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Aeromycoflora and Allergenic Fungal Spores: A Review

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ABSTRACT

"Primary Biological Aerosol Particles (PBAPs)" are vast volumes present of the air particles that are made up mostly of fungal spores. Fungal spores are considered as most important aeroallergens and cause adverse effects on plant and human health. Aerobiological monitoring revealed that they are constantly present in the atmosphere, although their concentrations change depending on the weather and locations. In addition, the presence of vegetation and its dissemination between indoor and outdoor environments also affects the fungal spore densities. This review briefly discusses various spore sampling techniques and categorizes the significant spore types for their detrimental properties on crops. The general population and identification of the variables influencing their dispersal and growth is also discussed along with currently used techniques for predicting fungal spore concentrations.

Key words : *Aeromycoflora, Allergenic Fungal*

Introduction

The eukaryotic, non-chlorophyllous, heterotrophic organisms known as fungus and fungus-like groups (like Oomycetes) are dependent on extracellular nutrients to survive in environment. The number of species of fungus is believed to range from 1.5 to 5 million, and they exhibit a vast range of life cycles, metabolisms, morphogenesis, and ecologies, including mutualism, parasitism, and commensalism, with several living entities (McLaughlin, *et al*., 2014). Irish famine is the typical example of their survival and occurence, which was caused by *Phytophthora infestans* (potato blight). During storage of agri-produce, many common molds such as *Alternaria*, *Aspergillus*, *Cladosporium*, and *Penicillium* were demonstrated to contaminate the food (Martinez-Bracero, *et al*., 2022). This review emphasizes about the latest findings on spatial variation of airborne fungal and fungus-like spores on the basis of different sampling techniques.

Airborne fungal spores

Numerous biological air pollutants, ranging in size from small viruses in nanometers (nm) and bacteria in (mm) to insects (cm), are usually found in the air. Among these, fungal spores constitute an important component of "primary biological aerosol particles (PBAPs)" and are present for significant periods of the year in a variety of biogeographic areas. Major sources of PBAPs include farms, woods, green areas, and decaying plant matter (Martinez-Bracero, *et al*., 2022; Grinn-Gofro' n, *et al*., 2018). Most fungal spores are discharged mainly through the air, where they will hang out for a while before traveling across short or long distances. Raindrops have the ability to aerosolize and splatter spores from the surfaces of their fungal colonies (Martinez-Bracero, *et al*., 2022).

Due to health-related implications and their socio-economic perspectives, there has been an increase in interest in the study of fungal spores over the last few decades (Figure 1), and recent years have witnessed an increase in the significance of real-time spore concentration determination (Feeney, *et al.*, 2018; Duflot, *et al.*, 2019, Sodeau, *et al.*, 2016).

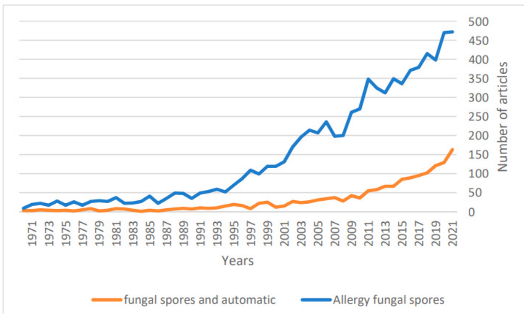

Figure 1. Comparison between articles published with search terms "allergy and fungal spores' "fungal spores and automatic" in the last 50 years (source Scopus December 2021).

Fungal Species

Among the various fungal spores, aerobiological surveys report the prevalence of fungal spores belonging to the *Cladosporium* and *Alternaria* genera, and they have been observed in various countries including United Kingdom (Martinez-Bracero, *et al.*, 2022' O'Connor, *et al.*, 2014; Sady's *et al.*, 2015), Denmark, Poland, Portugal Turkey, China, South Africa, Spain, Nigeria, the United States and Italy (Martinez-Bracero, *et al.*, 2022; Antón, *et al.*, 2019; Olaniyan, *et al.*, 2020; Odebode, *et al.*, 2018; Dietzel, *et al.*, 2019).

