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Determination of Some Fungal Spores in the Atmosphere of Iğdır and Comparison with Meteorological Factors

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Abstract: In this study, the density of fungal spores belonging to 10 specific taxa with allergenic effects and their relationship with meteorological factors in the atmosphere of Iğdır, Türkiye was investigated. Hirst trap device was used for atmospheric spore sampling during the study. As a result of the study, fungal spores were found more or less in the atmosphere in all months. A total of 156702 spores/m^3 were detected in the atmosphere of Iğdır during the study. The densities of the 10 taxa detected in the atmosphere of Iğdır were recorded as *Cladosporium* (85.00%), *Alternaria* (6.16%), *Aspergillus/Penicillium* (5.91%), *Fusarium* (1.30%), *Epicoccum* (0.61%), *Chaetomium* (0.26%), *Drechslera* (0.24%), *Stemphylium/ Ulocladium* (0.21%), *Pithomyces* (0.19%) and *Curvularia* (0.11%), respectively. It was determined that the density of fungal spores was at a high level between August and October and that this period posed a risk for individuals with an allergic tendency to fungal spores.

Keywords: Aerobiology, Atmospheric fungal spores, Volumetric method, Iğdır, Türkiye

Iğdır Atmosferindeki Bazı Mantar Sporlarının Belirlenmesi ve Meteorolojik Faktörlerle Karşılaştırılması

Öz: Bu çalışmada alerjik etkiye sahip geniş yayılışı bulunan belirli 10 adet taksona ait mantar sporlarının Iğdır, Türkiye atmosferindeki yoğunluğu ve meteorolojik faktörlerle ilişkisi araştırıldı. Çalışma süresince atmosferik spor örneklemeleri için Hirst tip örnekleme cihazı kullanıldı. Çalışma sonucunda tüm aylarda atmosferde az ya da çok mantar sporuna rastlandı. Çalışma süresince Iğdır atmosferinde toplam 156702 spor/m^3 tespit edildi. Iğdır atmosferinde tespit edilen 10 taksonun yoğunlukları sırasıyla *Cladosporium* (%85.00), *Alternaria* (%6.16), *Aspergillus/Penicillium* (%5.91), *Fusarium* (%1.30), *Epicoccum* (%0.61), *Chaetomium* (%0.26), *Drechslera* (%0.24), *Stemphylium/Ulocladium* (%0.21), *Pithomyces* (%0.19) ve *Curvularia* (%0.11) olarak tespit edildi. Ağustos – Ekim ayları arasında mantar spor yoğunluğunun yüksek seviyede olduğu ve bu dönem mantar sporlarına alerjik yatkınlığı olan bireyler için risk oluşturduğu tespit edildi.

Anahtar kelimeler: Aerobiyoloji, Atmosferik mantar sporları, Volümetrik yöntem, Iğdır, Türkiye.

Introduction

Among the particles carried by wind in the air, fungal spores are the most common. Fungal taxa are heterotrophic (cannot produce their own food) organisms in the living world and are widely distributed in the biosphere. Fungal particles are eukaryotic organisms that are either single or multicellular, have a haploid genome, have cell walls made of chitin and glucan, and produce spores (Naranjo-Ortiz and Gabaldón, 2019). The density of fungal spores dispersed from spore sacs during reproduction can vary due to various factors, such as geographical location, human activities, vegetation, air pollution and weather conditions (Grinn-Gofroń, 2015). In the respiratory system, large-sized fungal spores can reach the nasal cavities, medium-sized ones can reach the bronchi and bronchioles and small-sized ones can reach the alveoli (Deacon, 2006). The reason why fungal organisms are cosmopolitan is that they can germinate easily. Since they form a large number of spores with different morphological structures in their spore sacs during the reproduction period, they can be found in every condition and environment. They can be easily carried to various environments by winds. The density of fungal spores in the atmosphere is easily affected by meteorological factors, such as wind, temperature, humidity and precipitation, and the spore concentration changes. Therefore, determining the spore concentration of each region and preparing change graphs with meteorological factors are of great importance in the diagnosis and treatment of individuals with spore allergy.

Fungal spore causes various disorders, such as asthma in sensitive individuals and those with allergenic sensitivity to fungal spores (Bush and Portnoy, 2001). Some of these are respiratory allergies, such as asthma, allergic rhinitis, allergic sinusitis, allergic conjunctivitis and meningitis in infected individuals. These spores also cause an increase in IgA and IgE antibodies (Abbas et al., 2012; D'Amato et al., 1997; Kurup and Kumar, 1991; Khosravi et al., 2012; Dixit et al., 1992; Dixit et al., 1992; Bisht et al., 2004; Fuste et al., 1973; Rolston et al., 1985). Among the fungal spores that cause allergic diseases, there is a cosmopolitan genus, *Cladosporium*. This genus causes asthma in infected individuals (Bensch et al., 2012; Dugan et al., 2004). The optimum temperature conditions for the development of species belonging to this genus are between 20°C and 40°C (Gravesen, 1979). Studies have shown that *Cladosporium* species are among the most common causes of respiratory diseases, asthma and rhinitis, for example (Bouziane et al., 2005). It has even been reported that severe asthma attacks due to *Cladosporium* cause death (Abbas et al., 2012). It is a respiratory tract allergen of the genus *Alternaria* that causes allergic symptoms in the nasal and bronchial regions of the infected individual and causes the release of IgE antibodies (D'Amato et al., 1997; Filali et al., 2015; Fernández-Rodríguez et al., 2015). The other fungal genus that causes asthma, allergic rhinitis and allergic sinusitis in humans and animals is *Aspergillus* (Kurup and Kumar, 1991). *Penicillium* species secrete a fungal toxin called patulin, which has carcinogenic effects on the brain, liver and lung organs (Gravesen, 1979). The International *Penicillium* and *Aspergillus* Commission, which convened in Utrecht, Netherlands on April 14, 2012, brought these two genera together and evaluated them as a single taxon (*Aspergillus/Penicillium*) (Houbraken et al., 2014).

Fusarium is a fungal genus that increases IgE secretion in humans (Khosravi et al., 2012). *Epicoccum* is a fungal genus that increases allergen sensitization (Dixit et al., 1992) as well as IgE and IgG antibody secretions (Bisht et al., 2004). *Chaetomium*, a cosmopolitan genus with more than 80 species (Von Arx, 1986; Abdel-Azeem, 2020), has been shown to respond better to antibodies than other fungal species in cross-reactivity allergy tests (Provost, 2010).

Another fungal genus that increases IgE secretion is *Drechslera* (Menezes et al., 1995). It has been reported that the mycelium of *Drechslera hawaiiensis* belonging to this genus is seen in the brain region of patients and causes fatal meningitis (Fuste et al., 1973). It has also been reported to cause infections, such as corneal inflammation, skin lesions, peritonitis and inflammation of the facial sinuses (Rolston et al., 1985). *In vivo* and *in vitro* studies with extracts obtained from *Stemphylium/ Ulocladium* have found that this taxon to be allergenic (Agarwal et al., 1982). In a study conducted in homes where children with asthma symptoms, high concentrations of *Pithomyces* were found (Meng et al., 2012). In addition, this taxon was defined as a moderate allergen in a study (Aşçı et al., 2010). In a study conducted on *Curvularia lunata*, it was stated that this species is allergenic and causes sinusitis (Bartynski et al., 1990). In light of all these, it is thought that the 10 fungal species given above are very important allergens because they cause many allergic diseases in humans, such as respiratory tract allergy, asthma, allergic rhinitis, allergic sinusitis, allergic conjunctivitis and meningitis.

In this study, the densities of the 10 fungal genus mentioned above in the Iğdır atmosphere and their relationship with meteorological factors were investigated. It is thought that the obtained results will be useful in the fields of medicine, pharmacy and agriculture.

Material and Metod

Study Area

Iğdır, which was separated from Kars in 1992, is a province located in the Eastern Anatolia Region of Türkiye with its geographical location. Iğdır, which is the 15th smallest province of Türkiye in terms of surface area, has an altitude of 876 m above from sea level (Kaya, 2015). Neighbour city Ağrı is located in the south and southwest, and Kars is positioned in the northwest. The border of Iğdır province consist of Nakhchivan, which is affiliated with Armenia, Iran and Azerbaijan (Tan and Temel, 2017). As a continuation of the Karasu-Aras Mountains in the south of Iğdır province, there are Pamuk Mountain (2639 m), Durak Mountain (2811 m), Zor Mountain (3234 m), Büyük Ağrı (5137 m) and Küçük Ağrı Mountains (3896 m) (Göner, 1995; Şimşek and Alim, 2009). There are three border gates in total: the Dilucu Border Gate to Nakhchivan, the Boralan Border Gate to Iran and the Alican Border Gate to Armenia (Yulu, 2014) (Figure 1).

