STUDY OF ASCOMYCETES IN JOWAR FIELD OF MANGALVEDHA TEHSIL OF SOLAPUR DISTRICT (MS, INDIA): THEIR CORRELATION WITH METEOROLOGICAL FACTORS

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ABSTRACT
Present study deals with study of ascospores belonging to Ascomycetes in Jowar field of Mangalvedha Tehsil of Solapur District (MS, India). Influence of meteorological factors such as temperature, humidity and precipitation on the concentration of fungal spores was also evaluated. This aeromycological investigation was carried out by using continuous volumetric Tilak air sampler located in the various fields of Jowar during Rabi (Oct-2022 to Feb-2023) and Kharif (June-2023 to Oct-2023) season. During study, thirty four ascospores belonging to Ascomycetes group of fungus were collected and studied. *Chetomium sps* (3.57%), *Melanospora sps* (2.65%), *Bitrimonospora sps* (2.55%), *Leptosphaeria sps* (1.73%), and *Hypoxylon sps* (1.7%) were the dominant during Rabi whereas *Melanospora sps* (5.07%), *Pleospora sps* (2.05%), *Leptosphaeria sps* (1.95%), *Sordaria sps* (1.77%), and *Bitrimonospora sps* (1.77%) during Kharif. These findings highlight, influence of differential meteorological factors (temperature, humidity and precipitation) those exists during Rabi and Kharif season on the concentration of fungal spores.

Keywords: Ascospores, Ascomycetes, *Sorghum bicolor*, Jowar, Rabi, Kharif.

INTRODUCTION:

The investigation of airborne microorganisms is crucial for understanding ecosystems, addressing human health challenges, and improving various industrial processes (Jones, 2018). Aeromycology, the study of airborne fungal spores and their interactions, has become increasingly significant due to its widespread effects on agriculture, human health, ecology, and environmental science (Smith et al., 2019). This field comprises research on both indoor and outdoor environments, focusing on identifying the sources and effects of airborne fungi. It involves analyzing, characterizing, and monitoring fungal spores and particles present in the air.

Fungi, being ubiquitous in nature, release spores into the atmosphere as part of their reproductive process (Johnson et al., 2020). These spores can act as vectors for plant pathogens, leading to the spread of crop diseases. Airborne fungal spores also play a role in ecosystem dynamics by aiding in colonization and dispersal, thereby contributing to ecosystem resilience and adaptation. Their impact extends to agricultural crops, where they can cause diseases that result in significant yield losses and economic challenges. By understanding the composition of airborne fungi, researchers can predict and manage outbreaks more effectively, supporting better agricultural practices and crop protection strategies (Johnson et al., 2020).

Ascomycota, one of the largest and most diverse fungal groups, includes both beneficial and pathogenic species that significantly impact agricultural crops like *Sorghum bicolor* (commonly known as Jowar). Characterized by their unique reproductive structure, the ascus, this group includes several economically important fungi, some of which act as plant pathogens causing diseases such as Fusarium wilt, a major concern for Jowar production (Wang et al., 2020). However, Ascomycota also contains fungi that form symbiotic relationships with plants and contribute to soil health, nutrient cycling, and organic matter decomposition. For example, *Aspergillus* species play a role in nutrient availability by breaking down complex organic materials, while *Trichoderma* species are known to act as biocontrol agents against pathogenic fungi like *Fusarium*, reducing disease outbreaks on Jowar crops (Fischer et al., 2015; Singh et al., 2019). Thus, while some members of Ascomycota negatively affect Jowar through disease, others offer vital ecosystem services that support its growth and yield (Taylor et al., 2018).

Aeromycological research is particularly vital for safeguarding crops such as Jowar, a staple cereal in many regions, including India. Jowar is highly susceptible to fungal diseases, which can adversely affect its yield and quality (Navi et. al., 2019). In Solapur district, Jowar is a key agricultural crop, serving as a major source of income for the farming community. It plays a critical role in the local economy, providing livelihood opportunities, generating employment, and helping farmers manage financial challenges (Sharma & Deshmukh, 2018).

