatophagoides* dominate the acarofauna, non-pyroglyphid mites are certainly of clinical importance, above all in occupational medicine. Since several reports from Scandinavia (Terho et al., 1985; van Hage-Hamsten et al., 1985; Iversen et al., 1990) and the UK (Cuthbert et al., 1979, 1984; Blainey et al., 1988) have established that storage mites cause symptoms in the upper and lower airways, they are now considered as an important occupational hazard in rural populations. The significance of these species for causing allergic respiratory symptoms is becoming more and more apparent. The symptoms frequently occur while working in barns, or immediately thereafter. However, storage mites can also cause prob-

Correspondence to: M. van Hage-Hamsten, Department of Clinical Immunology, Karolinska Hospital, S-104 01 Stockholm, Sweden.

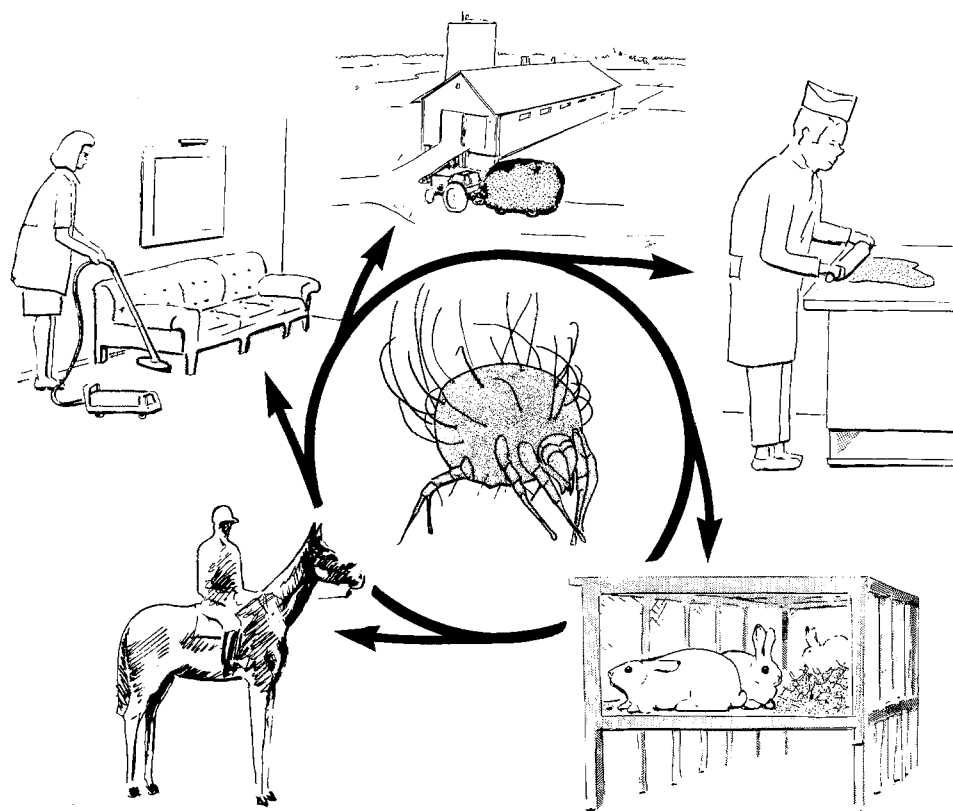


Fig. 1. Locality of storage mites.

lems for other occupational categories such as bakers (Musk et al., 1989; Revsbech and Dueholm, 1990) and grain-store workers (Revsbech and Andersen, 1987; Blainey et al., 1989). They can also infest stables, and horseriders are likely to become sensitized (Fig. 1). Several investigations of urban populations have likewise shown sensitization due to non-pyroglyphid mites (Wraith et al., 1979; Korsgaard et al., 1985). Dust mites in general include storage mites, which explains why they also constitute a part of the mite fauna in house dust in many countries, particularly in damp houses (Spieksma and Spieksma-Boezeman, 1967).

