

Indoor survey of moulds and prevalence of mould atopy in Israel

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Summary

Background Moulds are ubiquitous indoor as well as outdoor allergens and therefore potential candidates for indoor environmental control measures. However, very few studies have been performed to examine the significance of indoor moulds in allergic diseases and the effectiveness of measures to reduce the quantity of indoor moulds has not been established.

Objective To determine the significance and the contribution of moulds to allergic manifestations.

Methods Prevalence of allergic rhinitis and asthma in 395 members of a rural community were examined by questionnaire and examination of medical files. The atopic status in general and allergy to moulds was determined by skin-prick tests (SPTs) to a panel of aeroallergens including *Aspergillus*, *Penicillium*, *Alternaria* and *Cladosporium*. A study of indoor mould levels was performed by placing SDA plates in 59 houses. The type of fungi and the number of colonies from each species were recorded.

Results Forty-two subjects, comprising 10.9% of the study group had positive SPT to moulds, 61.9% of those were classified as symptomatic. When taking into account individuals with a borderline positive SPT to moulds, an additional 23 had positive results. Of the 65 mould-positive subjects, 48% were symptomatic and of the 13 who were allergic to moulds alone, only two had allergic symptoms. Viable moulds were recovered from all 59 houses examined. The most common isolated genus was *Aspergillus*, followed by *Penicillium*, *Alternaria* and *Cladosporium*. *Aspergillus* was also the most abundant mould in houses. There was no significant correlation between the abundance of moulds, positive SPT to that mould and symptomatology.

Conclusions Viable moulds are common in houses in temperate climates. Allergy to moulds itself has a low predictive value to development of allergic symptoms, but allergy to moulds in otherwise atopic subjects increases the risk of symptomatic allergic disease.

Keywords: atopy, moulds, asthma, allergic rhinitis, mould count

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Introduction

Allergic diseases, mainly asthma and allergic rhinitis, are among the most common chronic conditions. Although we

have a better understanding of the pathophysiological processes and the genetic basis of these illnesses, the prevalence and severity of allergic diseases is increasing. Since extrinsic agents cause allergic diseases, environmental control measures are often recommended to reduce exposure to the offending allergens. Indeed, the reduction of house dust mite exposure is accepted as a part of asthma

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management [1]. The efficacy of these measures has been demonstrated in numerous studies where atopic status, allergic symptomatology, house dust mite levels, bronchial hyperresponsiveness and markers of inflammation were investigated [2–6]. Mould spores are prevalent in houses and flourish in the presence of optimal growing conditions, including high humidity. Hence, they are also a potential target for intervention with environmental control measures. A study from Minnesota suggested that *Alternaria* was the primary allergen responsible for cases of death and near death in asthma patients [7]. Most of the mould surveys were performed in the outdoor environment [8,9] in spite of the fact that the major and more relevant site of harmful allergen exposure is indoors [10]. Surprisingly, there are few studies examining the indoor environment for moulds [11,12]. The effectiveness of measures to reduce quantities of moulds on the severity and development of asthma in patients allergic to moulds has not been studied systematically. The purpose of the present study was to investigate the existence and prevalence of viable indoor moulds in a rural community in Israel. The average level of humidity during the summer was 50–70%. The atopic status, as depicted by skin-prick test (SPT), and the prevalence of anamnestic allergic rhinitis and asthma were recorded and correlated. The results of this study may be used as a basis for developing a rational approach to the requirement of initiating indoor mould reduction measures.

Materials and methods

The entire population, aged 4–70 years, irrespective of their clinical status, of a small rural community, Netzer Tzireni (NTZ) in Israel, was asked to participate in the study. There were 505 eligible residents, ethnically heterogenic and without familial interrelationship. The compliance rate was 78.2%, a total of 395 participants. The village is located 12 km from the coast, at sea level, in a temperate climate, typical to the Mediterranean part of Israel (average temperature of $\approx 20^{\circ}\text{C}$ with mean annual rainfall of 500 mm).

The study was approved by the Ethics Committee of Tel Aviv University and each participant signed a consent form before completing the questionnaire.

