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ORIGINAL PAPER

Investigating the relationship between atmospheric concentrations of fungal spores and local meteorological variables in Kastamonu, Türkiye

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Abstract Certain fungal spores in the atmosphere are one of the main factors that cause asthma attacks and allergic rhinitis symptoms in susceptible individuals. Elevated concentrations of fungal spores cause a significant reduction in the quality of life of susceptible individuals, and an increase in workloads at hospitals. In addition, some fungal spores can contaminate agricultural crops, compromising plant health and food safety and inflicting economic losses. The analysis of atmospheric fungal spores through aerobiological studies and the determination of their relationship with meteorological factors can support reduced exposure to allergens and favor early precautions against agricultural pests. In this study, fungal spores in the atmosphere in Kastamonu, Türkiye were studied hourly throughout 2017 using the volumetric method. Through the study, fungal spores belonging to 41 different taxa were detected in Kastamonu's atmosphere: *Cladosporium,* 58.76%; *Leptosphaeria,* 8%; and *Pleospora,* 5.01%; and *Alternaria* 4.98% were the dominant fungal spores in Kastamonu's air. The annual spore integral was 3868 spores/m^3 per day, and 4.48% of the taxa featured concentrations of less than 1%. In terms of total spore concentration, the highest readings were taken at 3:00–4:00 am in the summer, 6:00–7:00 am in the spring, 3:00–4:00 pm in the fall, and 12:00–1:00 am in the winter. Air temperature stands out as the most effective meteorological parameter, showing a positive correlation with all the dominant fungal spores. The direction and intensity of the correlation between meteorological parameters and fungal spores in the atmosphere vary significantly for each species. Longer-term studies are recommended to determine behavioral patterns and to better understand the abundance of fungal spores and their associated meteorological factors.

Keywords Aerobiology · Annual spore integral · Hourly data · Meteorological factors

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1 Introduction

A significant portion of the aerobiological particles in the air is comprised of fungal spores, which are harmful to both human and plant health (Banchi et al., 2020; Damialis and Gioulekas, 2006; Tordoni et al., 2021). Millions of tons of fungal spores are released into the atmosphere each year from natural sources, such as forests, farms, rural areas, and decaying plant material (Kasprzyk, 2008). Due to their small size, 10–30 microns, fungal spores can remain suspended in the air for long periods of time and can be dispersed by wind over long distances (Kilic et al., 2020), and fungi can start producing spores very quickly under propitious habitat and climatic conditions. The relationship between local meteorological factors and fungal spores has been reported by many authors (Angulo-Romero et al., 1999; Ceter and Pinar, 2009; Oliveira et al., 2009a, 2009b; Kilic et al., 2010; Grinn-Gofroń and Bosiacka, 2014). Meteorological parameters such as air temperature and humidity affect the amount of spores, while wind and precipitation can contribute to their airborne dispersal or clearance (Angelosante Bruno et al., 2007).

Approximately 110 fungal taxa have been reported to be associated with allergic reactions. Among fungal spores, Ascomycetes, Basidiomycetes, and Zygomycetes are the main groups of fungi including genera that cause allergic reactions (Frączek et al., 2023; Nicoleta and Dorina, 2009; Kurup et al., 2000). Due to their small diameter, fungal spores can enter the lower respiratory tract and cause respiratory allergies (Kilic et al., 2020). *Alternaria*, *Cladosporium*, and *Aspergillus* are considered the most allergenic fungal spores, while taxa such as *Botrytis*, *Fusarium*, and *Curvularia* reduce quality of life due to their allergenic properties (Górzyńska et al., 2023). Fungal spores that cause acute and severe asthma attacks in susceptible patients, especially children, are associated with a high number of hospitalizations (Bush and Prochnau, 2004; Denning et al., 2014; Gabriel et al., 2016; Katotomichelakis et al., 2016). There is a significant positive correlation between the atmospheric concentrations of these fungal spores, especially *Alternaria*, and symptoms of respiratory problems, allergic asthma, and rhinosinusitis (Singh et al., 2008; Angelosante Bruno et al., 2007). *Alternaria* can also cause an inflammatory skin condition known as atopic dermatitis (Ozoh et al., 2019). Some fungal spores can contaminate agricultural products, causing food supply losses (Fones et al., 2020; Martinez-Bracero et al., 2022). Therefore, the measurement of annual spore distribution, airborne duration, peak periods and risk periods is extremely important to reduce the epidemiologic uncertainty of respiratory allergies and to protect the agricultural sector (Hernandez-Ramirez et al., 2021).