MITE BIOLOGY

The Acari, or mites and ticks, belong to the arthropodan class Arachnida, a group which also includes scorpions and spiders. Adult mites are about 300 μm in size and have four pairs of legs (Krantz, 1970). Male and female mites often differ widely from each other. The life cycle of all mites consists of dif-

ferent stages: egg, larva, nymphal stages and adult. Some species have a stage, termed the hypopial stage, that conveys resistance during periods of adverse environmental influences. The optimum conditions for storage mites are similar to those of the pyroglyphid mites (about 25–30°C and 80% relative humidity). However, the storage mite *Acarus siro* shows a considerably greater tolerance to low temperature. The lower threshold is about 5°C with a humidity of 67.5% (Cunnington, 1976). The most common storage mites belong to the families Acaridae and Glycyphagidae.

EXPOSURE TO STORAGE MITES

Since mites feed on a variety of substances, they can be found in many different products, such as grain, flour, straw, hay, brewer's yeast, cheese, flour, dried fish and fruits. Mite infestations can cause heavy financial losses. In Western Canada where the climate is temperate and large quantities of cereal grain are grown, Sinha (1963, 1964) reported infestation by mites. The most common storage mites found in barns in Scotland were *Glycyphagus*, *Tyrophagus* and *Acarus* (Jeffrey, 1976; Cuthbert et al., 1979). In England and Wales, *Tydeus* spp. (Griffiths et al., 1976) were also found, whereas, in addition, *Tarsonemus* spp. were frequently observed in Finland (Terho et al., 1982). The presence of significant amounts of *Tarsonemus* spp. in stored hay in Iceland is unique to this island according to Hallas (1981). The predatory mite *Cheyletus eruditus* was found to be the second most prevalent mite on farms in England and Wales (Griffiths et al., 1976). Further, Campbell and co-workers (1989) have sampled air from dairy barns in North America and demonstrated an abundance of *Lepidoglyphus destructor* aeroallergens. In a recent study, Iversen et al. (1990) found that *L. destructor* dominated in grain and straw in Denmark and *A. siro* in hay. Thus, storage mites cause inconvenience to many farmers throughout the world.

We have analyzed the mite fauna of 16 farms located on Gotland, an island in the Baltic Sea, to establish whether there is a clear relationship between environmental exposure to storage mites and development of allergic symptoms. Eight of these farms belonged to farmers with respiratory symptoms related to barn dust and eight to healthy farmers. All the farmers had previously participated in an epidemiological survey of hypersensitivity to respiratory allergens. Mites were found on all farms and the degree of infestation varied enormously, mite counts ranging from 75–150 000 mites/g dust. *Lepidoglyphus destructor* was the dominant species on 13 of 16 farms. *Tydeus* spp. was the second most common group, but *Glycyphagus* and *Acarus* were also found, as well as the predatory mite *Cheyletus*. Samples from farms worked by farmers with storage mite allergy contained a significantly higher

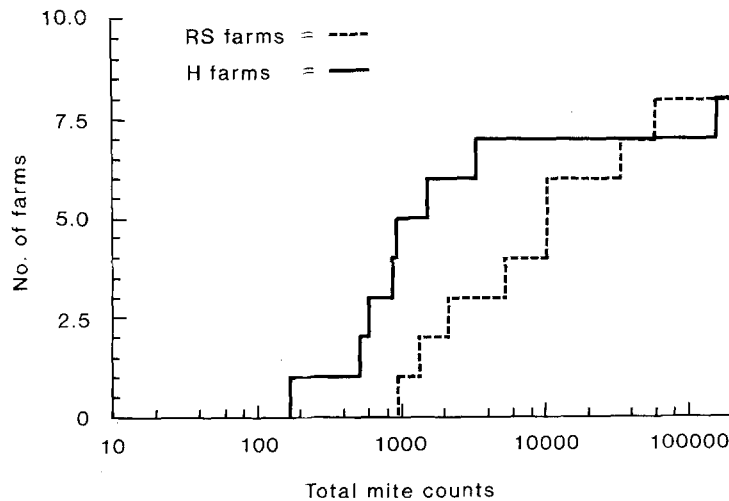


Fig. 2. Cumulative frequency of mite counts in samples taken from central part of hay stores on RS farms (farms worked by farmers with respiratory symptoms due to storage mite allergy) and H farms (farms worked by healthy farmers) (van Hage-Hamsten et al., 1991).

number of mites than samples from farms worked by healthy farmers ($P < 0.05$) (Fig. 2) (van Hage-Hamsten et al., 1991).