Iğdır province is located in the Eastern Anatolia Region of Türkiye and has remarkable characteristics in terms of its climate and vegetation. Iğdır province is geographically isolated as it is surrounded by Mount Ararat. This situation creates climate types in Iğdır province that can be categorized as semiarid, arid and very arid (Karaoğlu, 2023; Koçak et al., 2022). Iğdır's annual average temperature can be up to twice that of other provinces (Karaoğlu, 2014). Although these high temperatures provide a suitable environment for agricultural activities, they also make it difficult to manage water resources (Kaltakkıran, 2023). In addition, the annual average rainfall in the region is around 300-400 mm, which is a critical factor for agricultural production. The seasonal distribution of rainfall is low in the summer and more in the winter (Karaoğlu, 2014).

The vegetation in the region varies depending on the climatic conditions. Iğdır is an area where agricultural activities are intense and is known as a place where all types of agriculture can be done (Karaoğlu, 2014). Moreover, *Puccinellia distans* (Jacq.) Parl. and *Aeluropus littoralis* (Gouan) Parsl. species are commonly found in salty and alkaline pastures (Temel, 2018).

Analysis of Preparations under Microscope

Spore samples were collected with the help of volumetric pollen collection device. Microscopic slides were prepared by Wodehouse method, and spore slide examination was performed under a Leica brand DM500 model light microscope at 400 magnification.

For the identification and counting of fungal spores, the examination was carried out on microscopic slides along 4 horizontal lines with 2 mm intervals from the starting point. The results obtained were calculated and converted into fungal spore concentrations in one m^3 air (Soldevilla et al. 2007).

Evaluation of Results

Daily and monthly figures as well as monthly charts were created from the data obtained from the spore count results of the atmosphere of Iğdır province. Meteorological parameters and spores data were correlated with Spearman Correlation analysis (Table 4).

Meteorological Data

According to the meteorological data of Iğdır province, the lowest monthly average temperature (-0.34 °C) was measured in December, and the highest average temperature was measured in July (28.41 °C). The lowest average humidity rate was measured in June (41.33%), while the highest average humidity rate was measured in December (69.92%). The total precipitation amount in Iğır province in 2015 was determined as 209.6 mm. The lowest monthly total rainfall was determined in July (0.0 mm), while the highest was recorded in April (40.8 mm). The month with the lowest monthly total rainfall was determined in July (0.0 mm), while the month with the highest was determined in April (40.8 mm). Average temperature, humidity and precipitation values are given in Table 3 and Figure 3.

Results

In this study, the density of fungal spores belonging to 10 specific taxa was investigated. As a result of the study, a total of 156702 spores belonging to *Alternaria*, *Aspergillus/Penicillium*, *Chaetomium*, *Cladosporium*, *Curvularia*, *Drechslera*, *Epicoccum*, *Fusarium*, Pithomyces, Stemphylium/ Ulocladium taxa were detected.

The atmospheric concentrations of the 10 fungal spore taxa planned to be investigated in this study were determined as follows, respectively. These taxa were identified as *Cladosporium* (85.00%-133190 spore/m), Alternaria (6.16%-9654 spore/m^3), *Aspergillus/ Penicillium* (5.91%-9260 spore/m^3), *Fusarium* (1.30%-2040 spore/m^3), *Epicoccum* (0.61%-959 spore/m^3), *Chaetomium* (0.26%-404 spore/m^3), *Drechslera* (0.24%-376 spore/m^3), *Stemphylium*/*Ulocladium* (0.21%-335 spore/m^3), *Pithomyces* (0.19%-304 spore/m^3) and *Curvularia* (0.11%-180 spore/m^3) (Table 1 and Table 2).

Based on the data obtained in this study, the most detected fungal spores by month are; August 28.41% (44524), October 18.96% (29711), September 15.33% (24028), July 8.10% (12699), June %6.44 (10099), November 6.32% (9901), May 6.02% (9426), January 3.17% (4966), December 2.92% (4573), in April, 1.81% (2842), in March 1.71% (2672) and at least 0.80% (1261 spores/m^3) in February. (Table 1 and Table 2).

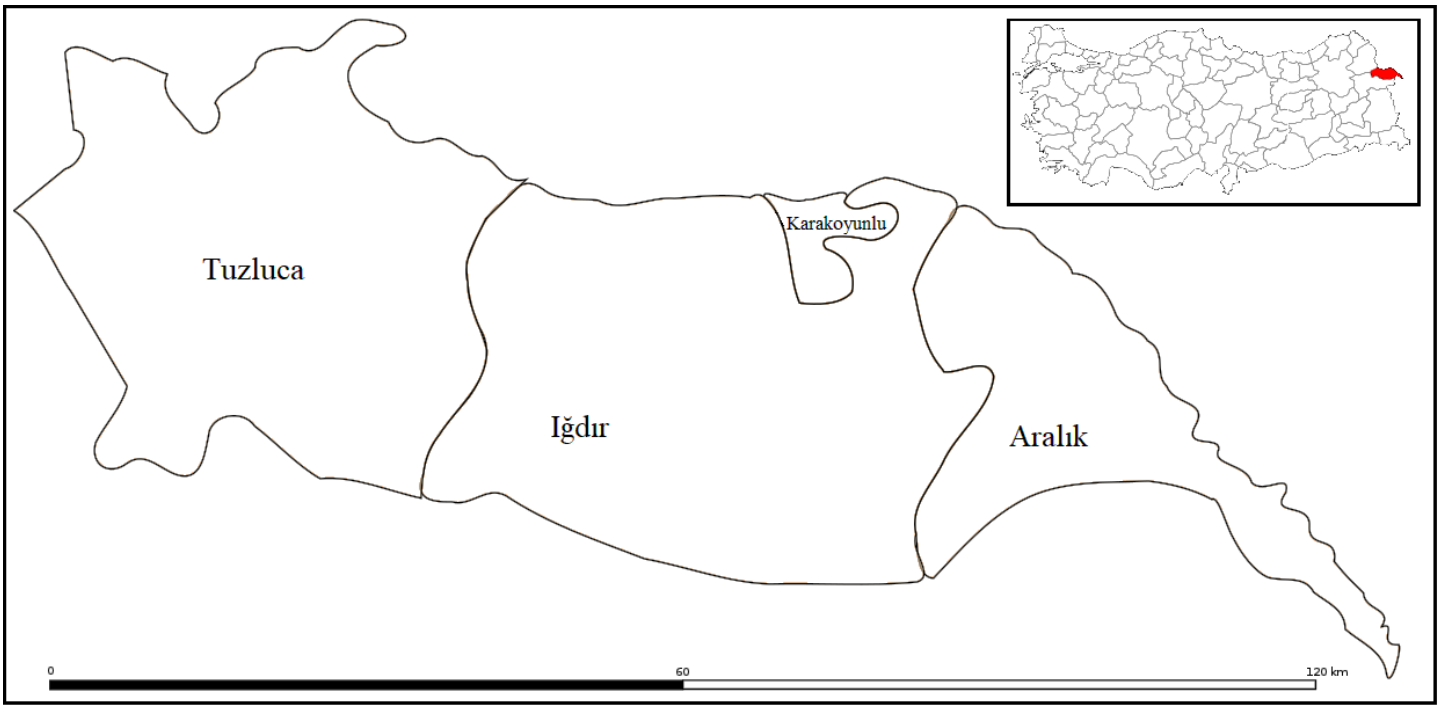

Figure 1. Location of Iğdır in Türkiye and districts of Iğdır province

Monthly Fungal Spor Distribution

Fungal spore distribution showed remarkable seasonal variation throughout the year. The number of fungal spores detected in January constituted 3.17% of the annual total, with *Cladosporium* (1.82%), *Aspergillus/ Penicillium* (0.77%) and *Epicoccum* (0.26%) being the most common species. In February, the number of spores decreased significantly, accounting for 0.80% of the annual total, but *Cladosporium* (0.41%) and Aspergillus/Penicillium (0.28%) were still dominant. A gradual increase in spore numbers was observed in March and April, with 1.71% of the annual total detected in March, and 1.81% in April. *Cladosporium* was also found to be at the highest rates compared to other species during this period. A significant increase in spore numbers occurred in May, with 6.02% of the annual total detected. During May, *Cladosporium* (4.79%) species were seen at higher rates, especially compared to other months, and species, such as *Alternaria* and *Fusarium* also showed a significant increase (Table 1 and Table 2).

In June, the number of spores increased slightly, accounting for 6.44% of the annual total. *Cladosporium* (5.15%) and Alternaria (0.65%) were among the most common species in this month. In the middle of the summer season, a more significant increase was recorded in the number of spores, especially in July. Spores were detected in this month accounting for 8.10% of the annual total. In July, *Cladosporium* (7.10%) was again dominant compared to other species (Table 1 and Table 2).

In August, the peak of the annual spore distribution was experienced, with 28.41% of the spores detected. During August, *Cladosporium* reached the highest rate of the entire year, accounting for 26.02% of the annual total. *Alternaria* (1.49%) and *Aspergillus/Penicillium* (0.50%) species were also detected at higher rates in this month (Table 1 and Table 2).