Cladosporium and *Alternaria* have been reported as the most abundant aeroallergens worldwide. Several concentration limits between 2000 and 4000 spores/m^3 have been proposed for *Cladosporium*, while more recent research has reduced the values to 500 to 1500 spores/m^3. In some earlier studies, even lowest concentration limits upto 50 spores/m^3 have been reported (Martinez-Bracero, *et al.*, 2022), and the varied values were being adopted in each study (10-30 spores/m^3 (Vélez-Pereira, *et al.*, 2019). On the other hand, general daily concentration of *Alternaria* has been reported upto 100 spores/m^3 (Martinez-Bracero, *et al.*, 2022).

Indoor and Outdoor Air Spores

The phrase "sick building syndrome" remained initially used during the 1970s to describe a scenario, wherein building inhabitants suffered from acute health issues that included many symptoms linked to spending time in a particular structure (Martinez-Bracero, *et al.*, 2022). Various symptoms were characterized that were correlated with the physical surroundings of a particular building and further linked to a rise in health issues among office employees (Martinez-Bracero, *et al.*, 2022). The existence of a particular fungus and its spores has been suggested as a biological reason for several illnesses including asthma attacks in sensitized individuals and acute respiratory failure. A number of studies have compared the prevalence of fungal spores found indoors and outdoors, illustrating the role of different ecological conditions in the survival and persistence of fungal spores (Cho, *et al.*, 2018).

Spore Trapping Methods and Analysis

There have been a variety of sampling techniques developed as a result of the vast range of studies involved in comprehending the impact that fungal spores might play on plant and human health. Numerous spore trappers have been manufactured for a single or variety of experiments under a different set of circumstances. Table 1 summarizes various sampling methods, particle size and techniques used in different types of samplers applied for fungal spores trapping.

Volumetric Samplers

A total of 637 samplers are now used worldwide, and the Hirst-type samplers have been employed as fundamental instrument for different studies related to PBAPs. Over 73% of the Hirst sampler are used to monitor fungal spores, despite being used primarily for pollens. A vacuum pump powers the Hirst sampler, which is based on the suction rate of the volumetric sample 10 L/min (Martinez-Bracero, *et al.*, 2022). Since the quality of the data obtained depends in part on the operator's expertise, there have recently been concentrated attempts to assess data quality (Galán, *et al.*, 2014; Sikoparija, *et al.*, 2017; Smith, *et al.*, 2019) and standardize such approaches (Galán, *et al.*, 2014, 2017; Sikoparija, *et al.*, 2017; Smith, *et al.*, 2019). This sampler type also has an electrical requirement because it requires the main power source for its operation. As a result, distant sampling may be challenging. However, they are the most often utilized samplers in literature research, especially those that concentrate on fungal air spores as allergen or as promoters of plant diseases (Martinez-Bracero, *et al.*, 2022; Grinn-Gofro' *et*

Table 1. Different types of samplers for fungal spores

Sampler	Sampling Method	Rate of Flow (l min–1)	Particle Size Range	Sample Period	Time Resolution	Culture	Microscope	Biosensor/ Molecular	Fluorescence (nm)
Instantaneous Bioaerosol Analysis and Collection (IBAC)	Laser Fluorescence	3.8	<7	Data storage dependent	1s to 1 min.	No	No	Yes	450-600 nm
BioScout	Laser diode Fluorescence	2	0.5-10	Data storage dependent	1s	No	No	No	>420 nm
Wideband Integrated Bioaerosol Sensor (WIBS)	Fluorescence (two Xeflashlamps)	2.4	5.0-30	Data storage dependent	Milliseconds	No	No	No	310-400 nm and 650 nm
Ultraviolet Aerodynamic Particle Sizer (UV-APS)	UV laser Fluorescence	1	0.5-20	Data storage dependent	1s-18 h (5 min generally)	No	No	No	430-575 nm
Andersen	Impaction	28.6	<10µm	0.2–20 min due to collection plate saturation	0.2 min	Yes	Processed needed to spore extraction	Yes, requires processing steps.	
Burkard Portable Air Sampler	Impaction	10 to 20	<10 µm	<1day	Dependant on plate changing	Yes	No	Yes, requires processing steps	
Passive	Impaction	Dependant on wind	>5 µm	Data storage dependent	Dependant on plate changing	No	Yes	Yes, requires processing steps	
Rototod	Impaction	100–150	<10 µm	up to 12–24 h dependant on concentration		No	Yes	Yes, requires processing steps	
PVAS	Impaction	10	>5 µm	up to 1 day	up to hourly	No	Yes	Yes, requires processing steps	
Hirst	Impaction	10	>5 µm	7 days	up to hourly (daily generally)	No	Yes	Yes, requires processing steps	