Given the economic and agricultural importance of Jowar in the region, an aeromycological study focusing on fungal species belonging to the Ascomycetes group was conducted in Jowar fields located in the Mangalvedha Tehsil of Solapur District. Present study aimed to better understand the dynamics of airborne fungi especially belonging to Ascomycota group during two seasons - Rabi and Kharif which has differential meteorological conditions altogether. Influence of meteorological factors on the prevalence of Ascomycetes was also evaluated in the study.

MATERIALS AND METHODS:

The study was conducted in the Mangalvedha region of Maharashtra, India (Latitude 17.53288° and Longitude 75.46333°) during the Rabi season, (October 4, 2022, to February 12, 2023) and Kharif season (June 10, 2023 to October 5, 2023).

Aeromycological data were collected using a continuous volumetric Tilak air sampler positioned in various Jowar fields within Mangalvedha taluka. The Tilak air sampler, first described by Tilak and Kulkarni (1970), is an electrically powered device designed to operate continuously, collecting samples every week. The air sampler was installed at a height of 3 feet above ground level. Its rotating drum takes seven days to complete one full cycle, during which airborne spores adhere to a cello tape strip coated with melted glycerin jelly. After each week, the tape was replaced and mounted onto slides for microscopic analysis.

Spore identification was carried out based on morphological characteristics, with reference to standard Aeromycology texts, monographs, and other classification resources. The classification framework proposed by Ainsworth (1971) was employed for categorization.

Meteorological data in terms of temperature, humidity and precipitation during study period was collected from the website of National Aeronautics and Space Administration (NASA), USA. (https://power.larc.nasa.gov/).

RESULTS AND DISCUSSION

Aeromycological study in Jowar field of Mangalvedha region of Maharashtra, India was carried out during Rabi and Kharif season. Time span of the study was given in Table 1.

Table 1: Dates of seed sowing, harvesting and period of air sampling over the Jowar field.

Season	Dates of sowing	Dates of harvesting	Period of sampling (days)
Rabi (2022-23)	4 Oct, 2022	13 Feb, 2023	133
Kharif (2023)	10 June, 2023	5 Oct, 2023	118

During study thirty four fungal spores (Table 2) belonging to ascomycetes were collected and analyzed. Total spore concentration and their % contribution during Rabi and Kharif were presented in Table 2.

Table 2 Fungal spores belonging to Ascomycetes observed during Rabi and Kharif season.

Sr. No	Fungal spore	Rabi 4/10/2022 – 13/02/2023		Kharif 10/06/2023- 5/10/2023	
		Total fungal spore conc/m^3 in air	% contribution of fungal spores	Total fungal spore conc/m^3 in air	% contribution of fungal spores
1	*Apiorhyncostoma sps*	70	0.09	28	0.04
2	*Aspergillus sps*	224	0.28	70	0.10
3	*Bitrimonospora sps*	2016	2.55	1232	1.77
4	*Botryosphaeria sps*	70	0.09	322	0.46
5	*Cephallophora sps*	294	0.37	252	0.36
6	*Chetomium sps*	2828	3.57	966	1.39
7	*Cucurbitaria sps*	182	0.23	280	0.4
8	*Dactylelia sps*	28	0.04	168	0.24
9	*Didymosphaeria sps*	854	1.08	616	0.89
10	*Diplococcium sps*	56	0.07	112	0.16
11	*Hypoxylon sps*	1344	1.7	952	1.37
12	*Hysterium sps*	350	0.44	280	0.4
13	*Keratinomyces sps*	42	0.05	28	0.04
14	*Lecanidion sps*	126	0.16	154	0.22
15	*Leptosphaeria sps*	1372	1.73	1358	1.95
16	*Lophiostoma sps*	546	0.69	924	1.33
17	*Massaria sps*	994	1.26	574	0.82
18	*Melanospora sps*	2100	2.65	3528	5.07
19	*Meliola citri*	574	0.73	350	0.5
20	*Nectria sps*	112	0.14	126	0.18
21	*Parodiella sps*	938	1.19	98	0.14
22	*Pleospora sps*	378	0.48	1428	2.05
23	*Podonectria sps*	350	0.44	140	0.2
24	*Pringsheimia sps*	140	0.18	112	0.16
25	*Scopulariopsis sps*	322	0.41	966	1.39
26	*Sordaria sps*	756	0.96	1232	1.77
27	*Sporormia sps*	84	0.11	56	0.08
28	*Sporomiella sps*	42	0.05	112	0.16
29	*Stachybotrys sps*	434	0.55	154	0.22
30	*Teichospora sps*	196	0.25	224	0.32
31	*Trematosphaeria sps*	252	0.32	686	0.99
32	*Triposporium sps*	644	0.81	182	0.26
33	*Valsaria sps*	336	0.42	238	0.34