As for the autumn months, the number of spores continued to remain at high levels in September and October. While 15.33% of the annual total was detected in September, this rate increased to 18.96% in October. During this period, *Cladosporium* was detected at very high rates, especially in October (17.58%), and *Alternaria* and *Aspergillus/Penicillium* species also showed a distinct presence (Table 1 and Table 2).

In November and December, a decrease in the number of spores was observed with the onset of winter. 6.32% of the annual total was detected in November and 2.92% in December. During this period, Cladosporium (4.80%) and *Aspergillus/Penicillium* (1.04%) species were found to be more common than other species, especially in November (Table 1 and Table 2).

As a result, fungal spore distribution showed significant seasonal changes throughout the year, with significant increases in spore numbers especially in summer and autumn. *Cladosporium* species was the dominant species throughout most of the year, but other species also showed seasonal densities depending on seasonal conditions. These findings revealed how fungal spore distribution changed depending on environmental factors and seasons, and provide important data to determine in which periods spore densities were higher (Table 1 and Table 2).

When total fungal spores were evaluated daily according to months, it was determined that August 27 was the most abundant day with 6040 spores/m^3. The second highest fungal spore density was detected on 28th August with 5219 spores/m^3 and the third highest fungal spore density was detected on 13th October with 4792 spores/m^3 (Figure 5).

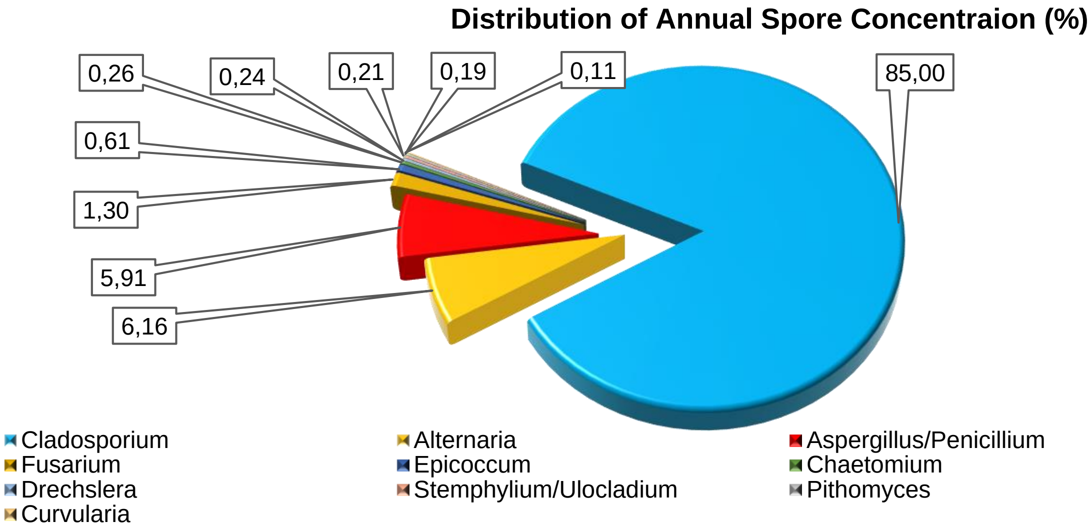

Figure 2. Annual spore concentration in the atmosphere of Iğdır (%)

Table 1. Monthly fungal spore distribution in Iğdır atmosphere (spore/m^3)

TAXA	January	February	March	April	May	June	July	August	September	October	November	December	Total Spore/m^3
Cladosporium	2855	638	1620	1924	7499	8076	11126	40776	20844	27555	7514	2763	133190
Alternaria	200	41	40	172	869	1018	973	2337	2131	1131	591	151	9654
Aspergillus/Penicillium	1208	446	932	642	247	211	384	776	640	556	1628	1590	9260
Fusarium	17	2	14	45	709	574	57	246	75	283	18	0	2040
Epicoccum	407	38	11	19	14	33	60	68	109	105	68	27	959
Chaetomium	73	15	6	13	8	130	42	42	31	9	17	18	404
Drechslera	21	13	14	7	9	17	36	77	104	32	33	13	376
Stemphillium/Ulocladium	33	5	6	2	8	10	1	156	62	31	19	2	335
Pithomyces	75	54	25	15	28	18	10	35	22	6	10	6	304
Curvularia	77	9	4	3	35	12	10	11	10	3	3	3	180
Total	4966	1261	2672	2842	9426	10099	12699	44524	24028	29711	9901	4573	156702

Table 2. Monthly percentage of fungal spore distribution in Iğdır atmosphere (%)

TAXA	January	February	March	April	May	June	July	August	September	October	November	December	Total % Spore/m^3
Cladosporium	1,82	0,41	1,03	1,23	4,79	5,15	7,10	26,02	13,30	17,58	4,80	1,76	85,00
Alternaria	0,13	0,03	0,03	0,11	0,55	0,65	0,62	1,49	1,36	0,72	0,38	0,10	6,16
Aspergillus/Penicillium	0,77	0,28	0,59	0,41	0,16	0,13	0,25	0,50	0,41	0,35	1,04	1,01	5,91
Fusarium	0,01	0,001	0,01	0,03	0,45	0,37	0,04	0,16	0,05	0,18	0,01	0,00	1,30
Epicoccum	0,26	0,02	0,01	0,01	0,01	0,02	0,04	0,04	0,07	0,07	0,04	0,02	0,61
Chaetomium	0,05	0,01	0,00	0,01	0,01	0,08	0,03	0,03	0,02	0,01	0,01	0,01	0,26
Drechslera	0,01	0,01	0,01	0,004	0,01	0,01	0,02	0,05	0,07	0,02	0,02	0,01	0,24
Stemphillium/Ulocladium	0,02	0,003	0,004	0,001	0,01	0,01	0,001	0,10	0,04	0,02	0,01	0,001	0,21
Pithomyces	0,05	0,03	0,02	0,01	0,02	0,01	0,01	0,02	0,01	0,004	0,01	0,004	0,19
Curvularia	0,05	0,01	0,003	0,002	0,02	0,01	0,01	0,01	0,01	0,002	0,002	0,002	0,11
Total	3,17	0,80	1,71	1,81	6,02	6,44	8,10	28,41	15,33	18,96	6,32	2,92	100,00

Table 3. Monthly average temperature (°C), humidity (%) and total precipitation (mm) of Iğdır atmosphere

Meteorological Data	January	February	March	April	May	June	July	August	September	October	November	December
Temperature (°C)	0.98	4.27	8.40	13.81	18.45	25.00	28.41	26.90	23.41	14.50	6.45	-0.34
Humidity (%)	64.62	60.13	50.54	47.41	52.24	41.33	35.28	41.99	43.81	72.11	67.06	69.82
Total Precipitation (mm)	2.4	4.4	4.6	40.8	8.0	25.4	0.0	15.4	1.0	87.8	4.2	15.6

