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Airborne *Ganoderma* basidiospores in a country with desert environment

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Aerobiological studies to identify *Ganoderma* basidiospores were conducted using Burkard Volumetric 7-Day Recording Sampler (Burkard Manufacturing Co. Ltd., England) at three separate cities in Saudi Arabia. At one site, Jizan, close to the coast of Red Sea, up to 17% of all basidiospores counted were identified as *Ganoderma* spp. while less than 1% *Ganoderma* spp. were identified at the two non-coastal sites. A clear seasonal pattern from late autumn to early summer (October–March) with a peak in December was recorded at Jizan and the maximum concentration of *Ganoderma* basidiospores reached $1.9 \times 10^3 \text{ m}^{-3}$ in December followed by $1.2 \times 10^3 \text{ m}^{-3}$ in January. The diurnal pattern of *Ganoderma* spore concentrations, when averaged over the year had late-evening maxima (a nocturnal pattern). However, other sites that showed low concentrations of *Ganoderma* basidiospores did not exhibit any peak or a high maximal level. The study demonstrates that even in a desert environment, airborne activities of *Ganoderma* basidiospores can be recorded. The impact of *Ganoderma* on asthmatic patients, particularly in such environments, needs to be investigated.

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Ganoderma basidiospores (a member of the class basidiomycotina), commonly known as bracket fungus or wood decay fungus (Horner et al. 1992), have been reported as an important and prevalent group of fungal airspora worldwide (Herxheimer et al. 1969, Hasnain et al. 1984, 1985; Lehrer et al. 1986, 1994; Levetin 1990, 1991; Hasnain 1993, Halwagy 1994, Li & Kendrick 1994, 1995). Gregory & Hirst (1952) first suggested that basidiospores might be associated with respiratory allergy. *Ganoderma* basidiospores have subsequently been reported as having allergenic properties (Lopez et al. 1976, Santilli et al. 1985, Lehrer & Horner 1990, O'Neil et al. 1990, Vijay et al. 1991) and have been implicated in the elicitation of respiratory allergic diseases (Sprenger et al. 1986, 1988; Cutten et al. 1988).

Tarlo et al. (1979) found *Ganoderma* basidiospores to be the most prevalent fungal air spores in Ontario (Canada) and reported human sensitization to *Ganoderma* extracts. Hasnain et al. (1984, 1985), Cutten et al. (1988) and Hasnain (1993), in their studies from Auckland, New Zealand, reported that *Ganoderma* basidiospores constituted a major component of the airspora and were potential sources of allergens involved in asthma and allergic rhinitis. These authors also suggested that persistent exposure to *Ganoderma* basidiospores could stimulate a base level of allergic responsiveness in susceptible atopic patients. Positive skin and inhalation tests to *Ganoderma applanatum* have been reported by Herxheimer et al. (1969). Lehrer et al. (1986) and Sprenger et al. (1986) in their studies found that 32% of atopic populations in New Orleans, Louisiana, and 30% in Seattle, Washington, U.S.A. were skin test positive to the basidiospores extracts

including *Ganoderma*. Singh et al. (1994) reported sensitization to *Ganoderma lucidum* in the atopic population in India. Intradermal and skin prick tests performed using antigenic extract of *G. lucidum* revealed that 28.4%, and 17.4% of patients showed marked skin reactivity to the spores and whole body extracts respectively.

Seasonal and diurnal patterns of spores of basidiomycetous fungi have been documented in various studies (Hasnain et al. 1984, Singh et al. 1994, Calderon et al. 1995, Li & Kendrick 1995). In New Zealand, the basidiospores of *Ganoderma* were reported to be present throughout the year with comparatively higher concentrations from December to April (summer and autumn in the Southern Hemisphere). Likewise, in Mexico, Canada and India the concentrations were higher from June to October (summer and autumn in the Northern Hemisphere). The studies also reported that *Ganoderma* basidiospores exhibited diurnal pattern with nocturnal maxima with peaks at midnight or in the early hours of the morning.

