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Prevalence of airborne basidiospores in three coastal cities of Saudi Arabia

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Abstract

Seasonal and diurnal variations of airborne basidiomycetous spores concentrations (basidiospores, smuts and rust spores) were studied using Burkard Volumetric Spore Traps in three major coastal cities viz., Dammam, Jeddah and Jizan in Saudi Arabia. The distance between the sites was approximately 1600 km from East to West. In addition to numerous airborne deuteromycetous spores identified at all sites, a considerable concentration of basidiomycetous spores were also recorded. The data revealed that basidiospores constituted a maximum of 17% of the total air spora in Jizan, while the maximum for Dammam and Jeddah was 11% each. Spores from smuts constituted the highest percentages of all basidiosmycetous spores ranging between 9–33% and 12–33% respectively in Dammam and Jizan. In Jeddah, it constituted between 14–26%. In contrast, rusts were less frequent at all sites. Maximum concentration of basidiospores showed that at certain months the level reached between 1000–6000 m^{-3}. The data did not exhibit any seasonal pattern in their maximum appearance. Maximum concentration of smuts were much higher compared to basidiospores and the level fluctuated between 500–4000 m^{-3}. Rusts were low in concentration (< 150 m^{-3}). The diurnal pattern of basidiospores concentration for at least one site (Jizan) averaged over the year showed a nocturnal trend consistent with basidiospores active discharge. The other two sites had no such trend. Diel periodicities of smuts and rusts spores did not exhibit any clear pattern. The study suggests that even in coastal regions having the same climatic conditions with a slightly different geography, show variation in basidiospores concentrations.

1. Introduction

Basidiospores, the sexual spores produced in appreciable quantities by the members of basidiomycetes (mushrooms, puff balls, bracket fungi etc.) constitute a significant component of the airspora in many parts of the world. Basidiospores occur widely and are morphologically distinctive. The size, shape, color and ornamentation of these basidiospores demarcates their identity from spores of other fungal groups in atmospheric samples (Levetin, 1990, 1991). Gregory and Hirst (1952) first suggested airborne basidiospores as possible allergens. Twenty years later, Salvaggio et al., (1971) documented increased levels of basidiospores in outdoor air with an asthma epidemic in New Orleans, USA. With the emerging data on basidiospores a few investigators embarked on a further study to characterise basidiomycetes and reveal the allergenicity of the spores. However, it has only been recently that various studies have confirmed the environmental prevalence and allergenicity of basidiospores (Lopez et al., 1976; Tarlo et al., 1979; Hasnain et al., 1984, 1985;

Santilli et al., 1985; Lehrer et al., 1986; O'Neil et al., 1990; Horner et al., 1992; Levetin et al., 1992; Lehrer et al., 1994; Singh et al., 1994). It is thus well established that basidiomycetes are important sources of aeroallergens in geographically disparate regions of the world (Sprenger et al., 1988; Levetin, 1990, 1991; Hasnain, 1993; Calderon et al., 1995; Crotzer and Levetin, 1996; Craig and Levetin, 2000).

A few earlier studies in Saudi Arabia (Al-Frayh et al., 1988; Hasnain et al., 1989, 1994, 1995; Al-Shalan et al., 1989) documented the occurrence of airborne fungal airspora where the presence of basidiospores were not recorded. However, in recent years, airborne basidiospores have been reported in some parts of the country (Hasnain et al., 1998; Hasnain et al., 2004). Therefore, it appears that no detailed information pertaining to atmospheric concentrations and seasonal fluctuations of airborne basidiospores as well as rusts and smuts spores is available for Saudi Arabia or any neighbouring countries.

The present study reports on the prevalence, concentration and seasonal variations of airborne basidiomycetous spores, some of which may be incriminated as major etiologic factors in the high incidence of respiratory allergic diseases (Al-Frayh et al., 2001) in the Kingdom of Saudi Arabia.

2. Materials and methods

2.1. *Sampling locations*

Atmospheric sampling at three major coastal cities Dammam, Jeddah and Jizan in Saudi Arabia, were carried out using Burkard Volumetric Spore Traps, during 1997–2000. The traps were operated continuously for more than 12 months and one-year's data were included for each site i.e., Dammam (October 1999–September 2000), Jeddah (September 1999–August 2000) and Jizan (December 1996–November 1997). The three coastal sites are distributed over a distance of approximately 1600 km from East to West. The locations were:

(a) Dammam: a coastal city by the Arabian Gulf in the Eastern province of Saudi Arabia. It is a newly devoloped oil producing city about 400 km east of Riyadh. Dammam has a desert, hot and humid environment with red sand, desert plants, the majority of these introduced from abroad. Previously, only desert weeds were found to exist in the region. Temperature in summer normally ranges between 40 and 50 °C during the daytime and in winter it ranges between 20 and 30 °C.