al., 2018, O'Connor *et al*., 2014; Martínez-Bracero *et al*. 2019). Other volumetric samplers based on the Hirst-type sampling have been manufactured, combining a smaller design with an inbuilt battery and enabling monitoring in remote areas without access to electricity. The Personal Volumetric Air Sampler is one of the examples that is ideally suited to the sampling of spores in distant areas lacking the resources of energy.

Fungal spores that have been trapped in a Vaseline-covered microscope slide move at the same speed as Hirst-type sampler (2 mm/h) using a clockwork arrangement because they are volumetric (10 L/min) (Garcia-Mozo *et al*., 2020, Martinez-Bracero *et al*., 2022). Another impaction tool that has been utilized in ambient monitoring is a Rotorod air sampler. This technique relies on accelerating airflow in order to hit particles as it approaches the trapping surface. This is accomplished by rapidly rotating the rod in a circular motion. The sampler is generally unaffected by the speed of the outside wind (Kapadi *et al*., 2019), and efforts are currently being made to standardize the results (Anderson, *et al*., 2020).

Non-Volumetric Samplers

The most basic samplers of this kind are sometimes referred to as "Passive samplers", because these samplers operate by passive deposition. Numerous fungal spore investigations have been conducted in the USA using these sorts of samplers (West *et al*., 2015). They have been demonstrated to function efficiently in observing coffee rust and sugarcane rust in Mexico, where there is no access to power (Martínez-Bracero *et al*., 2019; West *et al*., 2015). Compared to Hirst samplers, these samplers have demonstrated R2 values as high as 0.61. Lower amounts of spores were caught at lower wind speeds, demonstrating the reliance on wind speed. They are useful for identifying airborne fungal spores (Martínez-Bracero *et al*., 2019).

Fungal Spores and Climate

It has also been suggested that fungal spores (and other PBAPs) may influence climate by scattering and absorbing light, or by inadvertently influencing the cloud and precipitation (Conen *et al*., 2017). If there is enough relative humidity to provide saturation, water can condense onto the surface of a suitable particle, resulting in the formation of clouds. These aerosols, known as cloud condensation nuclei (CCN), form at temperatures higher than those of ice nuclei (IN) (Martinez-Bracero *et al*., 2022).

Bioaerosol has made a very important contribution to IN and CCN formation, and there is still a significant debate over the overall role of PBAPs in cloud formation. This aspect is still significantly under studied in comparison to the more prevalent atmospheric aerosols, including dust, organics, smoke particles, sea salt, and sulphates (Bieber *et al*., 2020). Several studies suggest that these biological IN/CCN contributes significantly, especially in terms of ice nucleation, even if the full degree of their impact is still not understood. These studies have suggested the impact of IN-PBAPs in other important areas, specifically the effect of aerosols on the hydrological cycle in the Amazon region (Martinez-Bracero *et al*., 2022; Whitehead *et al*., 2016).

Conclusion

Cladosporium and *Alternaria* were regarded as more significant fungal spore types discovered, because of their pathogenic, phytotoxic, and aeroallergen qualities, and their enormous abundance in the atmosphere. The various spore collection techniques were initially divided into "non-volumetric (passive) and conventional volumetric (active) samplers, such as the Hirst and Rotorod samplers with electrically powered components". The Burkard portable air sampler and the Andersen sampler, and active samplers are other examples using different approaches for collecting fungal spores. The use of real-time light-induced fluorescence instruments, such as the UV-APS, the Bio Scout, the IBAC, and the variety of WIBS devices" are other alternative means of sampling or quantifying the fungal spores.

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