Although there have been many studies focusing on the distribution and seasonal fluctuations of fungal spores in the external environment in recent years, the number of aerobiological studies conducted in Türkiye is relatively limited. Only a few of these studies have correlated the distribution of fungal spores with meteorological factors. In previous studies conducted in the Black Sea region of Türkiye, where the study area is located, it was reported that spores belonging to the taxa *Cladosporium*, *Alternaria*, *Leptosphaeria*, *Pleospora*, *Ustilago*, and *Fusarium* were dominant (Çeter, 2008; Çeter et al., 2012; Karabıcak, 2019). However, it is recommended that long-term studies be conducted in order to adequately understand the behavior of fungal spores in a given region.

This study aims to verify the fungal spores and their concentrations in the outdoor environment of Kastamonu and to establish the relationships between daily/hourly changes in the concentrations of the dominant fungal spores in the atmosphere and meteorological parameters.

2 Materials and methods

2.1 Sampling site

Kastamonu city is in the Central Black Sea region of Türkiye, which corresponds to 1.7% of it's territory. The Kastamonu province is generally mountainous, and the Western Black Sea Mountains lie in the north (Fig. 1). The surface area of Kastamonu is approximately 131,081 km^2, and the average elevation is 775 m above sea level. Kastamonu province's terrain in generally rugged. The city center where the monitoring study was carried out is located between the Küre Mountains in the north and the Ilgaz Mountains in the south (Karabicak, 2019).

Due to the effects of the high mountainous terrain in the north of the province, the maritime climate cannot penetrate into the inner parts, so a continental climate prevails in the city center of Kastamonu. In the city center of Kastamonu, where the measuring station is located, the average temperature between 1930 and 2023 was highest in July (20.2 °C) and lowest in January (−1.0 °C). The highest monthly

Fig. 1 Representation of the study area. **A**) Location of the monitoring station, **B**) Location of Kastamonu province, **C**) Location of Turkey on the world map. We take these pictures from Google Earth (https://earth.google.com/web/)

total precipitation was in May (75.4 mm), while the driest month was February (27.1 mm).

2.2 Sampling method

The samples were collected using a Hirst-type spore trap (from January to December 2017 at the Kastamonu University Science Faculty building, located in the northern district of Kastamonu – Türkiye (41°22′35″N 33°46′35″E). The flow rate of the Burkard spore trap is 10 L/minute. The volumetric air sampler was fitted with an optically clean, greased (Lubrisol) tape (Melinex) set in a drum rotating anticlockwise at a rate of 2 mm per hour. The counting of the spores was carried out meeting the minimum requirements of the European Society of Aerobiology (EAS) for fungal spore monitoring (Galán et al., 2014), and the EN16868 (2019) standard. According to Galán et al. (2017), the average daily spore concentration was reported as spores per cubic metre (spores/m^3) and the Annual Spore Integral (ASIn) as spores day per cubic metre (spore*day/m^3).

2.3 Statistical analysis

The annual pollen integral, obtained by summing up the daily spore concentrations calculated over a year, was used to compare the fungal spores detected in the atmosphere (Marchesi, 2019). We performed descriptive statistical correlation analyses for meteorological variables and spore concentration using R software (R Core Team, 2021). Correlation analyses were conducted to determine the association between spore concentration and meteorological variables.The correlation analyses used daily average spore concentrations and daily average temperature, relative humidity, precipitation and wind speed data from the nearest meteorological station. The normal distribution of the fungal spore concentrations was assessed using the Kolmogorov–Smirnov and Shapiro–Wilk tests. Since the spore concentrations did not feature a normal distribution, Spearman's correlation was used. The results were considered significant at the 95% confidence level. The dominant fungal spore taxa were shown graphically on a daily and hourly basis using the line graphs.

3 Results and Discussion

In 2017, when the monitoring study was conducted, the average monthly temperature was measured at the highest level in July, at 21.3 °C; and at the lowest level, in January, at −2.3°C. While the average daily wind speed throughout the year was 1.47 m/sec, the highest daily wind speed was 1.7 m/sec (Table 1).