(b) Jeddah: an ancient coastal city by the Red Sea in the Western province about 1000 km west of Riyadh. It is an industrial and business city. It has a coastal, humid environment with a mixture of urban and rural flora. Temperature in summer normally ranges between 40 and 50 °C during the daytime and in winter it ranges between 20 and 30 °C.

(c) Jizan: another ancient coastal city by the Red Sea in the Southern province about 1200 km south of Riyadh. The Jizan region runs along the Red Sea coast for almost 200 miles (300 km) and borders Yemen. It has a coastal humid environment. The region encompasses fertile plains and forested mountains. The mountainous region constitutes the backbone of the Arabian Peninsula. Jizan is one of the Kingdom's richest agricultural regions as well. The weather in Jizan is hot in summer and mild in winter. The average temperature throughout the year remain around 24 °C. Sandstorms are very common in all three regions, Dammam, Jeddah and Jizan.

2.2. *Burkard volumetric seven-day sampler*

The intake orifice of the samplers was approximately 5 m above ground level. Samplers were set for seven day sampling onto Melinex tape. The tapes were changed weekly and cut into one-day (24 hours) segments, which were mounted with gelvatol-phenol mixture onto a microscopic slide. Identification and counting were undertaken in 10 random fields for each hour (2 mm traverse) for a 24-hour period (240 fields). Slides were scanned at a magnification of 400× for counting and, where necessary, at 1000× for identification. The data were expressed as hourly mean concentration per cubic meter (m^{-3}) of air derived from each hourly count for each month by applying appropriate formula for mean determination and conversion factors (Hasnain et al., 1984, 2004). Each hour's count was added to calculate daily and monthly means and were converted to spores per cubic metre of air. Maximum or peak hourly concentrations of various spores per cubic metre of air were determined. Percentages of individual types were calculated against the total spores counted.

The airborne basidiomycetous spores were classified into three different groups as "basidiospores", "smuts" and "rusts" and the data for each group were presented separately.

3. Results

Because of the sporadic and occasional appearances of recorded basidiospores types, all basidiospores were grouped together as "basidiospores", which may have included *Coprinus micaceus*, *C. disseminatus*, *C. atramentarius*, *Agaricus bisporus*, other *Agaricus* and *Agrocybe* spp., *Chlorophyllum molybdites*, *Ganoderma applanatum*, *G. mastoporum* and to a lesser extent hyaline basidiospores. The percent catch of these basidiospores is presented in Table 1. The data reveals that "basidiospores" constituted a maximum of 17% in Jizan (October) and 11% in Dammam (April) and in Jeddah (September). Spores from smuts, originating from various infected grains and cereals (Table 1), constituted by far the highest percentages of all basidiomycetous spores ranging between 9–33% in Dammam, while in Jeddah the percentage ranged between 14–26% and in Jizan it varied between 12–33%. In contrast, rusts were less frequent at all sites.

The maximum concentrations of basidiospores, smuts and rusts are presented in Figure 1a, b and c respectively. The data show that at certain months the level reaches a peak and then declines. The data do not show either a consistent rise or fall or any seasonal pattern in their maximum appearance. As with basidiospores, various smuts types were grouped together as "Smuts" and may include teliospores of *Ustilago tritici*, *U. cynodontis*, *U. maydis*, *U. hordei*, *Sphacelotheca occidentilis* and *Tilletia caries*. Maximum concentrations of smuts (Figure 1b) were much higher compared to basidiospores, the level fluctuated between 500–4000 m^{-3} smut spores. Rusts (Figure 1c) mainly included Uredospores, probably from *Puccinia graminis* and were low in concentration (<150 m^{-3}).

The diel periodicity of " basidiospores" in the three coastal regions is presented in Figure 2a. The data show, at least for one site, a nocturnal trend consistent with basidiospores active discharge pattern. For the other site, because of low concentrations, no such trend may be established. Diel periodicity of smut spores presented in Figure 2b shows no clear pattern. However, the level of smuts also remained high in Jizan, consistent with basidiospores.