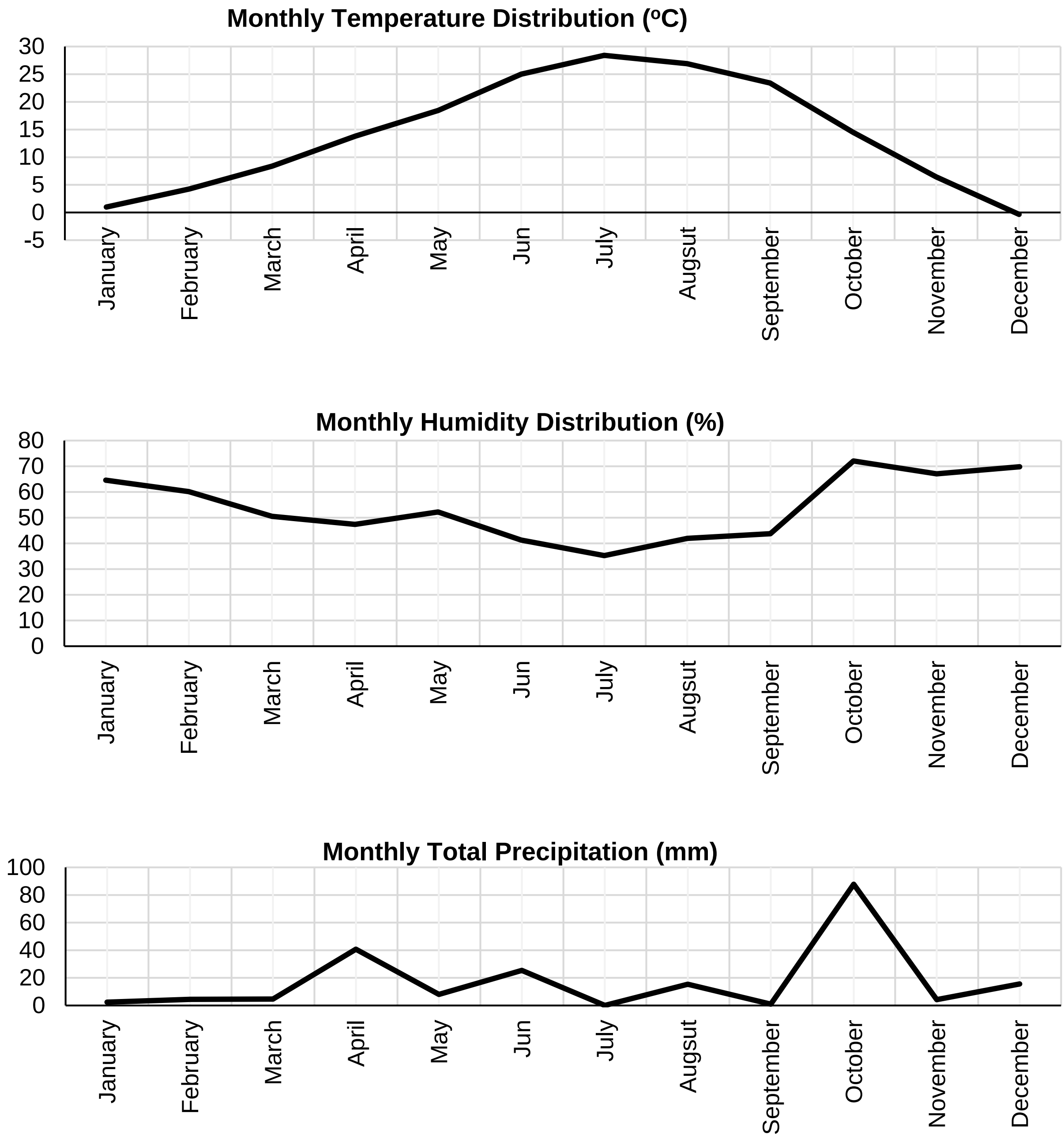

Figure 3. Meteorological data distribution in Iğdır atmosphere

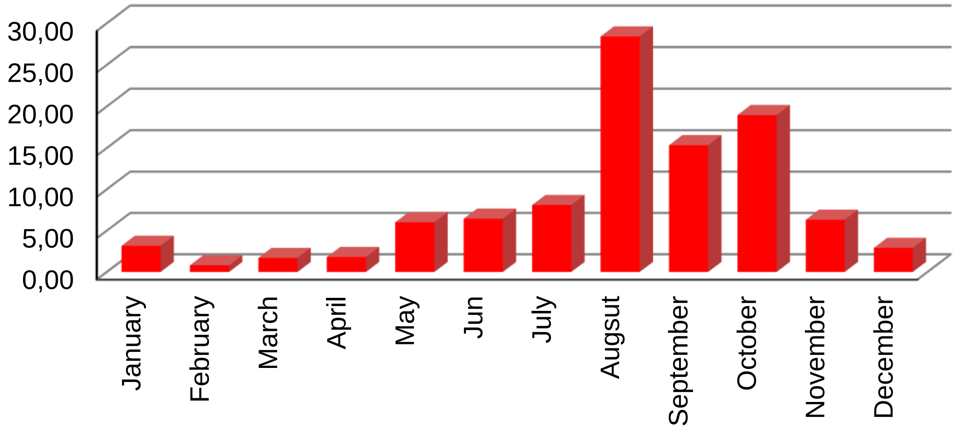

Figure 4. Monthly variation of fungal spores in Iğdır atmosphere (%)

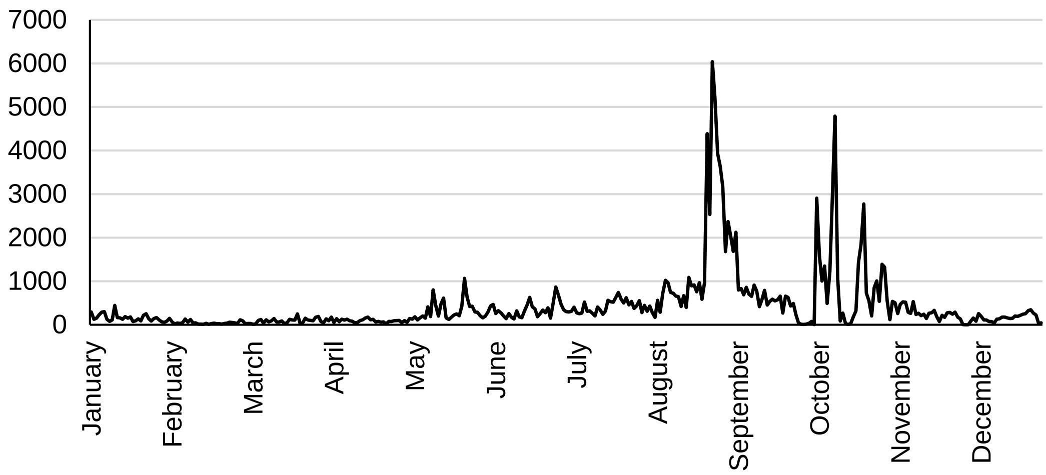

Figure 5. Daily variation of fungal spores in Iğdır atmosphere

Statistical Analysis

In this study, Spearman correlation analyses were performed on fungal spore data belonging to 10 taxa and meteorological parameters, such as average temperature, total precipitation, average humidity and average wind speed using the SPSS 20 software. The statistical analysis results were as follows.

In terms of average temperature, *Alternaria*, *Cladosporium*, *Drechslera* and *Stemphylium /Ulocladium* showed a significant positive relationship at the level of 0.01, while *Aspergillus/Penicillium* and *Pithomyces* showed a significant negative relationship at the level of 0.01 (p<0.01) (Table 4).

In terms of average humidity, *Curvularia* and *Pithomyces* showed a significant positive relationship at the level of 0.05 (p<0.05). In addition, *Aspergillus/Penicillium*, *Epicoccum* and *Fusarium* showed a significant positive relationship at the level of 0.01 (p<0.01), while *Alternaria* and *Cladosporium* showed a significant negative relationship at the level of 0.01 (p<0.01) (Table 4).

In terms of average wind, *Fusarium* showed a significant positive relationship at the 0.05 level (p<0.05). In addition, *Alternaria* showed a significant positive relationship at the 0.01 level (p<0.01), while *Aspergillus/Penicillium* and *Epicoccum* showed a significant negative relationship at the 0.01 level (p<0.01) (Table 4).

As a result of the statistical analysis, no significant relationship was observed between total precipitation and fungal spore taxa (Table 4).

Table 4. Spearman Correlation analysis

TAXA	Daily Average Temperature	Daily Total Precipitation	Daily Average Humidity	Daily Average Wind Speed
Alternaria	0.632^{**}	0.154	-0.223^{**}	0.125^{*}
Aspergillus/ Penicillium	-0.419^{**}	-0.179	0.275^{**}	-0.305^{**}
Chaetomium	0.003	-0.222	0.02	-0.039
Cladosporium	0.601^{**}	0.136	-0.201^{**}	0.063
Curvularia	-0.178	-0.248	0.206^{*}	0.038
Drechslera	0.226^{**}	0.234	-0.017	-0.032
Epicoccum	-0.098	0.12	0.252^{**}	-0.198^{**}
Fusarium	0.023	0.264	0.223^{**}	0.203^{**}
Stemphylium/Ulocladium	0.289^{**}	-0.098	-0.085	0.038
Pithomyces	-0.201^{**}	-0.009	0.152^{*}	-0.122

** Correlation is significant at the 0.01 level (2-tailed).
* Correlation is significant at the 0.05 level (2-tailed).

Table 5. Data on the 10 dominant fungal spore taxa in similar studies in Türkiye and abroad