The research identified 41 distinct types of fungal spores, with *Alternaria*, *Cladosporium*, *Leptosphaeria*, and *Pleospora* emerging as the most abundant (Table 2). We noted that *Cladosporium* has the highest Annual Spore Integral (ASIn) value, representing 58.37% of all spores (34,447 spores/m^3). *Leptosphaeria* (4675 spores/m^3), *Alternaria* (2941 spores/m^3), and *Pleospora* (2904 spores/m^3) constituted 7.92%, 4.98%, and 4.92% of all spores, respectively. Other fungal spores with a rate of over 1% were *Agrocybe*, *Coprinus*, Diatrypaceae, *Didymella*, *Exosporium*, *Fusarium*, *Oidium*, 1-Septal Ascospore, *Ustilago*, and *Xylaria*. The daily mean fungal spore concentration was 161.68 spores/m^3. The highest spore concentrations were noted on May 28, with *Leptosphaeria* and *Cladosporium* measuring 326.83 spores/m^3. However, on June 24 and May 27 higher concentrations were detected for *Alternaria* and *Pleospora,* with 147.69 spores/m^3 and 187.69 spores/m^3.

According to numerous studies conducted worldwide, spores belonging to the taxon *Cladosporium*

Table 1 The sampling months and average values for the monthly meteorological variables at the climatological station (air temperature, relative air humidity, total precipitation, and wind speed) are shown

Sampling period	Air temperature (°C)	Relative air humidity (%)	Total precipitation (mm)	Wind speed (m/sn)
January	−2.3	80.9	13.6	1.3
February	1.1	70.5	1.4	1.6
March	6.3	68.7	26	1.5
April	8.8	61.9	41.1	1.7
May	13.6	69	41.5	1.7
June	17.8	73.6	138.2	1.4
July	21.3	61.6	30.9	1.7
August	21.2	63.6	63.7	1.7
September	18.2	58.6	11.8	1.5
October	10	73.8	42.2	1.3
November	4.7	84.7	15	1.1
December	1.9	90.2	43.7	1.2
Average	10.21	71.42	39.09	1.47

Table 2 Distribution of fungal spores detected in the atmosphere of Kastamonu

Fungal types	ASIn	Mean of daily spore concentration (spores/m^3)	Peak day	Peak value (spores/m^3)	Frequency percentage (%)
Cladosporium	34,447	94	28.05.2017	1215	58.37
Leptosphaeria	4675	13	28.05.2017	327	7.92
Alternaria	2941	8	24.06.2017	148	4.98
Pleospora	2904	8	27.05.2017	188	4.92
Agrocybe	1604	4	8.06.2017	233	2.72
Diatrypaceae	1433	4	27.03.2017	260	2.43
Fusarium	1382	4	26.09.2017	252	2.34
Oidium	1168	3	20.07.2017	150	1.98
Coprinus	1063	3	11.06.2017	241	1.80
Exosporium	1019	3	19.07.2017	60	1.73
Didymella	993	3	30.05.2017	266	1.68
1-Septal Ascospore	894	2	18.06.2017	85	1.51
Ustilago	889	2	28.05.2017	85	1.51
Xylaria	858	2	8.06.2017	284	1.45
Melanomma	550	2	8.06.2017	79	0.93
Nigrospora	356	1	20.01.2017	31	0.60
Epicoccum	286	1	26.01.2017	7	0.49
Peronospora	210	1	19.01.2017	69	0.40
Venturia	160	0	13.03.2017	14	0,36
Stemphylium	159	0	19.07.2017	14	0,27
Coloured basidiospores	133	0	5.05.2017	30	0,27
Paraphaeosphaeria	123	0	23.08.2017	6	0,22
Torula	99	0	26.05.2017	13	0,21
Ganoderma	96	0	1.08.2017	3	0,17
Drechslera	65	0	20.03.2017	4	0,16
Periconia	36	0	26.03.2017	2	0,11
Pithomyces	34	0	21.01.2017	5	0,06
Myxomycetes	33	0	19.08.2017	2	0,06
Chaetomium	26	0	26.03.2017	2	0,06
Dictyosporium	21	0	8.06.2017	2	0,04
Boletus	18	0	20.07.2017	3	0,04
Arthrinium	17	0	24.01.2017	2	0,03
Didmyosphaetia	13	0	25.05.2017	3	0,03
Botrytis	12	0	4.03.2017	1	0,02
Puccinia	11	0	16.06.2017	2	0,02
Polythrincium	10	0	28.05.2017	2	0,02
Tetracoccosporium	10	0	23.03.2017	3	0,02
Multiseptal Ascospore	10	0	7.04.2017	1	0,02
Curvularia	9	0	7.01.2017	1	0,02
Sporormiella	6	0	15.10.2017	1	0,02
Melanospora	5	0	13.06.2017	2	0,01
Ascobolus	34,447	94	5.03.2017	1215	0,01