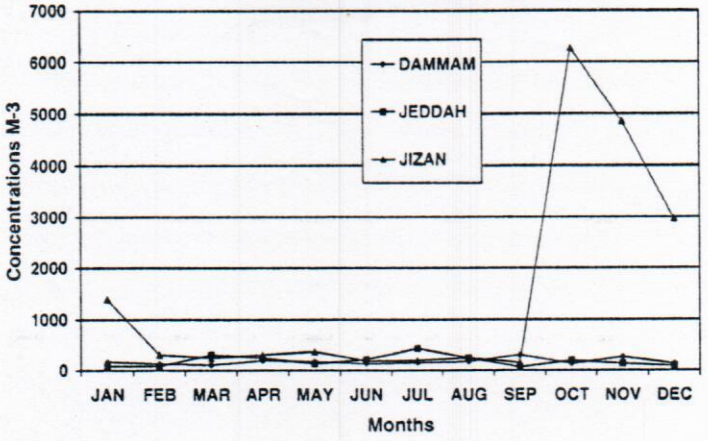
4. Discussion

The data collected from the three distinct locations (approximately 1600 km apart) using volumetric continuous sampling clearly indicate both regional

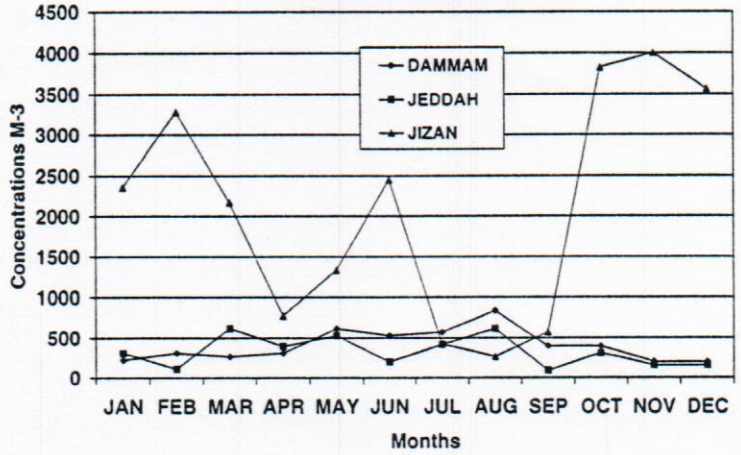
Table 1. Percentages of airborne basidiospores, smuts and rusts against total fungal spores in three coastal cities of Saudi Arabia

Spores (%)	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	July	Aug	Sept
DAMMAM (1999–2000)												
Basidiospores	4	4	3	3	5	7	11	9	7	8	6	7
Smuts	14	18	9	15	21	25	28	33	33	29	24	25
Rusts	0.4	1	0.1	0.2	0.3	1	0.4	0	1	0.4	0.3	1
Other spores	81.6	77	87.9	81.8	73.7	67	60.6	58	59	62.6	69.7	67
JEDDAH(1999–2000)	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	July	Aug
Basidiospores	11	6	5	6	5	9	5	2	6	6	4	4
Smuts	20	14	19	25	18	15	25	23	26	20	23	24
Rusts	0	0.4	1	1	0	1	0.2	0	0.2	1	0.3	0.4
Other spores	67	79.6	75	78	77	75	69.8	25	67.8	73	72.7	71.6
JIZAN (1996–1997)	Dec	Jan	Feb	Mar	Apr	May	Jun	July	Aug	Sept	Oct	Nov
Basidiospores	12	9	6	4	9	9	4	6	7	4	17	14
Smuts	24	21	24	18	32	33	30	31	25	25	12	16
Rusts	0.4	1	1	1	1	1	1	1	1	0.4	0.1	0.1
Other spores	63.6	69	69	77	58	57	65	62	67	70.6	72.9	69.9

(a) Maximum Concentrations of Airborne Basidiospores in Three Cities of Saudi Arabia



(b) Maximum Concentrations of Smut Spores in Three Cities of Saudi Arabia



(c) Maximum Concentrations of Airborne Rust Spores in Three Cities of Saudi Arabia

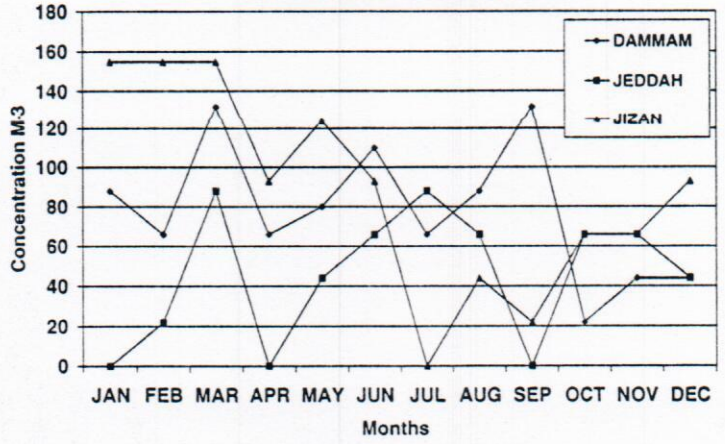


Figure 1. Maximum concentration of (a) airborne basidiospores, (b) airborne smut spores and (c) rust spores in three cities of Saudi Arabia.