Airborne *Ganoderma* basidiospores have not been previously documented from Saudi Arabia. The study reports, for the first time, occurrence of *Ganoderma* from a country with a desert environment. The possible implications of these basidiospores in the etiology of respiratory allergic diseases in the Kingdom of Saudi Arabia are also discussed.

MATERIAL AND METHODS

Burkard Volumetric Seven-Day Recording spore traps were operated from 1 December 1994 to 31 October 1996 at three



Fig. 1. A map showing sampling sites in Saudi Arabia.

geographically different regions in Saudi Arabia. The three sites are distributed over a distance of approximately 1000 km from North to South and include Jizan, a coastal town; Hail, an agricultural region and Ta'if, a hill resort in mountainous area (Fig. 1). One-year

of data was considered for each site. The traps were mounted approximately 3–5 m above the ground level at all sites and operated at 10 L/min. The exposed tapes were cut into 24-hour segments and each was mounted with gelytol-phenol mixture onto a glass slide. Identification and counting were done using ten random fields on each traverse representing each hour i.e. a total of 240 fields for each 24-hour period. The slides were scanned at a magnification of $\times 400$ and $\times 1000$ for counting and identification respectively (Hasnain et al. 1984). The data was expressed as hourly mean concentration m^{-3} of air derived from each hourly count for each month. *Ganoderma* spores were identified using reference slides and literature housed in the Allergy and Aerobiology Unit at King Faisal Specialist Hospital and Research Centre.

RESULTS

The results were recorded in various individual categories as well as in groups. The individual category mostly included dry type spores, for example, *Cladosporium*, *Alternaria*, and *Ulocladium*. The basidiospores were recorded both individually such as *Ganoderma*, and in groups including smuts, rusts and colored basidiospores. However, in this communication only data relating to *Ganoderma* (Fig. 2) are presented.

The percentages of *Ganoderma* spp. basidiospores were calculated for each site and each month of the year (Table I). In Jizan, the percentages of basidiospores identified as *Ganoderma* spp. were 17% and 15% for December and January respectively, compared to a maximum value of 1% in Hail and Taif in September. For the rest of the year, the proportion remained comparatively low at all three sites. Periodicities of *Ganoderma* basidiospores, calculated as mean hourly data for each month of the

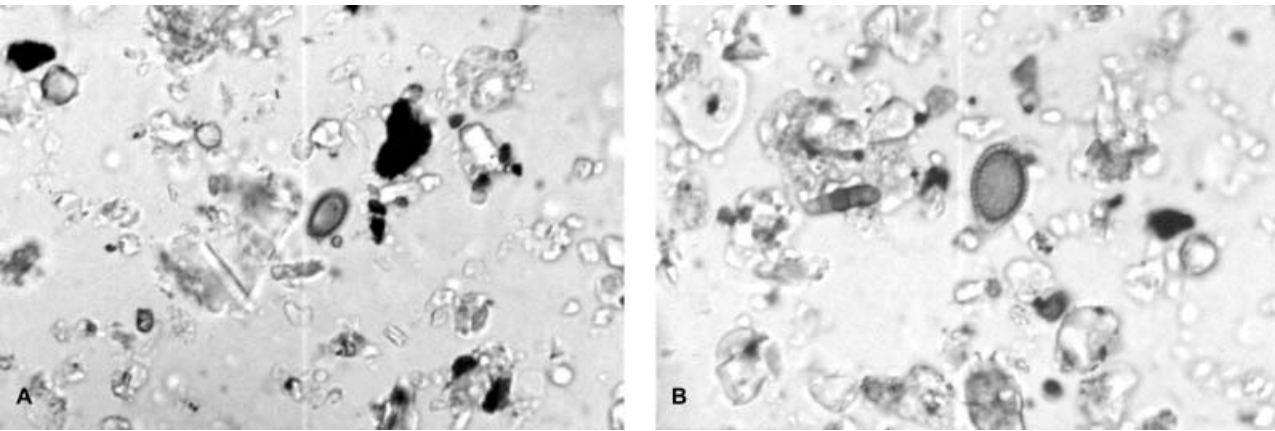


Fig. 2. Photomicrographs of two *Ganoderma* basidiospores recorded from Saudi Arabian environment (Jizan): (A) Possibly *Ganoderma applanatum*; (B) *Ganoderma mastoporum*. Scale – $\times 1000$.