STORAGE MITES AS AN OCCUPATIONAL ALLERGEN

Among the first allergic disorders attributed to mites was an outbreak of "epidemic asthma" in grain workers. The cause was the predatory mite *Ptyemotes ventricosus*, which feeds on the larvae of insects that live on infested grain and straw (Ancona, 1923). Immediate hypersensitivity to grain dust was shown to be common by Warren and colleagues in 1974. The authors concluded that grain dust may among other things contain a large number of mites, such as *L. destructor*, and that this mite species might be an important antigenic component of grain dust. A later report on grain elevator workers from Denmark stated that storage mite allergens appear to be the most important among those tested (Revsbech and Andersen, 1987). Blainey and colleagues (1989) also recently concluded that allergic responses to storage mites may be a factor responsible for work-related symptoms in grain-store workers. Further, sensitization to storage mites has also been demonstrated among bakers (Musk et al., 1989; Revsbech and Dueholm, 1990).

Several species of storage mite have also been shown to cause IgE-mediated sensitization among rural workers, who to a varying extent develop asthma, rhinitis or conjunctivitis when exposed to barn dust. In the first study, Storm van Leeuwen et al. reported in 1924 that attacks of asthma in a farmer were due to *A. siro* and *L. destructor*. Davies and colleagues (1976) concluded that

L. destructor was likely to be involved in the case of recurrent nocturnal asthma in one farmer after exposure to grain dust. IgE-mediated respiratory allergy to storage mites has since proved to be common on the Orkney Islands (Cuthbert et al., 1979), in the UK and in Finland (Ingram et al., 1979; Cuthbert et al., 1984; Terho et al., 1985). In 1979 Cuthbert and colleagues showed that among 38 farmers investigated, all gave positive skin prick test (SPT) to one or more of five mite species (*D. pteronyssinus* and four storage mites) tested. Five years later these authors reported that 35% of the persons who associated their allergic symptoms with barns and cowsheds were positive in radioallergosorbent test (RAST) to storage mites. *Lepidoglyphus destructor* was the mite species that gave the highest RAST values and the majority of positive skin tests among storage mites (Cuthbert et al., 1984). Nasal challenges with storage mites on 63 dairy farmers in Finland also showed that *L. destructor* was the most important species, causing allergic rhinitis (Terho et al., 1985). Bronchial provocation tests have provided further evidence of sensitization to storage mites (Ingram et al., 1979). Iversen et al. (1990), who studied Danish farmers, have demonstrated that the most prevalent positive RAST was against storage mites, found in 17% of farmers who suffered from asthma, and estimated to occur in 5% of the random sample of farmers. They also suggested that in humid and temperate regions of Europe, allergy to storage mites among farmers is not caused exclusively by occupational exposure. Damp housing conditions and indoor exposure to storage mites may also be important.

In Sweden, IgE-mediated allergy to storage mites is a far greater problem in rural populations than farmer's lung (van Hage-Hamsten et al., 1985). Early detection is mandatory since symptoms become aggravated with time. On the basis of an epidemiological survey of 2578 farmers on Gotland, we reported earlier that storage mites seem to be the most important allergen among farmers. From a clinical point of view the storage mite *L. destructor* was the main mite sensitizer with a prevalence of allergy (a typical case history, e.g. symptoms when handling stored hay or grain, and a positive RAST) of 6.8%. In

TABLE 1

Prevalence of positive RAST against various allergens among farmers on Gotland, Sweden

Allergen	RAST (%)
<i>L. destructor</i>	6.8
<i>D. pteronyssinus</i>	5.2
<i>B. kulagini</i>	4.5
Birch	1.7
Timothy	3.9
Dog	0.9

contrast, sensitization to pollens, animal danders and moulds was rare, although farmers are daily exposed to such common potent allergens (Table 1) (van Hage-Hamsten et al., 1987b). Using bronchial provocation tests, we have also studied the direct relationship between asthma, positive RAST to *L. destructor* and exposure to storage mites. All farmers with asthma and a positive RAST to *L. destructor* showed a positive response ($>20\%$ fall in forced expiratory volume in one second (FEV₁)) after bronchial inhalation of *L. destructor* extract (van Hage-Hamsten et al., 1988).