	Locations	*Cladosporium*	*Alternaria*	*Aspergillus/ Penicillium*	*Fusarium*	*Epicoccum*	*Chaetomium*	*Drechslera*	*Stemphylium/ Ulocladium*	*Pithomyces*	*Curvularia*	References
	Igdır	**85.00**	**6.16**	**5.91**	**1.30**	**0.61**	**0.26**	**0.24**	**0.21**	**0.19**	**0.11**	
Türkiye	Adana	73.00	27.00									(Yükselen et al., 2013)
	Ankara	75.50	6.10					1.30				(Çeter and Pınar, 2009)
	Bursa	88.11	4.99	4.65	0.84	0.62	0.13	0.24	0.14	0.15	0.13	(Ataygül et al., 2007)
	Elazığ	3.42	2.43		11.60	3.34	3.76	12.82	0.44	0.81	2.11	(Kilic et al., 2020)
	Gaziantep	56.01	5.82	0.58	0.04	0.43	0.15	0.22	0.23	0.01	0.05	(Akgül et al., 2016)
	Niğde	69.46	7.21	1.42	0.13	0.86	0.30	0.74	0.68	0.46	0.29	(Çeter et al., 2020)
	Yalova	55.36	7.59	0.25	0.86	0.88	0.03	0.20	0.27		0.05	(Yılmazkaya et al., 2019)
Abroad	Bangkok, Thailand	49.37	1.66	7.90	7.89					1.04	2.14	(Songnuan et al., 2018)
	Caxias do Sul, Brazil	32.86	0.74	5.33		0.54						(De Antoni Zoppas et al., 2006)
	Kolkata, India	32.94	2.58	6.51			2.33	2.97		1.45	1.24	(Chakrabarti et al., 2012)
	Madeira, Portugal	78.00	5.40		4.70	0.70		1.30		0.07	0.60	(Sousa et al., 2016)
	Madrid, Spain	43.13	0.92	2.48	0.02	0.09	0.10	0.30	0.04	0.003	0.02	(Herrero et al., 2006)
	Saclay, France	35.28	1.28		0.01	0.28	0.01		0.01	0.11		(Sarda-Estève et al., 2019)
	Stockholm, Swedish	41.52	0.30									(Hjelmroos, 1993)
	Szczecin, Poland	66.00	1.67	0.14	0.01	0.26	0.02	0.14	0.01		0.003	(Bednarz and Pawlowska, 2016)
	Szczecin, Polonya	73.35	2.48									(Grinn-Gofroń and Mika, 2008)
	Worcester, England	64.10	0.75	1.10		0.37		0.38	0.03	0.03		(Sadyś et al., 2015)
	Zarqa, Jordan	49.39	7.70	1.84	0.74	0.71	1.27		1.47			(Abu-Dieyeh and Barham, 2014)

Discussions

In this study, Cladosporium, *Alternaria*, *Aspergillus/ Penicillium*, *Fusarium*, *Epicoccum*, *Chaetomium Drechslera*, *Stemphylium/Ulocladium*, *Pithomyces* and *Curvularia* fungal spores per cubic were detected by using the volumetric method to determine their density in the air.

A total of 156702 spores/m^3 fungal spores were determined (Table 1). The most common fungal spore was *Cladosporium*, and the least common fungal spore was *Curvularia* (Table 1 and Table 2). While the highest density of fungal spores was determined in August, the lowest month was February (Table 1 and Table 2).

Cladosporium

Cladosporium, a cosmopolitan genus, is the largest and most heterogeneous taxon among the 772 living groups, known as molds (Bensch et al., 2012; Dugan et al., 2004). The optimum temperature conditions for the development of this mesophilic genus are between 20°C and 40°C (Gravesen, 1979). *Cladosporium* species are known to be the most common cause of respiratory diseases, such as asthma and rhinitis (Bouziane et al., 2005). Studies conducted on *Cladosporium* in Islamabad, the capital of Pakistan, revealed that these spores cause severe asthma attacks and even death (Abbas et al., 2012).

In this study conducted in the atmosphere of Iğdır in 2015, the density of *Cladosporium* was determined as 85.00% (Table 2). In studies conducted in Türkiye, *Cladosporium* taxon are seen as the most abundant taxon. It is thought that the main reason for this situation is the optimum temperature conditions required for the development of *Cladosporium* (Gravesen, 1979). Apart from this, it has been determined that Bursa (Ataygül et al., 2007) is among the provinces where it is detected between 80% and 90%. It has been observed that the provinces where this taxon is detected between 70% and 80% are Ankara (Çeter and Pınar, 2009) and Adana (Yükselen et al., 2013). It has also been reported that the provinces where this taxon is detected between 50% and 70% are Niğde (Çeter et al., 2020), Gaziantep (Akgul et al., 2016) and Yalova (Yılmazkaya et al., 2019) (Table 5). In similar studies conducted abroad, it has been observed that among the places where this taxon is detected at a rate of more than 50% are Madeira/Portugal (Sousa et al., 2016), Szczecin-Poland (Grinn-Gofroń and Mika, 2008; Bednarz and Pawlowska, 2016) and Worcester-England (Sadyś et al., 2015). *Cladosporium* is detected at a rate of 41.52% in Stockholm-Swedish (Hjelmroos, 1993), which is less than 50%. (Table 5).

Alternaria

Alternaria species, which are found in various plant parts, animals and the atmosphere, are observed as epiphytic, saprophytic and parasitic (Woudenberg et al., 2013). Alternaria species accumulate especially in the respiratory tract and cause allergic effects (Filali et al., 2015). These saprophytic spores infect the fruits and leaves of apple trees and cause economic losses (Rotondo et al., 2012). Alternaria spores, known as post-harvest pathogens, can also be found in lemons, tomatoes, cauliflower, broccoli, carrots and potatoes (Thomma, 2003). It is stated that allergenic species are among the most dangerous species in Europe, especially in respiratory tract allergies (Fernández-Rodríguez et al., 2015). In patients showing allergy symptoms in the nose (nasal) and bronchial regions, the presence of IgE antibodies is detected in skin prick tests performed with suspicion of Alternaria and Cladosporium spores (D'Amato et al., 1997).

In this study, it was observed that Alternaria constituted 6.16% of the total spores (Table 2). In similar studies conducted in Türkiye, this taxon is determined as the second most dense taxon. In the studies conducted, it has been reported that Adana (Yükselen et al., 2013) provinces are among the provinces where this taxon is 20% and above. It has been determined that the provinces where this taxon is detected between 10% and 20% is Konya (Kızılpinar Temizer, 2011). This taxon is recorded as 6.10% in Ankara (Çeter and Pınar 2009) (Table 5). In similar studies conducted abroad, some of the places where this taxon is detected between 1% and 10% are in Madeira-Portugal (Sousa et al., 2016), Szczecin-Poland (Grinn-Gofroń and Mika, 2008; Bednarz and Pawlowska, 2016), Worcester-England (Sadyś et al., 2015) and Stockholm-Swedish (Hjelmroos, 1993) (Table 5).

***Aspergillus/Penicillium* Type Spores**

The International Commission on *Penicillium* and *Aspergillus*, which met in Utrecht, the Netherlands, on April 14, 2012, decided to bring these two genera together and evaluated them as a single taxon (Houbraken et al., 2014). The genus *Penicillium*, which spreads more rapidly in temperate soils, also acts as a putrefactive agent in stale bread, citrus products and apples, and some *Penicillium* species secrete a fungal toxin, called patulin, which has carcinogenic effects on the brain, liver and lung organs (Gravesen, 1979). The genus *Aspergillus* can be an allergen, infectious agent and saprophyte and can exhibit both or all of these properties together (Pennington, 1980). The *Aspergillus* genus, which is a disease agent in humans and animals, causes allergic asthma, allergic rhinitis and allergic sinusitis in humans, and some species can cause infection in people with chronic diseases (e.g. diabetes, cancer, alcohol addiction, etc.) (Kurup and Kumar, 1991).

In this study, it was determined that *Aspergillus/ Penicillium* constituted 5.91% of the total spores (Table 2). Similar studies has determined this taxon as the third most dense taxon in Türkiye. In the studies conducted, it has been observed that the provinces where the density is determined to be more than 1% are Bursa (Ataygül et al., 2007) and Niğde (Çeter et al., 2020) (Table 5). In similar studies conducted abroad, this taxon is detected between 0.5% and 5.5% in Madeira-Portugal (Sousa et al., 2016), Szczecin-Poland (Bednarz and Pawlowska, 2016) and Worcester-England (Sadyś et al., 2015) (Table 5).

Fusarium

Cosmopolitan and pathogenic *Fusarium* species naturally spread and cause diseases in gardens, fields and forests (Ma et al., 2013). A study conducted on some members of this genus has revealed that they are resistant to 5 out of 6 different fungicidal drugs (Alastruey-Izquierdo et al., 2008). In a study, a list of pathogenic fungal species has been created and two species of the *Fusarium* genus are nominated for this list of 10 species (Dean et al., 2012). As a result of the test conducted in Iran, the presence of IgE due to *Fusarium solani* is detected in all patients (Khosravi et al., 2012) (Table 5).

In this study, *Fusarium* was found to constitute 1.30% of the total taxa detected (Table 2). In similar studies conducted in Türkiye, it is detected as more than 1% in Elazığ (Kılıç et al., 2020). Apart from this, it has been observed that the places detected as less than 1% are Yalova (Yılmazkaya et al., 2019), Bursa (Ataygül et al., 2007), Niğde (Çeter et al., 2020) and Gaziantep (Akgül et al., 2016). In similar studies conducted abroad, it has been observed at a rate of 7.89% in Bangkok-Thailand (Songnuan, 2018) and 4.70% in Madeira-Portugal (Sousa et al., 2016) (Table 5).

Epicoccum

In a study conducted with *Epicoccum purpurascens*, it has been reported that the spores and mycelium extracts of this species reacts to IgE and IgG antibodies in skin tests. (Bisht et al., 2004). In a study conducted on *Epicoccum nigrum* spores and extracts in two different regions in Texas, allergen sensitivity is recorded in skin tests (Dixit et al., 1992).