Table I. Percentages of airborne *Ganoderma* basidiospores against the total basidiospores from the three regions of Saudi Arabia.

Sampling Site	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
Jizan	15	4	0.4	0.2	0.1	0.1	0	0.4	0.4	1	4	17
Hail	0.1	0.4	0.1	0	0	0	0.2	0.2	1	0.3	0.1	0.05
Taif	0.02	0.1	0.04	0	0	0.05	0.2	0.2	1	0.2	0.2	0.1

sampling period, are seasonal (Fig. 3). Jizan recorded the highest concentrations (approaching 250 spores/m³), while, for other months, although the basidiospores were present, the concentrations were below 50 spores/m³. The highest hourly concentrations of airborne *Ganoderma* basidiospores were found in December and January at Jizan and were $1.9 \times 10^3 \text{ m}^{-3}$ and $1.2 \times 10^3 \text{ m}^{-3}$ respectively (Fig. 4).

For other sites concentrations were much lower rarely exceeding $0.1 \times 10^3 \text{ m}^{-3}$, but consistent with the seasonal data, the maximal levels occur from October to February, and in other months the levels remained less than 100 spores/m³ of air. Diurnal periodicities of airborne *Ganoderma* basidiospores at Jizan occur throughout the year but are more pronounced in December and January (Fig. 5). The concentration levels for the other two sites (Hail and Taif) were very low and therefore diurnal data for these sites is not included.

DISCUSSION

Methods of sampling widely used to study aeroallergens in the past (viable/cultural mode), extensively record the presence of dry-spores allergens such as *Alternaria*, *Aspergillum* and *Cladosporium*. In contrast, however, airborne *Ganoderma* basidiospores have not been reported from many countries with similar environments. There are few *Ganoderma* species have been reported worldwide (Hasnain et al. 1984, Tarlo et al. 1979, Craig & Levetin 2000) and two different types of *Ganoderma* basidiospores were identified here resembling basidiospores of *G. applanatum* and *G. mastoporum*. Yet *Ganoderma* is well known as an individual basidiospore allergen in Pacific and North American countries. Recent allergological interest in *Ganoderma* and other basidiospores is limited by a lack of

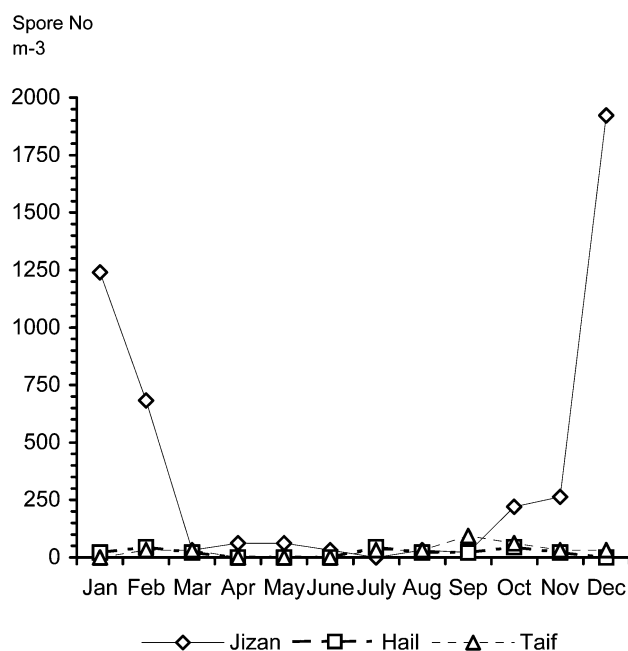


Fig. 3. Seasonal periodicities of airborne *Ganoderma* basidiospores in Jizan, the data are hourly mean concentration (Spore m⁻³) derived from each hourly counts for each month.