are the most abundant in the atmosphere. In the study conducted by Çeter (2008) covering the years 2006 and 2007, it was reported that *Cladosporium*, *Alternaria*, *Leptosphaeria*, *Pleospora*, *Ustilago*, and *Fusarium* spores were dominant in the atmosphere. In a similar study conducted by Topbaş et al. (2006) in five different areas of Trabzon city in the Black Sea region having similar climatic conditions, the most common spores in the atmosphere were *Cladosporium* (34.4–72.8%), *Leptosphaeria* (4.3–11.7%), *Alternaria* (2.1–5.7%), *Aspergillus/Penicillium* (2.6–29.0%), *Pleospora* (0.5–3.9%), and *Ustilago* (0.8–2.5%). When the monitoring station data were compared, we saw significant differences between meteorological parameters and spore concentrations. For example, the prevalence of *Pleospora* was higher in the Gümüşhane and Sinop regions, which are located in the same climate zone as the station where this study was conducted, while that of *Cladosporium* spores was higher in the Gümüşhane and Çankırı provinces than at other stations. In a survey conducted of the atmosphere in inland areas of Niğde (Türkiye), fungal spores belonging to 39 different taxa were detected. The most common spores were found to be *Cladosporium* (69.46%), *Alternaria* (7.21%), *Melanoma* (2.98%), *Leptosphaeria* (2.69%), and *Exosporium* (1.98%) (Çeter et al., 2020). As reported in similar studies conducted worldwide, and in Türkiye, spores of taxa such as *Cladosporium*, *Alternaria*, *Leptosphaeria*, *Pleospora*, *Ustilago*, and *Aspergillus/Penicillium* are among the most abundant in the atmosphere (Almaguer-Chávez et al., 2018; Anees-Hill et al., 2021; Kilic et al., 2020; Paula et al., 2022; Singh and Mathur, 2021).

In this study, the highest average monthly spore concentration was found in June, and the lowest, in December, as fungal spore concentrations fluctuate over the course of the year. The total number of spores was approximately three times less in February than in January. After this decrease in February, pollen concentrations increased more than four-fold in March. The increasing average monthly spore concentration peaked in June after a modest decline in April. It then dropped to the May level again in July, August, and September, following a stable course during these three months. It has been determined that the average monthly spore concentration steadily declined until the end of the year.

Fungal spore concentrations have also been observed to vary seasonally throughout the year, generally being highest in the summer and lowest in the winter. *Alternaria* spores, which were seen at a very low level in the first five months of the year, increased significantly in June, peaking in this month, after which they decreased regularly until December. It is observed that the amount of *Cladosporium* spores started to increase starting in May, peaked in June, and then decreased steadily until December. While the pollen concentrations of *Leptosphaeria* started to increase beginning in March, and reached their peak in May, the increase in *Pleospora* started in March and peaked in April. After a sharp decrease in the spore densities of both taxa in July compared to the previous month, a partial increase was detected in August (Fig. 2).

Many studies have reported that the concentrations of fungal spores fluctuate throughout the year. Although the concentration of fungal spores generally increases in the summer months, peak values and periods vary from region to region and from taxon to taxon. In Slovakia the sporulation of *Cladosporium*, which represents 71% of all spores, was between June and November, while for *Alternaria* it was from the last period of June to the beginning of September. *Leptosphaeria* was detected from the middle of June to early September, and *Pleospora*, unlike in Kastamonu, was detected in much lower concentrations in the atmosphere, and the periods when it was most intense were found to be between the last 10 days of March and the first 20 days of May (Ščevková and Kováč, 2019). It was reported that fungal spores reached their highest level on September 9 in Porto, Portugal, which is located at a latitude close to our working station (Oliveira et al., 2005). It has been reported that the intensity of spores increases in the summer and late autumn and reaches its lowest levels in January and February. While *Cladosporium* and *Alternaria* peaked in September, it was determined that *Leptosphaeria* had uniform behavior, and was more frequent throughout the year (Oliveira et al., 2005). Similarly, in a study conducted in Northeastern Greece, it was found that *Cladosporium* and *Alternaria* spores were the most common ones detected in the summer months (Katsimpris et al., 2022; Komnos et al., 2022).