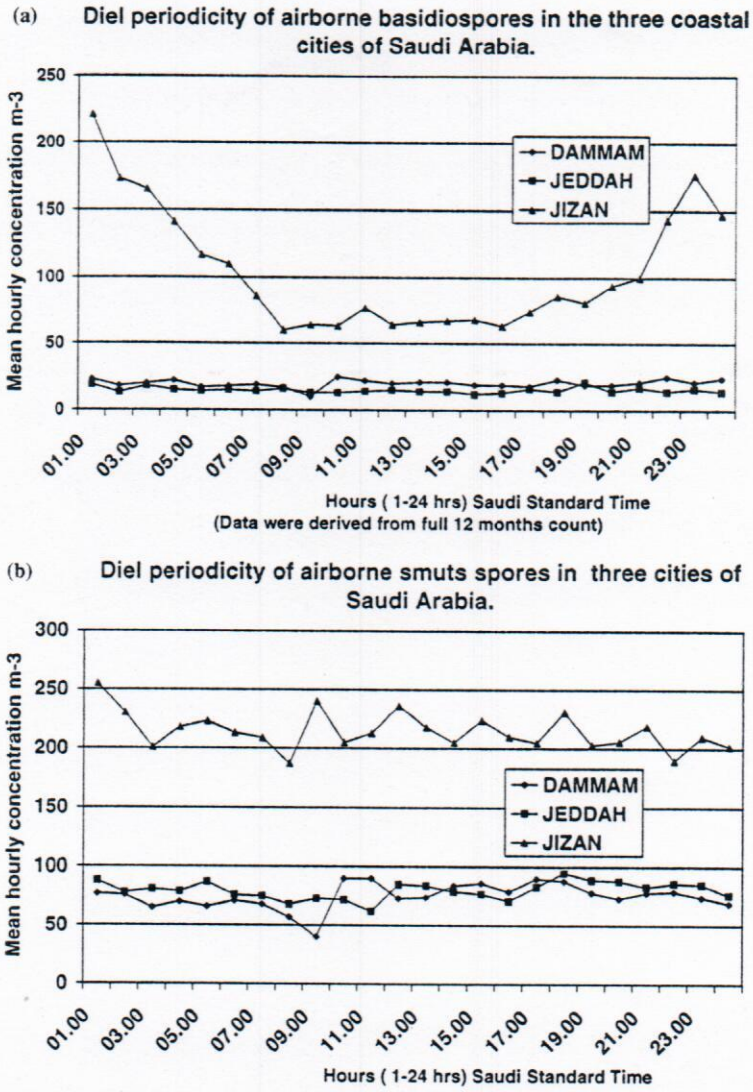


Figure 2. Diel periodicities of (a) airborne basidiospores in three coastal cities and (b) smuts spores in three cities of Saudi Arabia.

and seasonal diversities in airborne basidiospores concentrations. Despite the fact that the growth and discharge of basidiospores are very common in coastal areas and areas with high rains and humidity, we found that even in the coastal regions there are variations. This can be observed in Jizan (coastal city) having higher "maximum" concentrations than the two other coastal cities (Dammam and Jeddah) during the different periods. In addition, seasonal fluctuations also occurred in Jizan with lowest basidiospores concentrations around < 500 m^{-3} in August and September to a maximum concentration > 6000 m^{-3} in October. This difference within a site in different seasons is approximately 12-fold and particularly with concentration levels in October, November and December may be clinically significant for some individuals with basidiospores sensitivity. The reason (s) as to why one coastal site has higher concentrations of basidiospores than the other two, can partially be explained by the presence of sources of basidiomycetes fungi in this coastal and forested region of Jizan. In addition, being a border town with Yemen, which has even more forested hilly areas, it is likely that cross-border transportation of light and dry basidiospores such *Ganoderma* may have taken place.

Most basidiospores (e.g., *Ganoderma*, *Coprinus* etc.,) show a nocturnal pattern of release and

subsequently higher concentrations during the night or early hours of the day. Though the mean concentration levels are comparatively lower, the Jizan site displays this nocturnal trend consistent with findings of other workers (Tarlo et al., 1979; Hasnain et al., 1984; Calderon et al.,1995).

Rusts and smuts were classified as components of basidiomycetous spores but the data are presented separately. Comparison between smuts and rusts spores also revealed variations showing higher smuts concentrations than rust spores. In general the concentrations of rust spores were low and did not exhibit any clear pattern unlike other basidiospores.

In conclusion, these data display regional and seasonal variations of basidiomycetous spores between the sites having little or no climatological differences. However, as the geography of the three sites is different, showing only one site out of three coastal sites with higher basidiospores concentration, it is therefore not inconcievable that the geography and the surroundings of the region may have influenced the data. Therefore, the data enhances the importance of geography, because even in coastal regions there may be differences in basidiospore concentrations. This finding may be beneficial in the evaluation and determination of various causes of allergies and asthma in different coastal parts of the world.

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