34	*Xylaria sps*	1274	1.61	210	0.3

Morphological features of Ascospores:

All the spores were identified according to their morphology. The ascospores of *Apiorhyncostoma* species which accounted 0.09 and 0.04% during Rabi and Kharif, respectively are typically elongated with apical extensions or appendages that help them adhere to surfaces or participate in dispersal. These appendages can vary in length and shape depending on the species. *Aspergillus* species (Rabi- 0.28 & Kharif-0.10%) produce conidia that are round to ovoid in shape. These conidia typically have smooth to rough walls, and they are borne on phialides (specialized conidiogenous cells) that are arranged in a vesicular structure. The vesicle, a bulbous structure, releases conidia during the asexual reproduction process.

Bitrimonospora spores which accounted 2.55 and 1.77% during Rabi and Kharif, respectively are multicellular, elongated, and exhibit characteristic septation. These spores usually have a segmented structure, which is marked by visible cross walls (septa), aiding in identification under the microscope. *Botryosphaeria dothidea* ascospores are fusiform (spindle-shaped) to ellipsoidal with slight septation. These spores are often pale or light-colored, with smooth surfaces and taper at both ends. They are released from ascocarps and typically exhibit minimal pigmentation. They constitute 0.09% during Rabi and 0.46% in Kharif.

The conidia of *Cephalosporium irregularis* accounted 0.37 and 0.36% during Rabi and Kharif, respectively. They are cylindrical to irregularly shaped. These conidia are produced in slimy heads, which consist of sticky masses, helping them adhere to substrates or other organisms. *Chaetomium* ascospores (3.57 & 1.39% during Rabi & Kharif respectively) are lemon-shaped to ellipsoidal, with setae (hair-like structures) or spiny ornamentation on the surface. These spores are typically dark in color and are often surrounded by long, hair-like filaments, which aid in dispersal and attachment. *Cucurbitaria* ascospores are elliptical to fusiform in shape and are characterized by brown pigmentation and distinct septation. These spores are often released from mature fruiting bodies, and their dark coloration helps in their identification. Their presence is 0.23 & 0.40% during Rabi and Kharif respectively.

The conidia of *Dactylelia* species (Rabi- 0.04% & Kharif- 0.24%) are elongated and cylindrical. These spores are specialized for trapping nematodes and play a role in the parasitic behavior of the fungus. Their structure allows for attachment to nematodes, aiding in the parasitic process. *Didymosphaeria* ascospores (1.08% & 0.89%) are dark-colored, with two cells and a smooth to rough-walled surface. These spores are often released from dark ascocarps and may show slight roughness in their outer walls. Conidia of *Diplococcium* species are bicellular, elongated, and often take a club-shaped form. These spores are typically found in groups and play an essential role in the asexual reproduction of the fungus. They accounted for 0.07 & 0.16% in Rabi & Kharif, respectively.