Clinical data collection and analysis

Clinical data were collected from a questionnaire and from the participants' medical files. The questionnaire was completed by each participant or by the parents of children aged 4–17 years. It included details regarding spontaneous and trigger-induced wheezing, nocturnal cough not associated with respiratory tract infection, rhinitis, sneezing or eye and skin symptoms not associated with infection. Seasonally, duration of symptoms, recurrence and age of onset of

symptoms, were also recorded. In addition, the questionnaire enquired whether the participant was ever diagnosed by a physician as having bronchial asthma (BA) or allergic rhinitis (AR), and whether treatment for these conditions had been prescribed in the past. In surveying the medical files, we looked for evidence of diagnosed allergic diseases. The criteria for classifying a patient as having BA or AR were adopted from Broder *et al.* [13] with minor modifications as published earlier [14]. In cases where there was a discrepancy between the questionnaire and the records in the medical files, the participant was interviewed again. Patients with a previous diagnosis of allergic conjunctivitis or atopic eczema, but no evidence of BA or AR, were classified as 'others'.

Skin tests

Skin-prick tests were carried out according to published methods [15]. The extracts were stored at 40°C . A drop of each extract was placed on the forearms and the skin was pricked through the droplet. Mould allergens were placed on the same forearm. Excess fluid was blotted off immediately; the diameter of the weal-and-flare were measured after 20 min. A positive response was considered when the weal diameter was > 3 mm. Histamine (1 mg/mL) was used as a positive control and saline-glycerol solution as a negative control. A participant who had at least one positive SPT was considered atopic. Among the extracts used were trees: pecan, olive, date palm, Cypress, Ailanthus, weeds: pigweed, English Plantain, sagebrush, lamb's quarters, Grasses: rye perennial and bermuda, house dust mites (HDM): *Dermatophagoides pteronyssinus* and *Dermatophagoides farinae*, and the following moulds: *Cladosporium* spp., *Penicillium* spp., *Alternaria tenuis* and *Aspergillus* spp. Allergens were obtained from Hollister-Stier, and were used at 1:20 w/v with 50% Glycerin as preservative. All the allergens were fresh and used for the study only.

Airborne viable moulds

Twenty-nine homes, 14 residents with allergic respiratory symptoms and 15 asymptomatic, which comprised 89% of the residences of participants tested positive to moulds by SPT, were examined for the presence of moulds, and compared with 30 homes of skin-negative subjects. The houses were selected randomly. Sabouraud dextrose agar (SDA) plates (Difco) were used for cultures. Subjects who participated in this part of the study placed a plate in each of the following locations: kitchen, bathroom and bedroom. One hundred and seventy-seven plates in 59 different homes were exposed for 8 h overnight. The plates were collected and incubated at 27°C . The fungi were identified by one of

Table 1. Study population

Age group (years)	Number (%)	Positive Male/Female	SPT-Number (%)
4–9	59 (14.9)	29/30	18 (30.5)
10–16	73 (18.5)	39/34	38 (52.0)
> 17	263 (66.6)	111/152	125 (47.5)
Total	395 (100)	179/216	181 (45.8)

us (E.S.K, Israel Reference Laboratory for Medical Mycology) and the number of colonies from each species was determined on each plate.

Statistics

Statistical analysis was performed using 'Statistix Ver 3.1' analytical Software, St Paul, MN. Calculating the 25 and 75 percentiles of colony counts for each mould species at each collection date, was the basis for categorization into high and low colony counts. Chi-square test was used to compare the rate of existence of high and low counts among the various mould species, and also to analyse the possible statistical distinction between the patients with positive skin test and clinically symptomatic patients in the high and low colony count houses.

Results

The description of the investigated population, including age distribution and the result of skin tests is presented in Table 1. The majority of the subjects were aged between 17 and 70 years. A similar gender distribution is seen throughout the different age groups. Forty-six per cent of the participants had a positive skin test to at least one of the allergens tested. It is clear from these data that rates of positive skin tests increase with age: from 30.5% in the age range of 4–9 years, to $\approx$ 50% in the age range >10 years.

The incidence of positive skin tests to the different aeroallergens is shown in Table 2. The most prevalent sensitizing allergen was the house dust mite; 28.9% of the

Table 3. Prevalence of positive SPT (> 3 mm) to different mould genera in the mould sensitive population

Mould genera	<i>Aspergillus</i>	<i>Alternaria</i>	<i>Penicillium</i>	<i>Cladosporium</i>
Number	22/42	12/42	12/42	6/42
%	52	28	28	14

patients showed a positive skin test for this mite, and 10.6% had positive skin test to moulds. The prevalence of the skin-test reactivity to the different mould genera is summarized in Table 3. As shown, *Aspergillus* was the most prevalent in inducing immediate skin sensitivity (52% of mould-sensitive subjects) followed by both *Alternaria* and *Penicillium* (28% each) and finally *Cladosporium* (14%). Twenty-three more subjects had borderline sensitivity to at least one of the mould extracts tested (weal diameter was 3 mm or less). Taking these patients into account increases the incidence of sensitization to moulds in the study group to 16.6%, without altering significantly the ratio between the moulds causing the response.