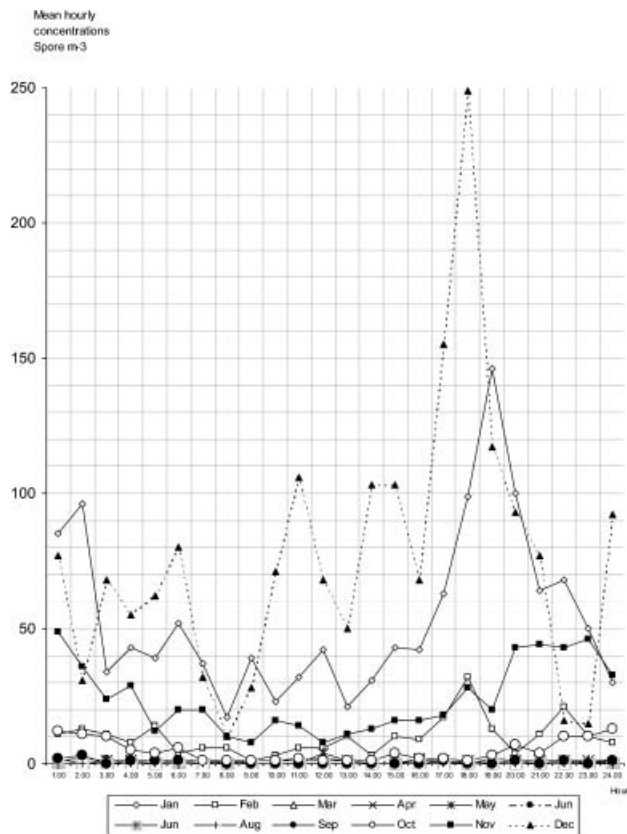


Fig. 4. Maximal monthly concentrations of airborne *Ganoderma* basidiospores at different sites.

knowledge about the environmental and climatic controls on its distributions.

The presence of *Ganoderma* basidiospores within the airspora of Saudi Arabia and the high concentrations may be important for understanding allergic reactions. Aerobiological investigations should contribute to the understanding of allergic manifestations caused by basidiospores of *Ganoderma*. Significant concentrations of *Ganoderma* basidiospores were only found in Jizan, a small town close to Red Sea, where humidity is generally high, one of the factors contributing to basidiospore release. This town borders Yemen, which has a different flora and fauna with forested ranges, providing a possible source area for Jizan. High concentrations of *Ganoderma* occur in December and January, when temperatures are generally in the range 15–20°C and relative humidity is high exceeding 70%. This temperature and humidity range is similar to that observed in other studies where *Ganoderma* release patterns peak in summer and autumn seasons (Hasnain et al. 1984, Cutten et al. 1988, Craig & Levetin 2000). The only difference being that these climatic conditions are encountered in the Saudi Arabia winter season.

In contrast to Jizan, at Hail and Taif there were limited source areas for *Ganoderma* spores due to a lack of hosts' availability. Since the winds are generally very high in the desert and are likely to transport lighter airborne spores efficiently, it is conceivable that *Ganoderma* spores observed