IgE-MEDIATED ALLERGY TO STORAGE MITES

Since storage mites can be found in house dust (Spieksma and Spieksma-Boezeman, 1967; Maunsell et al., 1968; Korsgaard et al., 1985) they may be of particular importance for people living in damp houses where growth of moulds may encourage the development of *Glycyphagus* species in particular (Wraith et al., 1979). Allergic sensitization to storage mites has been reported from England (Maunsell et al., 1968; Wraith et al., 1979), the Netherlands (Spieksma and Voorhorst, 1969), Southeast Asia (Woodcock and Cunnington, 1980), Hong Kong (Gabriel et al., 1982), and Australia (Green and Woolcock, 1978). In 1983, Warren et al. reported that 12% of unselected asthmatics attending the adult chest clinic of the St. Boniface General Hospital, London, were positive in skin prick tests (SPTs) to *L. destructor*. Subsequently, Korsgaard et al. (1985) found that 60 out of 133 (45%) consecutive patients with known or suspected respiratory allergy at the Chest Clinic of Aarhus Municipal Hospital, Denmark, were positive in SPT to one or more storage mites.

The storage mite *Blomia* is a common mite in house dust in tropical and subtropical regions (van Bronswijk and de Cock, 1973; van Bronswijk et al., 1973). Miyamoto et al., 1969, using skin tests, reported sensitization to this mite species. Recently, Hurtado and Parini (1987) from Venezuela showed that *B. tropicalis* was present in 96% of bedding dust samples in Caracas. This particular mite has also been isolated from dust samples collected in Florida, USA and a high frequency of specific IgE antibodies to *Blomia* has been found in persons from Tampa Bay (Fernandez-Caldas et al., 1991). A similar investigation of homes in the surroundings of Sao Paulo, Brazil, revealed that *Blomia* species are present in house dust samples with a prevalence similar to that found in Florida (Croce, pers. commun.). In our epidemiological study of IgE-mediated allergy among Swedish farmers, we found a prevalence of 4.5% of positive RAST against *B. kulagini* (van Hage-Hamsten et al., 1990).

IMMUNOLOGICAL STUDIES

The role of a possible allergenic relationship between non-pyroglyphid and pyroglyphid mites has not been completely studied, although there have been

many reports of a lack of correlation between skin prick test and RAST (Wraith et al., 1979; Agha and Gnanasakthy, 1981; Korsgaard et al., 1985) and a lack of cross-reactivity in RAST inhibition studies, indicating that *D. pteronyssinus* and storage mites each possess unique allergens (van Hage-Hamsten et al., 1987a). Ford and Platts-Mills (1987) recently concluded that patients exhibiting positive skin tests to both pyroglyphid and non-pyroglyphid mites generally appear to do so on account of multiple sensitization to different species rather than because of cross-reacting antibodies. However, a close correlation between pyroglyphid and non-pyroglyphid mites, pointing to cross-reacting allergens using skin prick test and RAST (Blainey et al., 1988, 1989; Luczynska et al., 1990), has also been reported.

We have previously studied the allergenic properties of *B. kulagini* and *L. destructor* among subjects from Brazil and Sweden (van Hage-Hamsten et al., 1990). The results from the RAST inhibition suggest that *L. destructor* and *B. kulagini* share some allergenic components, but they also seem to lack some allergenic determinants in relation to each other (Fig. 3). However, this apparent deficiency of allergen(s) is dependent on where the subject has been sensitized, since *B. kulagini* dominates in Brazil and *L. destructor* in Sweden. These results demonstrate the complexity of the human immunological response to different mite species. Thus, conclusions drawn regarding allergenic cross-reactivity are dependent on the population tested and on which mite species is the main sensitizer in that region.

Regarding allergenic characterization, only *Tyrophagus* and *Lepidoglyphus* have been studied so far. Arlian and co-workers (1984) have, with the use of crossed immunoelectrophoresis and crossed radioimmuno-electrophoresis,