Twenty-six of the 42 (61.9%) participants with positive SPT (>3 mm) to moulds had symptomatic respiratory allergies and were considered as 'symptomatic'. Two had BA alone, 14 AR and 10 had both AR and BA. When the participants with SPT $\leq$ 3 mm, 13 participants, were included, only 48% had symptomatic disease. There was a significant difference in the frequency of allergic diseases between those with SPT $\leq$ 3 mm to those having SPT > 3 mm ($P = 0.0057$) (Table 4). Most of the mould-sensitive subjects, had positive SPT to other environmental allergens (multi-atopy, Table 4), but 13 patients, including those with SPT $\leq$ 3 mm, were atopic to moulds only. 85% (11 out of 13) who were sensitive to moulds alone (mono-atopy, Table 4), were classified as asymptomatic. Among the 13 exclusively mould-sensitive subjects, five were allergic to *Penicillium*, four to *Aspergillus* (one of these was allergic to both *Penicillium* and *Aspergillus*) and *Alternaria* and only one to *Cladosporium*. The difference in the prevalence of symptomatology between patients

Table 2. Prevalence of positive skin test to moulds and selected allergens

	HDM	Grass	Sage	Pecan	Cypress	Olive	Date	Mould
Number	114	70	65	53	44	40	26	42
%	28.9	18.2	16.5	13.4	11.1	10.1	6.6	10.6

HDM, house dust mite.

Table 4. Comparison of symptoms in different group individuals with positive SPT to moulds

	Total	Mono-atopy	Multi-atopy	> 3 mm	≤ 3 μm
Number	65	13	52	42	23
Symptomatic	32	2	30	26	6
Asymptomatic	33	11	22	15	17
P		0.02	NS	NS	0.05

allergic to moulds and other aeroallergens and those allergic to moulds only, was highly significant ($P = 0.0027$). Furthermore, among the 181 atopic (positive SPT) participants, 91 had symptoms, among the 57 with positive SPT to HDM and pollens 31 were symptomatic (NS), but among the 21 who had positive SPT to HDM, pollens and moulds 16 were symptomatic, $P < 0.045$.

Indoor mould counts

The results of the mould collection are shown in Fig. 1. All houses contained viable moulds. Similar to the skin test results, the most common moulds found in homes were *Aspergillus* spp. (in 85% of the homes); then, in decreasing order: *Rhizopus*, *Penicillium*, *Alternaria*, *Helminthosporium* and finally *Cladosporium* spp. In most of the houses more

than one species of fungal spores were found. To achieve an estimate of the abundance of each mould species, a semi-quantitative analysis was carried out, the results of which are shown in Fig. 2. High counts of *Aspergillus* were obtained in 51 out of 59 houses, the parallel figures for *Penicillium*, *Alternaria*, and *Cladosporium* were 40/59, 39/59 and 17/59, respectively. Thus, *Aspergillus* was the most prevalent as well as the most abundant mould species found in this study. *Aspergillus* was also found to be the most common mould in the homes of patients suffering from respiratory diseases. As shown in Fig. 2, a high quantity of moulds at home did not predict either skin-test results or allergic symptoms. *Alternaria* counts were high in houses of 39 participants, among these, seven had positive SPT to *Alternaria*, six had symptoms, while among the 20 participants with low *Alternaria* counts, only two had positive SPT and only one was symptomatic. However, these differences were not significant.