In this study, it was determined that *Epicoccum* taxon constituted 0.61% of total spores (Table 2). In similar studies conducted in Türkiye, the province with a density of more than 1% is determined in Elazığ (Kılıç et al., 2020). *Epicoccum* spore densities of less than 1% in Yalova (Yılmazkaya et al., 2019), Bursa (Ataygül et al., 2007), Niğde (Çeter et al., 2020) and Gaziantep (Akgül et al., 2016) are given in Table 5. In similar studies conducted abroad, *Epicoccum* taxon is detected at a rate of 0.71% in Zarka/Jordan (Abu-Dieyeh and Barham, 2014), 0.70% in Madeira-Portugal (Sousa et al., 2016), 0.54% in Caxias do Sul-Brazil (De Antoni Zoppas et al., 2006), 0.37% in Worcester-England (Sadyś et al., 2015) and 0.28% in Andrzej-Sorbon (Sorbonne et al., 2015). in Saclay-France (Sarda-Estève et al., 2019), 0.26% in Szczecin-Poland (Bednarz and Pawlowska, 2016) and 0.09% in Madrid-Spain (Herrero et al., 2006) (Table 5).

Chaetomium

Chaetomium is a cosmopolitan genus, comprising more than 80 species (Von Arx, 1986; Abdel-Azeem, 2020). Most are saprophytic and cellulolytic, and some species have been isolated from human skin lesions and some produce toxins (Udagawa, 1984; Webster and Weger, 2007). A cross-reaction allergy test conducted on several fungal with *Chaetomium* globosum has revealed that this species responds better to antibodies than other fungal species (Provost, 2010).

In this study, it has been observed that *Chaetomium* taxon constitutes 0.26% of the total spores (Table 2). In similar studies conducted in Türkiye, *Chaetomium* taxon is detected in Elazığ at more than 1% (Kılıç et al., 2020). Apart from this, the density is detected as less than 1% in Niğde (Çeter et al., 2020), Gaziantep (Akgül et al., 2016), Bursa (Ataygül et al., 2007) and Yalova (Yılmazkaya et al., 2019) (Table 5). In similar studies conducted abroad, it has been detected as 2.33% in Kolkata, India (Chakrabarti et al., 2012), 1.27% in Zarka, Jordan (Abu-Dieyeh and Barham, 2014), 0.10% in Madrid, Spain (Herrero et al., 2006), 0.018% in Szczecin, Poland (Bednarz and Pawlowska, 2016) and 0.01% in Saclay, France (Sarda-Estève et al., 2019) (Table 5).

Drechslera

A study conducted on mice has showed that *Drechslera* ronoceras is a better IgE inducer than *Cladosporium cladosporioides* under the same conditions (Menezes et al., 1995). Another study has reported that the mycelium of the *Drechslera hawaiiensis* species is seen in the brain region of patients and caused fatal meningitis (Fuste et al., 1973). It also causes infections, such as corneal inflammation, skin lesions, peritonitis and inflammation of the facial sinuses (Rolston et al., 1985).

In this study, it was determined that the density of *Drechslera* constituted 0.24% of the total spores (Table 2). In similar studies conducted in Türkiye, it has been determined to be 12.82%, higher than 1%, in Elazığ (Kılıç et al., 2020) and Ankara (Çeter and Pınar, 2009). Apart from this, its density is detected as less than 1% in Kırşehir (Bülbül et al., 2011), Niğde (Çeter et al., 2020), Bursa (Ataygül et al., 2007), Gaziantep (Akgül et al., 2016) and Yalova (Yılmazkaya et al., 2019) (Table 5).

In similar studies conducted abroad, the density of *Drechslera* is detected as higher than 1% in Zarka-Jordan (Abu-Dieyeh and Barham, 2014), Kolkata-India (Chakrabarti et al., 2012), Madeira-Portugal (Sousa et al., 2016), Worcester-England (Sadyś et al., 2015), Madrid/Spain (Herrero et al., 2006) and Szczecin/Poland (Bednarz and Pawlowska, 2016) (Table 5).

Stemphylium/Ulocladium

In *in-vivo* and *in-vitro* studies using *Stemphylium/ Ulocladium* extract, this taxon is found to be allergenic (Agarwal et al., 1982). In this study, it was determined that *Stemphylium/Ulocladium* taxon constituted 0.21% of the total fungal spores (Table 2).

In similar studies conducted in Türkiye, the densities of this taxon are determined to be less than 1% in the provinces of Elazığ (Kılıç et al., 2020), Yalova (Yılmazkaya et al., 2019), Bursa (Ataygül et al., 2007), Niğde (Çeter et al., 2020) and Gaziantep (Akgül et al., 2016) (Table 5). In similar studies conducted abroad, it has been observed as 1.47% in Zarka-Jordan (Abu-Dieyeh and Barham, 2014), 0.04% in Madrid-Spain (Herrero et al., 2006), 0.03% in Worcester-England (Sadyś et al., 2015), 0.01% in Szczecin-Poland (Bednarz and Pawlowska, 2016) and 0.01% in Saclay-France (Sarda-Estève et al., 2019).

Pithomyces

A study conducted on various taxa, including the genus *Pithomyces*, in homes where children with asthma symptoms, and in homes where healthy individuals served as controls, have been found that the air in homes where healthy individuals live have slightly higher concentrations of *Pithomyces* than in homes where children with asthma symptoms live (Meng et al., 2012). *Pithomyces* has been reported as a moderate allergen (Aşçı et al., 2010).

In this study, *Pithomyces* was detected at 0.19% (Table 2, Table 5). In similar studies conducted in Türkiye, the densities of this taxon has been found to be less than 1% in Elazığ (Kılıç et al., 2020), Bursa (Ataygül et al., 2007), Niğde (Çeter et al., 2020) and Gaziantep (Akgül et al., 2016) (Table 5). In similar studies conducted abroad, it has been detected at rates of 1.45% in Kolkata, India (Chakrabarti et al., 2012), 1.04% in Bangkok/Thailand (Songnuan, 2018), 0.11% in Saclay, France (Sarda-Estève et al., 2019), 0.03% in Worcester, England (Sadyś et al., 2015) and 0.003% in Madrid/Spain (Herrero et al., 2006) (Table 5).

Curvularia

A study conducted on *Curvularia lunata*, one of the *Curvularia* spores has stated that this species is allergenic and causes sinusitis (Bartynski et al., 1990).

In this study, it was determined that *Curvularia* taxon constituted 0.11% of the total fungal spores (Table 2). In similar studies conducted in Türkiye, it is detected at a rate of more than 1% in Elazığ (Kılıç et al., 2020). This taxon is detected at lower densities than 1% in the provinces of Niğde (Çeter et al., 2020), Bursa (Ataygül et al., 2007), Yalova (Yılmazkaya et al., 2019) and Gaziantep (Akgül et al., 2016) (Table 5). In similar studies conducted abroad, it is detected at rates of 2.14% in Bangkok-Thailand (Songnuan, 2018), 1.24% in Kolkata-India (Chakrabarti et al., 2012), 0.6% in Madeira-Portugal (Sousa et al., 2016), 0.02% in Madrid-Spain (Herrero et al., 2006) and 0.003% in Szczecin-Poland (Bednarz and Pawlowska, 2016) (Table 5).

In a study conducted in Szczecin, Poland, it has been determined that *Cladosporium* taxa show a positive relationship with temperature and a negative relationship with humidity. In addition, it has been reported that *Alternaria* taxa show a positive relationship with temperature and a negative relationship with humidity (Grinn-Gofroń and Mika, 2008). In a study conducted in Barrackpore, India, *Aspergillus/Penicillium* have been found to have a negative significant relationship with daily mean temperature and wind speed (Roy and Gupta Bhattacharya, 2020). Another study conducted in Szczecin, Poland, it has been found to have a positive relationship with daily mean humidity (Grinn-Gofroń, 2011). In a study conducted in the Central and Eastern Black Sea region, *Fusarium* taxon is found to have a positive significant relationship with humidity and wind speed (Grinn-Gofroń et al., 2020). A negative relationship has been found between *Epicoccum* taxon and wind speed (Grinn-Gofroń et al., 2020). In addition, this taxon has been found to have a positive significant relationship with humidity in another study (Oliveira et al., 2010) A study conducted in Madeira, Portugal has found a positive significant relationship between *Drechslera* taxon and temperature (Sousaa et al., 2016). A positive significant relationship has been found between *Stemphylium* taxon and temperature (Grinn-Gofroń et al., 2020). A negative significant relationship has been reported between *Pithomyces* taxon and temperature (Chakrabarti et al., 2012). A positive significant relationship has been found between *Curvularia* taxon and humidity (Grinn-Gofroń et al., 2020).

Conclusion

In this study, the density of some allergenic fungal taxa in the Iğdır atmosphere were investigated. No data was detected that *Pithomyces* is definitively an allergen. The remaining 9 taxa appeared to be allergenic and some of them had pathogenic and saprophytic effects. It is thought that the findings obtained would be useful to allergists in the diagnosis and treatment of individuals with allergic predisposition. It is also thought that it would be a helpful knowledge in many fields, such as medicine, pharmacy, agriculture, meteorology and veterinary medicine.