The distribution of spores during the day follows a fluctuating course, taking into account the

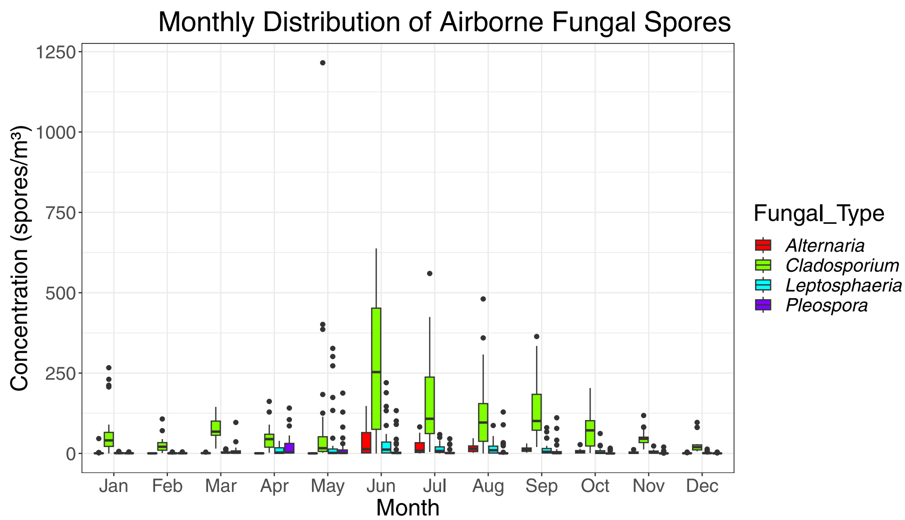

Fig. 2 Monthly distribution of fungal spores found in air graph. Vertical lines and box plots show quartile distributions, horizontal lines show medians. Dots show extreme values

hourly averages observed throughout the year. *Cladosporium* and *Alternaria* spore concentrations for both species peaked in the middle of the day and were lower in the morning hours. *Pleospora* concentrations peaked between 4:00 and 5:00 pm, while *Leptosphaeria* reached its highest concentration between 4:00 and 5:00 am. However, the highest spore concentrations occurred between 8:00 and 9:00 pm on May 28, 2017, with 6068 spores/m^3 for *Cladosporium*; between 12:00 and 1:00 am on June 24, 2017, with 481 spores/m^3 for *Alternaria*; between 3:00 and 4:00 am on April 20, 2017, with 1406 spores/m^3 for *Pleospora*; and between 5:00 pm and 6:00 pm on May 27, 2017, with 1199 spores/m^3 for *Leptosphaeria* (Figs. 3, 4).

The distribution of daily atmospheric spores varies from country to country. For example, spore intensity peaks in the middle of the day in some regions (Al-Subai, 2002; Fayad, 2016), while in others it does so in the afternoon (Rodríguez-Rajo et al., 2005; Grinn-Gofrom and Strzelczak, 2009). In some places, it has been noted to peak at night (Quintero et al., 2009). Although the diurnal changes in spore concentrations vary from region to region, the diurnal behavior of *Cladosporium* and *Alternaria* in different years appears to have a clear pattern, to a large extent. The distribution of spores during the day is affected by meteorological parameters as well as proximity to spore resources (Bardei et al., 2017; Grinn-Gofroń et al., 2020; Oliveira et al., 2009b; Skjøth et al., 2012;