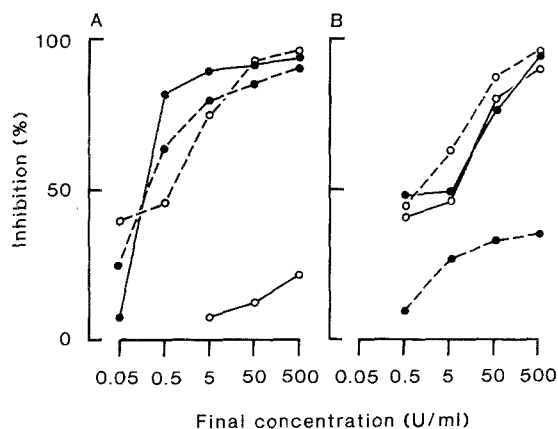


Fig. 3. Inhibiting effect of *L. destructor* extract on a positive RAST to discs coated with *L. destructor* (●—●) and *B. kulagini* (●—●) and inhibiting effect of *B. kulagini* extract on a positive RAST to discs coated with *L. destructor* (○—○) and *B. kulagini* (○—○) on sera from (A) Sweden and (B) Brazil (van Hage-Hamsten et al., 1990).

demonstrated that *T. putrescentiae* mite bodies and feces contain as many as twenty antigens and five allergens. We have identified eleven allergenic components in *L. destructor* by sodium dodecylsulphate polyacrylamide gel electrophoresis (SDS-PAGE) and immunoblotting under reducing conditions (Johansson et al., 1988). The principal allergen of this species has a molecular mass of 14–15 kDa, as assessed by gel electrophoresis under non-reducing conditions (Johansson et al., 1991; Ventas et al., 1992). Affinity chromatography of this principal allergen of *L. destructor* has been described (Ventas et al., 1992) as well as the N-terminal amino acid sequence (van Hage-Hamsten et al., 1992). The N-terminal segment of the 15-kDa allergen, showed in contrast to the group I, III or IV allergens from the house dust mites *Dermaphagoides* spp. no homology with either cysteine and serine proteases or mite amylase or other proteins in the Swissprot sequence database (release 21) with FASTA program (Pearson and Lipman 1988). In addition, we have recently used immunoblot multiallergen inhibition to study allergenic cross-reactivity between the two dust mites *L. destructor* and *D. pteronyssinus* (Johansson et al., 1991). Human IgE antibodies to the 25-kDa component in *D. pteronyssinus*, most likely *Der p* I, showed considerable cross-reactivity with *L. destructor* extract. The major allergen component at 15 kDa in *L. destructor* must possess distinct allergenic determinant(s), since inhibition of IgE binding with *D. pteronyssinus* extract was very difficult. About 2000 times more of *D. pteronyssinus* extract than of *L. destructor* extract was needed for 50% inhibition. *Lepidoglyphus destructor* was accordingly shown to be a stronger inhibitor of *D. pteronyssinus* than vice versa, probably because the sera were obtained from persons who were more sensitized to the former than to the latter species. However, clinically, these mite species seem not to cross-react since farmers with specific IgE antibodies to *L. destructor* do not develop a significant fall in FEV₁ (<20%) when challenged with *D. pteronyssinus*. Likewise challenges with *D. pteronyssinus* were negative in asthmatic farmers who were RAST positive to *L. destructor* and negative to *D. pteronyssinus* (van Hage-Hamsten et al., 1988).

The SDS-PAGE and immunoblotting method has the advantage, in comparison with the RAST inhibition technique, that multiple allergens can be studied individually. One disadvantage is that the allergens must be denatured in order to penetrate the gel, and this might affect the allergen-binding sites of interest. During the last few years the development of allergen-specific monoclonal antibodies has progressed dramatically. Two monoclonal antibodies to 39-kDa and 14-kDa allergen components in *L. destructor*, one of which is raised in our laboratory, have been described (Ansotegui et al., 1991; Ventas et al., 1991). Our monoclonal antibody specifically recognizes an antigen of *L. destructor* of 39 000 daltons in SDS-PAGE (Ansotegui et al., 1991). By a modified RAST with the monoclonal antibody, sera from patients with known allergy to *L. destructor* were tested. The results showed the presence of

specific IgE against the 39 000-dalton protein (Ansotegui et al., 1991). Furthermore, 20 out of 43 sera from farmers RAST positive to *L. destructor* detect this allergen component (van Hage-Hamsten et al., 1993). Monoclonal antibodies enable us to study relationships between different dust mites and to develop immunoassays for measuring allergen concentrations in barn and house dust samples. These measurements are useful tools not only in the medical assessment of patients but also in the standardization of *L. destructor* extracts. However, further research on identification and characterization of dust mite allergens and their cross-reactivity is required in order to understand the complexity of these allergens and their epitopes.