Author contributions

In this study, microscopic analyses were performed by Baykan ATAŞ and Mustafa Kemal ALTUONOĞLU. The evaluation of the results and the writing of the article were performed by Mustafa Kemal ALTUNOĞLU.

Conflicts of interest

The authors declare that they have no conflict of interest.

Ethical Statement

It is declared that scientific and ethical principles were followed during the preparation of this study and that all studies used are stated in the bibliography (Mustafa Kemal ALTUNOĞLU, Baykan ATAŞ).

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References

Abbas, S., Katelaris, C. H., Singh, A. B., Raza, S. M., Khan, M. A., Rashid, M., Abbas, M. and Ismail, M. (2012). World allergy organization study on aerobiology for creating first pollen and mold calendar with clinical significance in islamabad, pakistan; a project of world allergy organization and pakistan allergy, asthma and clinical immunology centre of islamabad. *World allergy organization Journal*, 5(9), 103-110

Abdel-Azeem A.M. (2020) Taxonomy and Biodiversity of the Genus *Chaetomium* in Different Habitats. In: Recent Developments on Genus *Chaetomium*. Abdel-Azeems AM (ed), *Fungal Biology*. *Springer Nature*, *Switzerland AG,* 3–77

Abu-Dieyeh, M.H. and Barham, R. (2014). Concentrations and dynamics of fungal spore populations in the air of Zarqa, Jordan, using the volumetric method. *Grana*, 53(2), 117-132

Agarwal, M.K., Jones, R.T. and Yunginger, J.W. (1982). Shared allergenic and antigenic determinants in *Alternaria* and *Stemphylium/Ulocladium* extracts. *Journal of Allergy and Clinical Immunology*, 70(6), 437-444

Akgül, H., Yılmazkaya, D., Akata, I., Tosunoğlu, A. and Bıçakçı, A. (2016). Determination of airborne fungal spores of Gaziantep (SE Turkey). *Aerobiologia,* 32(3), 441-452

Alastruey-Izquierdo, A., Cuenca-Estrella, M., Monzon, A., Mellado, E. and Rodríguez-Tudela, J.L. (2008). Antifungal susceptibility profile of clinical *Fusarium* spp. isolates identified by molecular methods. *Journal of Antimicrobial Chemotherapy*, 61(4), 805-809

Aşçı, B., Çeter, T., Alan, Ş., Pınar, N.M. ve Yalçınkaya, B. (2010). Ankara havasının doğal kirleticileri. *Biyoloji Bilimleri Araştırma Dergisi*, 3(1), 19-25

Ataygül, E., Çelenk, S., Canıtez, Y., Bıçakçı, A., Malyer, H. and Sapan, N. (2007). Allergenic fungal spore concentrations in the atmosphere of Bursa, Turkey. *Journal of Biological and Environmental Sciences*, 1(2), 73-79

Bartynski, J.M., McCaffrey, T.V. and Frigas, E. (1990). Allergic fungal sinusitis secondary to dermatiaceous fungi—*Curvularia lunata* and *Alternaria*. *Otolaryngology—Head and Neck Surgery*, 103(1), 32-39

Bednarz, A. and Pawlowska, S. (2016). A fungal spore calendar for the atmosphere of Szczecin, Poland. *Acta Agrobotanica*, 69(3), 1-9

Bensch, K., Braun, U., Groenewald, J.Z. and Crous, P.W. (2012). The Genus *Cladosporium*. *Studies in Mycology*, 72, 1-401

Bisht, V., Arora, N., Singh, B.P., Gaur, S.N. and Sridhara, S. (2004). Purification and characterization of a major cross-reactive allergen from *Epicoccum purpurascens*. *International Archives of Allergy and Immunology*, 133(3), 217-224

Bouziane, H., Latgé, J.P., Fitting, C., Mecheri, S., Lelong, M. and David, B. (2005). Comparison of the allergenic potency of spores and mycelium of *Cladosporium*. *Allergologia et immunopathologia*, 33(3), 125-130

Bush, R.K. and Portnoy, J.M. (2001). The role and abatement of fungal allergens in allergic diseases. *Journal of Allergy and Clinical Immunology*, 107(3), 430-440

Chakrabarti, H.S., Das, S. and Gupta-Bhattacharya, S. (2012). Outdoor airborne fungal spora load in a suburb of Kolkata, India: its variation, meteorological determinants and health impact. *International Journal of Environmental Health Research*, 22(1), 37-50

Çeter, T. ve Pınar, N.M., (2009). 2003 Yılında Ankara Atmosferi Mantar Sporları Konsantrasyonu ve Meteorolojik Faktörlerin Etkisi. *Mikrobiyol Bul,* 43, 627-638.

Çeter, T., Bayar, E., Eltajthisi, M.N., İşlek, C. and Pınar, N.M. (2020). Investigation of fungi spores concentration in Niğde Atmosphere (Turkey). *Communications Faculty of Sciences University of Ankara Series C Biology*, 29(2), 351-364

D'Amato, G., Chatzigeorgiou, G., Corsico, R., Gioulekas, D., Jäger, L., Jäger, S., Kontou-Fili, K., Kthisidakis, S., Liccardi, G., Meriggi, A., Palma-Carlos, A., Palma-Carlos, M.L., Pagan Aleman, A., Parmiani, S., Puccinelli, R., Russo, M., Spieksma, F. Th. M., Torricelli, R. and Wüthrich, B. (1997). Evaluation of the prevalence of skin prick test positivity to *Alternaria* and *Cladosporium* in patients with suspected respiratory allergy: a European multicenter study promoted by the Subcommittee on Aerobiology and Environmental Aspects of Inhalant Allergens of the European Academy of Allergology and Clinical Immunology. *Allergy*, 52(7), 711-716

De Antoni Zoppas, B.C., Valencia-Barrera, R.M., Vergamini Duso, S.M. and Fernández-González, D. (2006). Fungal spores prevalent in the aerosol of the city of Caxias do Sul, Rio Grande do Sul, Brazil, over a 2-year period (2001–2002). *Aerobiologia*, 22(2), 117-124

Deacon, J. W., (2006) Fungal Biology, 4th edition. *Blackwell Publishing, Oxford/UK*, 371.

Dean, R., Van Kan, J.A., Pretorius, Z.A., Hammond-Kosack, K.E., Di Pietro, A., Spanu, P.D., Rudd, J.J., Dickman, M., Kahmann, R., Ellis, J. and Foster, G.D. (2012). The Top 10 fungal pathogens in molecular plant pathology. *Molecular Plant Pathology*, 13(4), 414-430

Dixit, A.B., Lewis, W.H. and Wedner, H.J. (1992). The allergens of *Epicoccum nigrum* link: I. Identification of the allergens by immunoblotting. *Journal of Allergy and Clinical İmmunology*, 90(1), 11-20

Dugan, F.M., Schubert, K. and Braun, U. (2004). Check-list of *Cladosporium* names. *Schlechtendalia*, 11, 1-103

Fernández-Rodríguez, S., Tormo-Molina, R., Maya-Manzano, J.M., Silva-Palacios, I. and Gonzalo-Garijo, Á. (2014). Outdoor airborne fungi captured by viable and non-viable methods. *Fungal Ecology*, 7, 16-26.

Fernández-Rodríguez, S., Sadyś, M., Smith, M., Tormo-Molina, R., Skjøth, C.A., Maya-Manzano, J.M., Silva-Palacios, I. and Gonzalo-Garijo, Á. (2015). Potential sthisces of airborne *Alternaria* spp. spores in South-west Spain. *Science of the Total Environment*, 533, 165-176

Filali Ben Sidel, F., Bouziane, H., del Mar Trigo, M., El Haskthisi, F., Bardei, F., Redouane, A., Kadiri, M., Riadi, H. and Kazzaz, M. (2015). Airborne fungal spores of *Alternaria*, meteorological parameters and predicting variables. *International Journal of Biometeorology*, 59(3), 339-346

Fuste, F.J., Ajello, L., Threlkeld, R., and Henry Jr, J.E. (1973). *Drechslera hawaiiensis*: causative agent of a fatal fungal meningo-encephalitis. *Sabthisaudia*, 11(1), 59-63

Göner, İ. (1995). Iğdır Ovası ve Çevresinde Yaylacılık. *Doğu Coğrafya Dergisi*, 1(1), 229-245

Gravesen, S. (1979). Fungi as a cause of allergic disease. *Allergy*, 34(3), 135-154

Grinn-Gofroń, A. and Mika, A. (2008). Selected airborne allergenic fungal spores and meteorological factors in Szczecin, Poland, 2004–2006. *Aerobiologia*, 24(2), 89-97

Grinn-Gofroń, A. (2011). Airborne *Aspergillus* and *Penicillium* in the atmosphere of Szczecin,(Poland)(2004–2009). *Aerobiologia*, 27(1), 67-76