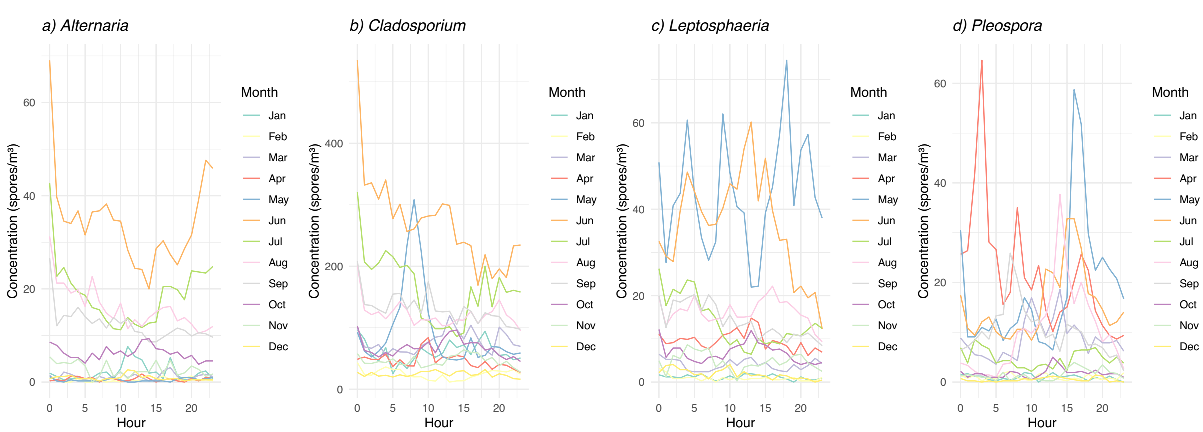

Fig. 3 Line plot of the hourly concentrations of the main fungal spores, *Alternaria*, *Cladosporium*, *Leptosphaeria*, and *Pleospora*, in the 2017 research study (Kastamonu)

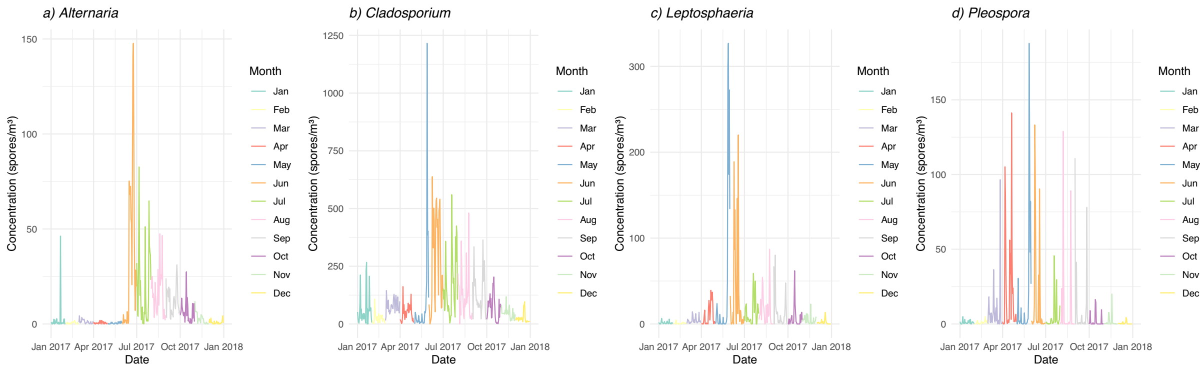

Fig. 4 Line plot of the daily concentrations of the main fungal spores, *Alternaria*, *Cladosporium*, *Leptosphaeria*, and *Pleospora*, in the 2017 research study (Kastamonu)

Thibaudon and Lachasse, 2006). The data obtained in this study show that *Alternaria* and *Cladosorium* spores, called dry season spores, are concentrated during the hours when humidity is highest. There is a negative correlation between the daily concentrations of these spore species and average daily humidity. However, the increased density of spores at night, when humidity is higher, may be due to the distance from the monitoring station to the agricultural areas where the primary sources of spores are concentrated. Similarly, Giner et al. (2001) reported that the distance of the monitoring station from the countryside may lead to delays in the detection of these spores.

A study in the Voršava, Poland region showed that concentrations of more than 80 *Alternaria* spores/m^3 caused symptoms in susceptible patients, while symptomps precipitated by *Cladosporium* appeared with concentrations surpassing 2800 spores/m^3 (Rapiejko et al., 2007). In the current study in Kastamonu province both fungal spore concentrations were higher. The results indicate a significant increase in levels, as shown by the daily averages, with a particular emphasis on *Alternaria* spore concentrations. In this context, it seems highly probable that allergic symptoms were triggered by these fungal spores in the province of Kastamonu in May and June.