Discussion

The study presented here examined simultaneously the prevalence of positive SPT to moulds, allergic symptomatology and the presence of mould spores in the residences of the whole population of a rural community in Israel. Of the study population, 10.6% had positive SPT to one of the four mould species examined. To the best of our knowledge, comparable data in a random population are not available. Peat *et al.* [16] reported that among 6388 children (age 8–11 years) the prevalence of positive SPT to *Alternaria* was 4–23.1% in seven different climatic regions. No other mould species were tested and adults were not included in that study. In other studies where prevalence of positive SPT to moulds was reported, the study population only included patients who were referred for evaluation of various allergic conditions and therefore all participants were symptomatic. In a group of 1372 patients referred for allergic evaluation, Potter *et al.* [17] reported 8–15% positive RAST for each of the mould antigens tested, Alt a, Asp f and Clad h. Two previous reports from Israel estimated the prevalence of positive SPT to moulds in asthmatic patients. Tas [18] in 1966, reported that about 10% of the asthmatic patients in his clinic in Israel were allergic to moulds, while Kantor and Wasserman claimed that up to 70% of the patients in their clinic were allergic to moulds [19]. Tas did not provide data regarding the types of moulds tested, selection and age of patients, and did not specify if the patients also had AR, or if patients with AR alone were included. Tas [18] suggested that since Kantor and Wasserman used self-prepared extracts it is possible that the extract was contaminated with house dust and therefore a considerable number of the positive SPT could represent false positive result. Differences in the rate of positive SPT can be due to various

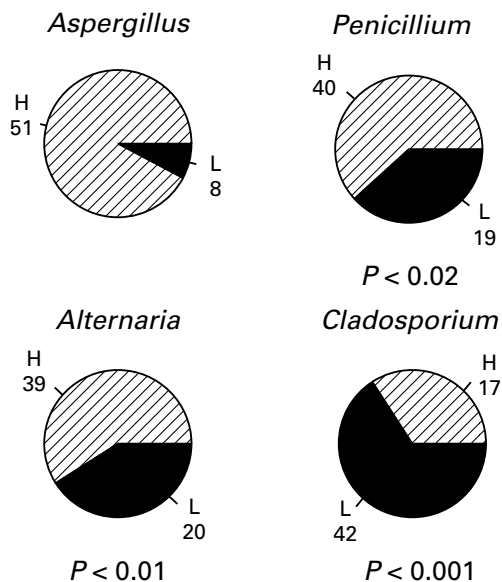


Fig. 1. Percentage of high and low counts of each mould species. H, high and intermediate counts of mould spores; L, Low counts of mould spores. P-value — each mould species as compared with *Aspergillus*.

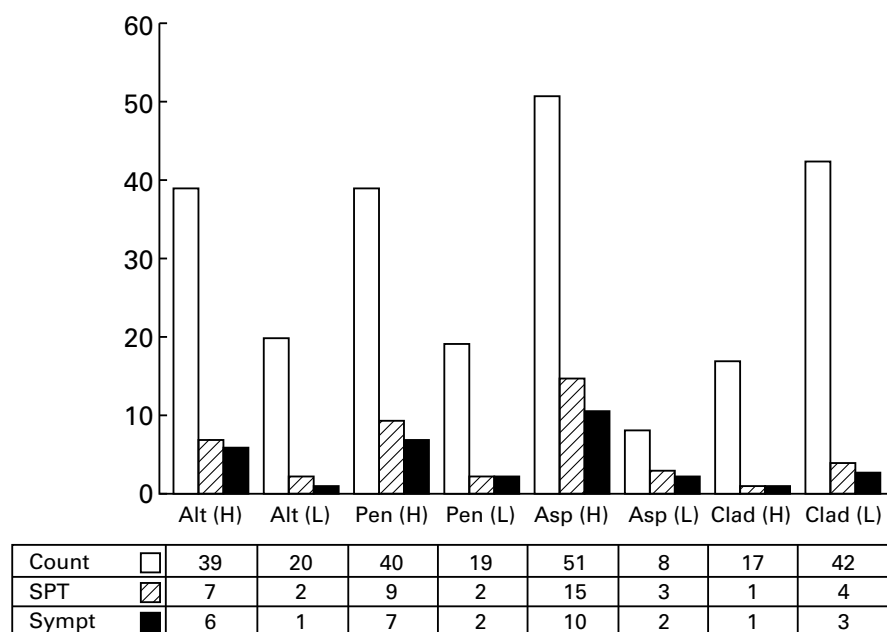


Fig. 2. Correlation between high and low counts of each mould, results of SPT to that mould and symptoms. Alt, *Alternaria*, Pen, *Penicillium*, Asp, *Aspergillus*, Clad, *Cladosporium*; SPT, Number of participants with positive SPT to that mould.