CONCLUSIONS

Dust mites, which comprise both house dust and storage mites, are a widespread risk factor in inhalant allergy. Unfortunately, many physicians only consider mites of the genus *Dermatophagoides* as a possible source of mite allergens. In order to ensure good results from hyposensitization treatment, however, they should consider which other mite species might be involved in IgE-mediated sensitization in their particular region.

ACKNOWLEDGMENTS

This work was supported by the Swedish Work Environment Fund (Project No. 83-1182, 82-0881), the Swedish Medical Research Council (Grant No. 16x-105), the Konsul Nilsson Foundation, the Swedish Medical Society, the Swedish Association against Asthma and Allergy, the Ellen, Walter and Lennart Hesselman Foundation, the Petrus and Augusta Hedlund Foundation, King Gustaf V 80th Birthday Fund and the Karolinska Institute.

REFERENCES

- Agha, M. and Gnanasakthy, A., 1981. A cluster analysis of the effects of storage mites as allergens in relation to certain occupations and living conditions. *Clin. Allergy*, 11: 499-504.
- Ancona, G., 1923. Asma epidemico da "Pediculoides ventricosus". *Il Policlinico*, 30: 45-70.
- Ansotegui, I.J., Härfast, B., Jeddi-Tehrani, M., Johansson, E., Johansson, S.G.O., van Hage-Hamsten, M. and Wigzell, H., 1991. Identification of a new major allergen of 39 kilodaltons of the storage mite *Lepidoglyphus destructor*. *Immunol. Letters*, 27: 127-130.
- Arlan, L.G., Geis, D.P., Vyszynski-Moher, D.L., Bernstein, I.L. and Gallagher, J.S., 1984. Antigenic and allergenic properties of the storage mite *Tyrophagus putrescentiae*. *J. Allergy Clin. Immunol.*, 74: 166-171.
- Blainey, A.D., Topping, M.D., Ollier, S. and Davies, R.J., 1988. Respiratory symptoms in arable farm workers: the role of storage mites. *Thorax*, 43: 697-702.
- Blainey, A.D., Topping, M.D., Ollier, S. and Davies, R.J., 1989. Allergic respiratory disease in grain workers: The role of storage mites. *J. Allergy Clin. Immunol.*, 84: 296-303.
- Campbell, A.R., Swanson, M.C., Fernandez-Caldas, E., Reed, C., May, J.J. and Pratt, D.S., 1989. Aeroallergens in dairy barns near Cooperstown, New York and Rochester, Minnesota. *Am. Rev. Respir. Dis.*, 140: 317-320.