Grinn-Gofroń, A. and Bosiacka, B. (2015). Effects of meteorological factors on the composition of selected fungal spores in the air. *Aerobiologia*, 31(1), 63-72

Grinn-Gofroń, A., Çeter, T., Pinar, N.M., Bosiacka, B., Çeter, S., Keçeli, T., Myśliwy, M., Acar Şahin, A. and Bogawski, P. (2020). Airborne fungal spore load and season timing in the Central and Eastern Black Sea region of Turkey explained by climate conditions and land use. *Agricultural and Forest Meteorology*, 295, 108191

Herrero, A.D., Ruiz, S.S., Bustillo, M.G. and Morales, P.C. (2006). Study of airborne fungal spores in Madrid, Spain. *Aerobiologia*, 22(2), 133-140

Hjelmroos, M. (1993). Relationship between airborne fungal spore presence and weather variables: *Cladosporium* and *Alternaria*. *Grana*, 32(1), 40-47

Houbraken, J., de Vries, R.P. and Samson, R.A. (2014). Modern taxonomy of biotechnologically important *Aspergillus* and *Penicillium* species. *Advances in Applied Microbiology*, 86, 199-249

Kaltakkıran, G. (2023). Analysis of meteorology and climate data for energy applications in ardahan province. *Iğdır Üniversitesi Fen Bilimleri Enstitüsü Dergisi*, 13(3), 2026-2041. https://doi.org/10.21597/jist.1223780

Karaoğlu, M. (2014). Agricultural meteorological properties of aras basin in turkey. *Türkiye Tarımsal Araştırmalar Dergisi*, 1(1), 1. https://doi.org/10.19159/tutad.24089

Karaoğlu, M. (2023). Creation of iğdır geological map with geographic information systems (gis) and comparison with large soil groups. https://doi.org/10.21203/rs.3.rs-3739798/v1. Accessed 07 July 2024.

Kaya, F. (2015). Iğdır ili'nin idari coğrafya analizi. *Journal of International Social Research*, 8(41) 703-716

Khosravi, A.R., Fatahinia, M., Shokri, H. and Yadegari, M.H., (2012). Allergens from *Fusarium solani* identified by immunoblotting in asthma patients in Iran. *Arh Hig Rada Toksikol.*, 63(1), 1-5

Kilic, M., Altunoglu, M.K., Akdogan, G.E., Akpınar, S., Taskın, E. and Erkal, A.H. (2020). Airborne fungal spore relationships with meteorological parameters and skin prick test results in Elazig, Turkey. *Journal of Environmental Health Science and Engineering*, 18(2), 1271-1280

Koçak, R., Tor, M., Dönmez, S., & Tekeli, A. (2022). Iğdir ili aralik ilçesi sellerinin gpm uydu yağiş verilerinden ilk ve son ürünleri ile incelenmesi. *VIII. Uzaktan Algılama-CBS Sempozyumu (Uzal-CBS 2022)* https://doi.org/10.15659/uzalcbs2022.12801

Kurup, V.P. and Kumar, A. (1991). Immunodiagnosis of aspergillosis. *Clinical Microbiology Reviews*, 4(4), 439-456

Menezes, E.A., Gambale, W., Macedo, M.S., Abdalla, D.S., Paula, C.R., and Croce, J. (1995). Biochemical, antigenic and allergenic characterization of crude extracts of *Drechslera (Helminthosporium) monoceras*. *Mycopathologia*, 131(2), 75-81

Meng, J., Barnes, C.S., Rosenwasser, L.J. and Children's Mercy Center for Environmental Health. (2012). Identity of the fungal species present in the homes of asthmatic children. *Clinical and Experimental Allergy*, 42(10), 1448-1458

Naranjo-Ortiz, M.A. and Gabaldón, T. (2019) Fungal Evolution: Major Ecological Adaptations and Evolutionary Transitions. *Biological Reviews*, 94, 1443-1476. https://doi.org/10.1111/brv.12510

Oliveira, M., Delgado, L., Ribeiro, H. and Abreu, I. (2010). Fungal spores from Pleosporales in the atmosphere of urban and rural locations in Portugal. *Journal of Environmental Monitoring*, 12(5), 1187-1194

Pennington, J.E. (1980). *Aspergillus* lung disease. *Medical Clinics of North America*, 64(3), 475-490

Rolston, K.V., Hopfer, R.L. and Larson, D.L. (1985). Infections caused by *Drechslera* species: case report and review of the literature. *Rev Infect Dis.*, 7(4), 525-529

Rotondo, F., Collina, M., Brunelli, A. and Pryor, B.M. (2012). Comparison of *Alternaria* spp. collected in Italy from apple with *A. mali* and other AM-toxin producing strains. *Phytopathology*, 102(12), 1130-1142

Roy, S. and Gupta Bhattacharya, S. (2020). Airborne fungal spore concentration in an industrial township: distribution and relation with meteorological parameters. *Aerobiologia*, 36(4), 575-587

Sadyś, M., Strzelczak, A., Grinn-Gofroń, A. and Kennedy, R. (2015). Application of redundancy analysis for aerobiological data. *International Journal of Biometeorology*, 59(1), 25-36

Sadyś, M., Kennedy, R. and West, J.S. (2016). Potential impact of climate change on fungal distributions: analysis of 2 years of contrasting weather in the UK. *Aerobiologia*, 32(1), 127-137

Sarda-Estève, R., Baisnée, D., Guinot, B., Sodeau, J., O'connor, D., Belmonte, J., Besancenot, Jp., Petit, J.E., Thibaudon, M., Oliver, G., Sindt, C. and Gros, V. (2019). Variability and geographical origin of five years airborne fungal spore concentrations measured at Saclay, France from 2014 to 2018. *Remote Sensing*, 11(14), 1671 1-29

Soldevilla, C.G., Gonzalez, P.C., Teno, P.A. and Vilches, E.D. (2007). Spanish Aerobiology Network (REA): management and quality manual. *Servicio de publicaciones de la Universidad de Córdoba*, 1-300.

Songnuan, W., Bunnag, C., Soontrapa, K., Pacharn, P., Wangthan, U., Siriwattanakul, U. and Malainual, N. (2018). Airborne fungal spore distribution in Bangkok, Thailand: correlation with meteorological variables and sensitization in allergic rhinitis patients. *Aerobiologia*, 34(4), 513-524

Sousa, L., Camacho, I. C., Grinn-Gofroń, A. and Camacho, R. (2016). Monitoring of anamorphic fungal spores in Madeira region (Portugal), 2003–2008. *Aerobiologia*, 32(2), 303-315

Şimşek, O. and Alim, M. (2009). Iğdır İli'nin turizm potansiyeli. *Sosyal Bilimler Enstitüsü Dergisi*, 3, 1-26

Tan, M. ve Temel, S. (2017). Erzurum ve Iğdır şartlarında yetiştirilen farklı kinoa genotiplerinin kuru madde verimi ve bazı özelliklerinin belirlenmesi. *Journal of the Institute of Science and Technology*, 7(4), 257-263

Temel, S. (2018). Tuzlu-alkali meralarda yaygın olarak yetişen çorak çimi (puccinellia distans) ve sahil ayrığı (aeluropus littoralis) bitkilerinin farklı gelişme dönemlerindeki besin içeriklerinin belirlenmesi. *Uluslararası Tarım ve Yaban Hayatı Bilimleri Dergisi*, 4(2), 237-246. https://doi.org/10.24180/ijaws.440309

Thomma, B.P. (2003). *Alternaria* spp.: from general saprophyte to specific parasite. *Molecular Plant Pathology*, 4(4), 225-236

Von Arx, J.A. (1986). The ascomycete genus *Gymnoascus*. *Persoonia*, 13(2), 173–183

Webster, J. and Weber, R., (2007). Introduction to Fungi, Third Edition, *Cambridge University Press, Cambridge/UK*, 331.

Woudenberg, J.H.C., Groenewald, J.Z., Binder, M. and Crous, P.W. (2013). *Alternaria* redefined. *Studies in Mycology*, 75(1), 171-212

Yılmazkaya, D., Akgül, H., Altunoğlu, M. K., Tosunoğlu, A. ve Bıçakçı, A. (2019). Fungal spore calendar of Yalova province (2005). *Mantar Dergisi*, 10(2), 116-123

Yulu, A. (2014) Dilucu Sınır Kapısı'nın Iğdır Şehri üzerindeki etkileri. *Coğrafya Dergisi*, (28), 20-35

Yükselen, Ü.A., Akdağ, P., Korkmaz Güvenmez, H., Çeter, T., Yılmaz, M., Bingöl Karakoç, G., Pınar, N.M. ve Ufuk Altıntaş, D. (2013). Adana atmosferindeki fungal spor konsantrasyonlarının meteorolojik faktörlerle değişimi ve elde edilen fungal ekstrelerin deri prik testinde kullanımı. *Asthma Allergy Immunology*, 11(2), 103-111