factors such as number of allergens tested, climatic region and age of patients, among others. In a study from Turkey, 614 patients with respiratory allergies were tested for 19 different fungal extracts and 26% of them were found to have positive SPT to *Aspergillus* [20]. Iversen and Dhal [21] found 10% of positive SPT to moulds among 677 asthmatic patients from Denmark. In that particular study only three fungi were tested, *Cladosporium*, *Aspergillus* and *Alternaria*, excluding an important mould allergen, *Penicillium*. The importance of the age of the patients was demonstrated in a study from Hungary where the prevalence of positive SPT to moulds increased from 10.6% to 38.5% between 1977 and 1987 in a cohort of asthmatic children [22]. Since there has been little standardization of fungal antigenic preparations and there are considerable batch to batch variations [23], it is possible that the group of patients with weal ≤ 3 mm presumably represent a group of patients in which the result of the SPT may be false positive. There was a significant difference in symptomatology between these patients and the rest of the individuals with positive SPT to moulds. This result reinforces the well-known observation that results of SPT to moulds require careful interpretation.

The most prevalent sensitizing mould in our study was *Aspergillus* followed by *Alternaria* and *Penicillium*. This may be due to a relative abundance of this mould in the residences. It should be stressed that the study population included all the residents of NTZ and not only those with allergic manifestations. It is possible that among asthmatic patients the results may be different [17,22]. In agreement with reports from other countries [24–26], and as was shown in a survey carried out in the Department of

Botany, Tel Aviv University (unpublished data), *Alternaria* and *Cladosporium* are the most prevalent outdoor moulds, while *Aspergillus* is a typical indoor mould. In an earlier report from Israel, Barkai-Golan *et al.* [27] using SDA plates, exposed outdoors, showed that *Cladosporium* was the most abundant spore in both Tel Aviv and Eilat, cities with extremely different meteorological conditions. Tel Aviv has a relatively humid climate while Eilat is very dry. *Alternaria* was the second most abundant mould, followed by *Penicillium* while *Aspergillus* was much less common. As reported in other countries [9], including a neighbouring country, Egypt [28], *Aspergillus* was found to be the most prevalent mould found indoors. Since we placed the plates in houses it is not surprising that *Aspergillus* was the most abundant mould. Verhoeff *et al.* [12] on the other hand reported that *Cladosporium* was the most frequently detected fungus in 100% of indoor samples. This difference may be attributed to the selection of particularly damp houses in one study and geographical differences in the other. However, their study confirmed the vague relationship between indoor and outdoor samples [12].

The collection method employed by us may underscore the relative importance of rapidly growing moulds and may be influenced by the actual temperature and humidity on the day of collection. In order to overcome this problem, at least partly, we made an attempt to normalize for temperature, humidity and other conditions. Mould counts were divided into percentiles specific for each mould and each day and time of collection; this made our results more accurate, reducing the variations caused by the collection method,

weather variations and duration of sampling. We recognize that a complete elimination of the problems involved in this method of fungal sampling is impossible. A sampler, such as N6-Andersen sampler may yield more accurate results, but the results with Petri dishes correlate closely with those obtained with N6-Andersen sampler [12] and Petri dishes are much more readily available.

Close to half of the patients who were SPT positive to moulds had allergic symptoms, but only 15% of those who were sensitive exclusively to mould, were symptomatic. This indicates that mould sensitivity alone is not as important as the other allergens in inducing allergic symptoms. A similar observation was reported by others [20]. Moreover, it is known that individuals with multiple allergies have a higher rate of symptomatic disease than those with a single allergy [29].

In spite of the lack of a statistically significant correlation between high mould count, positive SPT and atopic symptoms, there seems to be a tendency towards higher rates of symptomatology when positive SPT and mould counts were high. This tendency was observed for *Alternaria* and *Penicillium* but not for *Aspergillus* and *Cladosporium*. The lack of significant correlation between abundance of moulds, SPT and symptoms could partly be explained by the fact that non-viable spores of moulds could induce symptoms, but would not grow on plates.

In conclusion, this study demonstrated that houses in temperate climates contain significant amounts of viable moulds of the species known to be allergenic and moulds are not confined to very humid areas or to the outdoor environment. Therefore moulds should be considered as an important indoor allergen, with a potential to sensitize allergic individuals. Although it seems that mono-allergy to moulds does not have an important clinical significance, the clinical manifestations of patients suffering from other allergies may worsen with exposure to moulds, provided that they are also allergic to moulds. Therefore, the procedures to reduce domestic exposure to moulds [30] should be considered along with other indoor environmental measures in allergic patients with positive SPT to moulds. The efficacy of anti-mould environmental control measures should be studied systematically.

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