Spore No m-3

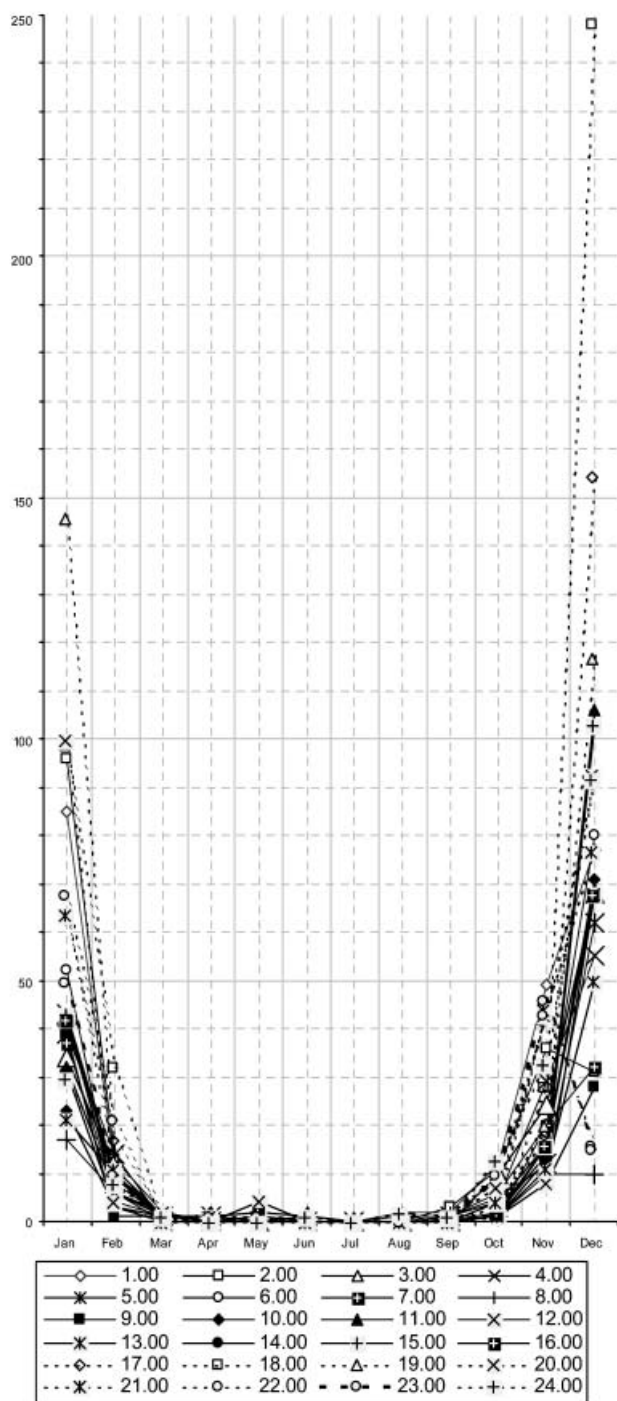


Fig. 5. Diurnal periodicities of *Ganoderma* basidiospores in Jizan (based on hourly data for the whole year period).

at Hail and Taif were from distant sources. Apparently there were aging trees in some areas of the town, but no efforts were made to identify any fruiting bodies. *Ganoderma* has a broad host range, and is known to sporulate well in the presence of high humidity conditions found in coastal areas.

Jizan has the highest (24%) asthma prevalence (Al-Frayh et al. 1998, 2001) amongst the children in different areas of

Saudi Arabia. However, in addition to *Ganoderma* basidiospores, there are many other known allergens recorded in Jizan (Hasnain et al.: Unpubl. data), and no attempts have been made to correlate *Ganoderma* with the high incidence of asthma in Jizan. Correlation of patients' diary including skin prick test are required to conclude if *Ganoderma* as an important allergen.

CONCLUSIONS

An aerobiological study of the desert regions of Saudi Arabia revealed locally high concentrations of *Ganoderma* basidiospores. High levels are associated with towns such as Jizan that are in proximity to source areas. Other regions have very low concentrations of *Ganoderma* that are probably due to re-suspension and transport from a distant source. Interestingly Jizan has the highest level of asthma prevalence in children and it is possible that *Ganoderma* may be a causative factor. The acceptance of this non-dematiaceous bracket fungus as a common inhalant allergen, even in and around coastal areas, has been negatively influenced in most parts of the world, due to lack of aerobiological support and/or difficulties in obtaining commercial *Ganoderma* extracts. Likewise, in Saudi Arabia, no basidiospores extracts are currently in the list of diagnostic profile. Therefore, in order to confirm the role of *Ganoderma* as an inhalant allergen, further investigations are required.

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