- Cunnington, A.M., 1976. The effect of physical conditions on the development and increase of some important storage mites. *Ann. Appl. Biol.*, 82: 175–178.
- Cuthbert, O.D., Brostoff, J., Wraith, D.G. and Brighton, W.D., 1979. "Barn allergy": asthma and rhinitis due to storage mites. *Clin. Allergy*, 9: 229–236.
- Cuthbert, O.D., Jeffrey, I.G., McNeill, H.B., Wood, J. and Topping, M.D., 1984. Barn allergy among Scottish farmers. *Clin. Allergy*, 14: 197–206.
- Davies, R.J., Green, M. and Schofield, N.McC., 1976. Recurrent nocturnal asthma after exposure to grain dust. *Am. Rev. Respir. Dis.*, 114: 1011–1019.
- Ford, A.W. and Platts-Mills, T.A.E., 1987. Standardized extracts, dust mite, and other arthropods (inhalants). *Clin. Rev. Allergy*, 5: 49–73.
- Fernández-Caldas, E., Trudeau, W.L., García-Ramos, E., van Hage-Hamsten, M., Johansson, S.G.O. and Lockey, R.F., 1991. Sensitization to house dust and storage mites in urban dwellers (Abstract). *J. Allergy Clin. Immunol.*, 87: 322.
- Gabriel, M., Cunnington, A.M., Allan, W.G.L., Pickering, C.A.C. and Wraith, D.G., 1982. Mite allergy in Hong Kong. *Clin. Allergy*, 12: 157–171.
- Green, W.F. and Woolcock, A.J., 1978. *Tyrophagus putrescentiae*: an allergenically important mite. *Clin. Allergy*, 8: 135–44.
- Griffiths, D.A., Wilkin, D.R., Southgate, B.J. and Lynch, S.M., 1976. A survey of mites in bulk grain stored on farms in England and Wales. *Ann. Appl. Biol.*, 82: 180–184.
- Hallas, T.E., 1981. Mites of stored hay in Iceland. *J. Agric. Res. Icel.*, 13: 61–67.
- Hurtado, I. and Parini, M., 1987. House dust mites in Caracas, Venezuela. *Ann. Allergy*, 59: 128–130.
- Ingram, C.G., Jeffrey, I.G., Symington, I.S. and Cuthbert, O.D., 1979. Bronchial provocation studies in farmers allergic to storage mites. *Lancet*, ii: 1330–1332.
- Iversen, M., Korsgaard, J., Hallas, T. and Dahl, R., 1990. Mite allergy and exposure to storage mites and house dust mites in farmers. *Clin. Exp. Allergy*, 20: 211–219.
- Jeffrey, I.G., 1976. A survey of the mite fauna of Scottish farms. *J. Stored Prod. Res.*, 12: 149–156.
- Johansson, E., van Hage-Hamsten, M. and Johansson, S.G.O., 1988. Demonstration of allergen components in the storage mite *Lepidoglyphus destructor* by an immunoblotting technique. *Int. Arch. Appl. Immunol.*, 85: 8–13.
- Johansson, E., Borgå Å., Johansson, S.G.O. and van Hage-Hamsten, M., 1991. Immunoblot multiallergen inhibition studies of allergenic cross-reactivity of the dust mites *Lepidoglyphus destructor* and *Dermatophagoides pteronyssinus*. *Clin. Exp. Allergy*, 21: 511–518.
- Korsgaard, J., Dahl, R., Iversen, M. and Hallas, T., 1985. Storage mites as a cause of bronchial asthma in Denmark. *Allergol. Immunopathol.*, 13: 143–149.
- Krantz, G.W., 1970. *A Manual of Acarology*. OSU Book Stores, Corvallis, OR.
- Luczynska, C.M., Griffin, P., Davies, R.J. and Topping, M.D., 1990. Prevalence of specific IgE to storage mites (*A. siro*, *L. destructor* and *T. longior*) in an urban population and cross-reactivity with the house dust mite (*D. pteronyssinus*). *Clin. Exp. Allergy*, 20: 403–406.
- Maunsell, K., Wraith, D.G. and Cunnington, A.M., 1968. Mites and house-dust allergy in bronchial asthma. *Lancet*, i: 1267–1270.
- Miyamoto, T., Oshima, S., Mizuno, K., Sasa, M. and Ishizaki, T., 1969. Cross-antigenicity among six species of dust mites and house dust antigens. *J. Allergy*, 44: 228–238.
- Musk, A.W., Venables, K.M., Crook, B., Nunn, A.J., Hawkins, R., Crook, G.D.W., Graneek, B.J., Tee, R.D., Farrer, N., Johnson, D.A., Gordon, D.J., Darbyshire, J.H. and Newman Taylor, A.J., 1989. Respiratory symptoms, lung function, and sensitization to flour in a British bakery. *Br. J. Ind. Med.*, 46: 636–642.
- Pearson, W.R. and Lipman, D.J., 1988. Improved tools for biological sequence comparison. *Proc. Natl. Acad. Sci. U.S.A.*, 85: 2444–2448.