The presence, density, and seasonal distribution of fungal spores in the atmosphere are strongly affected by meteorological factors. The results support the idea that meteorological factors can predict possible increases in spore densities in long-term studies. It is observed that rainy days have a significant negative effect on the concentration of some fungal spores. During the study period, *Alternaria*'s spore integral was determined as 2264 spores/m^3 on rainless days, while this value decreased to 680 spores/m^3 on rainy days. Similarly, *Cladosporium*'s integral was found to be 22,696 spores/m^3 on rainy days, while it was 11,737 spores/m^3 on rainless days. However, it was detected that *Pleospora* and *Leptosphaeria* spores tend to be detected a little more on rainy days. The pollen integral of *Pleospora* and *Leptosphaeria* was found to be 1054 spores/m^3 and 2128 spores/m^3 on rainy days, respectively, while it was found to be 1853 spores/m^3 and 2553 spores/m^3 on rainless days. The incidence of *Alternaria* spores increases on days when the average daily temperature exceeds 15 °C. It reaches its peak on days when the average daily temperature is between 18 and 20 °C, while *Alternaria* spores are very rare on days below 5 °C. While *Cladosprium* spores increase between 15 and 20 °C, they are very rare below 5 °C. The concentration of *Leptosphaeria* spores increases between 10 and 15 °C, while the concentration of *Pleospora* is higher on days above 10 °C. *Pleospora*, however, appears to be less affected by temperature changes than other taxa. Spore intensity increases significantly mostly due to hot weather following rains. While the incidence of *Pleospora* spores is slightly higher on days with somewhat windy weather, the amount of *Alternaria*, *Cladosporium*, and *Leptospora* spores decreases on days when wind speeds exceed 2 m/s (Fig. 5).

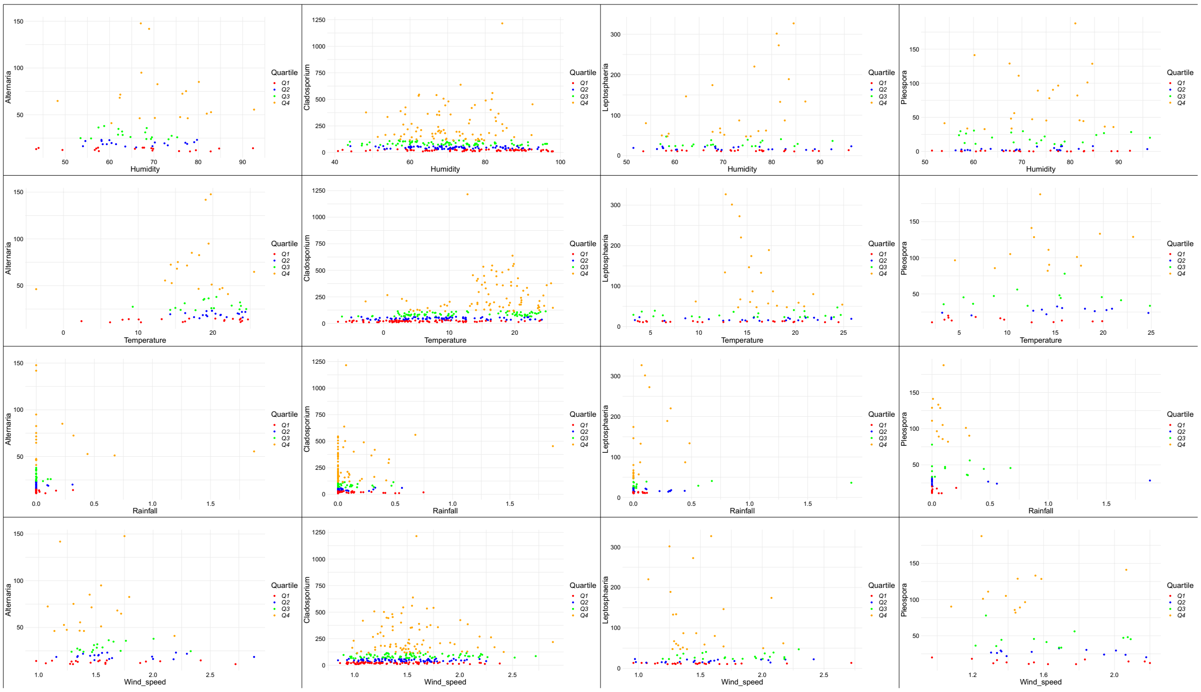

Fig. 5 Highlighting the key elements of the current research, specifically the focus on four specific taxa (*Alternaria*, *Cladosporium*, *Leptosphaeria*, and *Pleospora*) and their relationship with the four meteorological parameters, i.e., Temperature, Humidity, Rainfall. The dots show the distribution of the concentration detected in the relevant meteorological parameter in sports on the basis of quartiles