- Revsbech, P. and Andersen, G., 1987. Storage mite allergy among grain elevator workers. *Allergy*, 42: 423–429.
- Revsbech, P. and Dueholm, M., 1990. Storage mite allergy among bakers. *Allergy*, 45: 204–208.
- Sinha, R.N., 1963. Stored product acarology in Canada. In: J.A. Naegele (Editor), *Advances in Acarology*, Vol. 1. Cornell Univ. Press, Ithaca, NY, pp. 70–88.
- Sinha, R.N., 1964. Mites of stored grain in western Canada – ecology and methods of survey. *Proc. Entomol. Soc. Manitoba*, 20: 19–33.
- Spieksma, F.Th.M. and Spieksma-Boezeman, M.I.A., 1967. The mite fauna of house dust with particular reference to the house-dust mite *Dermatophagoides pteronyssinus*. *Acarologia*, 9: 226–241.
- Spieksma, F.Th.M. and Voorhorst, R., 1969. Comparison of skin reactions to extracts of house dust, mites, and human skin scales. *Acta Allergol.*, 24: 124–146.
- Storm van Leeuwen, W.S., Bien, Z. and Varenkamp, H., 1924. Experimentelle allergische Krankheiten (asthma bronchiale, rhinitis vasomotoria). *Z. Immunf. Exp. Ther.*, 40: 552–569.
- Terho, E.O., Leskinen, L., Husman, K. and Kärenlampi, L., 1982. Occurrence of storage mites in Finnish farming environments. *Allergy*, 37: 15–19.
- Terho, E.O., Husman, K., Vohlonen, I., Rautalahti, M. and Tukiainen, H., 1985. Allergy to storage mites or cow dander as a cause of rhinitis among Finnish dairy farmers. *Allergy*, 40: 23–26.
- van Bronswijk, J.E.M.H. and de Cock, A.W.A.M., 1973. The genus *Blomia* Oudemans (Acari: Glycyphagidae). II. Comparison of its species. *Acarologia*, 15: 490–505.
- van Bronswijk, J.E.M.H., de Cock, A.W.A.M. and Oshima, S., 1973. The genus *Blomia* Oudemans (Acari: Glycyphagidae). I. Description of *Blomia tropicalis* sp.n. from house dust in tropical and sub-tropical regions. *Acarologia*, 15: 477–489.
- van Hage-Hamsten, M., Johansson, S.G.O., Höglund, S., Tüll, P., Wirén, A. and Zetterström, O., 1985. Storage mite allergy is common in a farming population. *Clin. Allergy*, 15: 555–564.
- van Hage-Hamsten, M., Johansson, S.G.O., Johansson, E. and Wirén, A., 1987a. Lack of allergenic cross-reactivity between storage mites and *Dermatophagoides pteronyssinus*. *Clin. Allergy*, 17: 23–31.
- van Hage-Hamsten, M., Johansson, S.G.O. and Zetterström, O., 1987b. Predominance of mite allergy over allergy to pollens and animal danders in a farming population. *Clin. Allergy*, 17: 417–423.
- van Hage-Hamsten, M., Ihre, E., Zetterström, O. and Johansson, S.G.O., 1988. Bronchial provocation studies in farmers with positive RAST to the storage mite *Lepidoglyphus destructor*. *Allergy*, 43: 545–551.
- van Hage-Hamsten, M., Machado, L., Barros, M.T. and Johansson, S.G.O., 1990. Comparison of clinical significance and allergenic cross-reactivity of storage mites *Blomia kulagini* and *Lepidoglyphus destructor*. *Allergy*, 45: 409–417.
- van Hage-Hamsten, M., Johansson, E., Wirén, A. and Johansson, S.G.O., 1991. Storage mites dominate the fauna in Swedish barn dust. *Allergy*, 46: 142–146.
- van Hage-Hamsten, M., Bergman, B., Johansson, E., Persson, B., Jörnvall, H., Härfast, B. and Johansson, S.G.O., 1992. N-terminal aminoacid sequence of principal allergen of storage mite *Lepidoglyphus destructor*. *Lancet*, 340:614.
- van Hage-Hamsten, M., Lagging, E., Härfast, B. and Johansson, S.G.O., 1993. Occurrence of IgE antibodies to the 39 kilodalton component of the mite *Lepidoglyphus destructor* in urban and rural subjects. *Allergy* (in press).
- Ventas, P., Carreira, J., and Polo, F., 1991. Identification of IgE-binding proteins from *Lepidoglyphus destructor* and the production of monoclonal antibodies to a major allergen. *Immunol. Letters*, 29: 229–234.

- Warren, P., Cherniack, R.M. and Tse, K.S., 1974. Hypersensitivity reactions to grain dust. *J. Allergy Clin. Immunol.*, 53: 139–149.
- Warren, C.P.W., Holford-Strevens, V. and Sinha, R.N., 1983. Sensitization in a grain handler to the storage mite *Lepidoglyphus destructor* (Schrank). *Ann. Allergy*, 50: 30–33.
- Woodcock, A.A. and Cunningham, A.M., 1980. The allergenic importance of house dust and storage mites in asthmatics in Brunei, S.E. Asia. *Clin. Allergy*, 10: 609–615.
- Wraith, D.G., Cunningham, A.M. and Seymour, W.M., 1979. The role and allergenic importance of storage mites in house dust and other environments. *Clin. Allergy*, 9: 545–561.