According to Spearman's correlation analysis, temperature level showed a significant positive correlation with *Alternaria* ($p<0.01$, $r=0.57$), *Cladosporium* ($p<0.01$, $r=0.42$), *Pleospora* ($p<0.05$, $r=0.12$) and *Leptosphaeria* ($p<0.01$, $r=0.33$), while humidity showed a negative correlation with *Alternaria* ($p<0.01$, $r=-0.21$) and *Cladosporium* ($p<0.05$, r $=-0.14$). In addition, rainfall amounts were positively correlated with *Pleospora* ($p<0.05$, $r=0.13$) and *Leptosphaeria* ($p<0.05$, $r=0.14$), and wind speed was positively correlated with *Cladosporium* ($p<0.01$, r $=0.16$), *Pleospora* ($p<0.01$, $r=0.21$) and *Leptosphaeria* ($p<0.05$, $r=0.14$). The increases in *Alternaria* and *Cladosporium* in the summer months are due to seasonal temperature increases (Fig. 6).

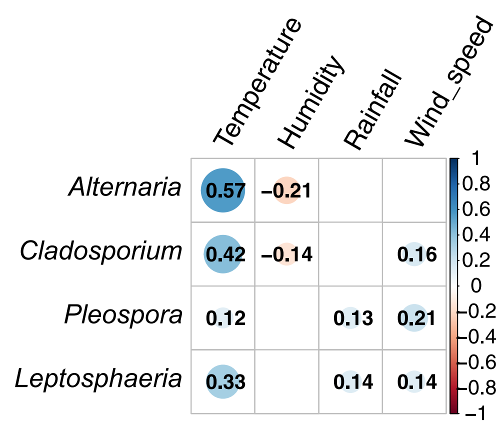

Fig. 6 Correlation plot between spore concentrations and meteorological variables. The colour and size of each circle indicate the correlation coefficient; meteorological parameters without any significant correlations are not shown

Numerous studies have thoroughly investigated the relationship between fungal spore concentrations and meteorological conditions. Our results concurred with similar findings by different studies that noted that that amounts of *Alternaria* and *Cladosporium* spores increase with temperature and decrease with rainfall and relative humidity (Oliveira et al., 2009b; Artac et al., 2014; Recio et al., 2012). Haskouri et al. (2016) stated that *Leptosphaeria* and *Pleospora* spore concentrations showed a positive correlation with wind, as determined in the current study. As seen in many studies, temperature is the meteorological parameter showing the strongest correlation with total spore concentration (Grinn-Gofroń et al., 2011, 2020; Martínez-Bracero et al., 2022; Sevindik et al., 2021; Troutt and Levetin, 2001). The dominant pollen group detected in the study area was mesophilic. These spores, which constitute a significant portion of allergenic spores, exhibit optimum growth at 20–40 °C (Grinn-Gofroń and Bosiacka, 2014). Thus, sensitive individuals may encounter allergens more between July and October, when the air temperature is above 20 °C. Although the relationships between meteorological factors and spore concentrations are, generally, well established, the degree and direction of these relationships may vary depending on the region and year. We should stress the need for long-term monitoring of them in different regions, which could facilitate the prediction of spore concentrations.

4 Conclusion

This study reveals the distribution and quantity of spores seen in Kastamonu's atmosphere throughout the year and their relationships with meteorological factors. *Cladosporium*, *Alternaria*, *Leptosphaeria*, and *Pleospora* were detected as the most abundant spores in the atmosphere, representing more than 75% of all those detected. It is thought that there may be an increase in the occurrence of allergic symptoms in sensitive individuals, especially during periods when the concentration of *Cladosporium* and *Alternaria* spores is higher than 2800 spores/m^3 and 80 spores/m^3, respectively, such as in May and June. During the year studied, *Cladosporium* and *Alternaria* spores seemed to be most abundant at midnight, and we noted that the evening hours were more favorable for *Leptosphaeria* and *Pleospora*. Temperature stands out as the meteorological factor that contributes most to fungal spores during the summer, after a rainy period. In addition, during the summer months, when the air temperature facilitates the growth and reproduction of fungi, the concentration of atmospheric fungal spores is at its highest levels. The composition of fungal spores in the atmosphere of a region can vary depending on different influences, such as the region's geography, flora, and land use areas.

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Data availability Data will be available upon request.

Declarations

Conflict of interest The authors declare no competing interests.

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