Hypoxylon ascospores (Rabi- 1.7% & Kharif- 1.37%) are elliptical and darkly pigmented, often with smooth surfaces. These spores are frequently found in fruiting bodies, which are often dark or woody in appearance, contributing to their easy identification. *Hysterium* ascospores are fusiform (spindle-shaped) and often exhibit translucent or darkened walls. These spores tend to have a slightly curved shape, which is useful for identification, and can be found in fruiting bodies that are dark in color. The conidia of *Keratinomyces* species are cylindrical or spindle-shaped and are smooth-walled. These conidia are often produced in chains and have a distinct appearance due to their regular, linear formation.

Lecanidion ascospores are hyaline (colorless), oval to elongated, and septate. The septa divide the spore into multiple cells, which can help in the identification of the species. These spores are generally smaller in size and are produced within specialized fruiting structures. *Leptosphaeria* ascospores are fusiform and multiseptate, typically with pigmented walls. The spore has a characteristic shape and the presence of multiple septa contributes to its classification. Ascospores of *Lophiostoma* species are fusiform to curved and multiseptate. These spores typically have dark pigmentation, making them easily distinguishable under a microscope.

Massaria ascospores are dark, fusiform, and distinctly septate. The septa divide the spore into multiple cells, and their dark pigmentation can range from brown to black. *Melanospora* ascospores are round to ellipsoid, dark, and smooth-walled. The smooth surface and dark coloration of these spores aid in their identification. Conidia of *Meliola citri* are oval and darkly pigmented, typically borne in chains or clusters. These spores are often found in sticky masses and contribute to the spread of the fungal disease. *Nectria* ascospores are ellipsoidal to fusiform in shape, often hyaline, and have smooth walls. These spores are typically released from brightly colored fruiting bodies.

Parodiella ascospores are fusiform, septate, and slightly pigmented. These spores exhibit a clear division into cells due to the septa, and their color can range from pale to slightly dark. *Pleospora* ascospores are broadly ellipsoidal, dark, and multiseptate. These spores are often large and have a distinct appearance due to their shape and multiple septa. Ascospores of *Podonectria aurantil* are narrow, hyaline (colorless), and multiseptate. These spores are characterized by their elongated shape and clear appearance. Conidia of *Pringsheimia* species are elongated, hyaline, and septate. These spores typically grow in chains or clusters, forming a distinct structure during asexual reproduction.

The conidia of *Scopulariopsis* species are lemon-shaped, rough-walled, and borne in chains. These conidia often have a characteristic rough surface texture, helping in their identification. *Sordaria* ascospores are dark, ellipsoidal, and smooth-walled, with distinct germ pores. These pores allow for the germination of the spores under favorable conditions. Ascospores of *Sporormia* are dark, multiseptate, and often cylindrical in shape. These spores typically have a segmented structure due to multiple septa. The ascospores of *Sporomiella* species are dark, multiseptate, and ellipsoidal. They are marked by distinct septa and are often found in dark-colored fruiting bodies. Conidia of *Stachybotrys* are oval to ellipsoidal, dark, and borne in slimy masses. These masses make it easier for the conidia to adhere to surfaces.

Ascospores of *Teichospora* species are fusiform, multiseptate, and darkly pigmented. The multiseptate structure and dark coloration are key features for identifying this group. *Trematosphaeria* ascospores are elongated, fusiform, and often septate. These spores are typically smooth or slightly rough-walled and show noticeable septation. Conidia of *Triposporium* species are star-shaped, with branched appendages. The conidia's unique shape and branching appendages make them easy to identify. *Valsaria* ascospores are fusiform, dark, and multiseptate. The combination of fusiform shape and multiple septa helps in distinguishing these spores. *Xylaria* ascospores are dark, elliptical, and have a germ slit. The germ slit is a notable feature that distinguishes them from other fungal spores.

Seasonal trends in fungal spores

A comparative analysis of concentration of each spore species in Rabi and Kharif season is given in Figure 1.

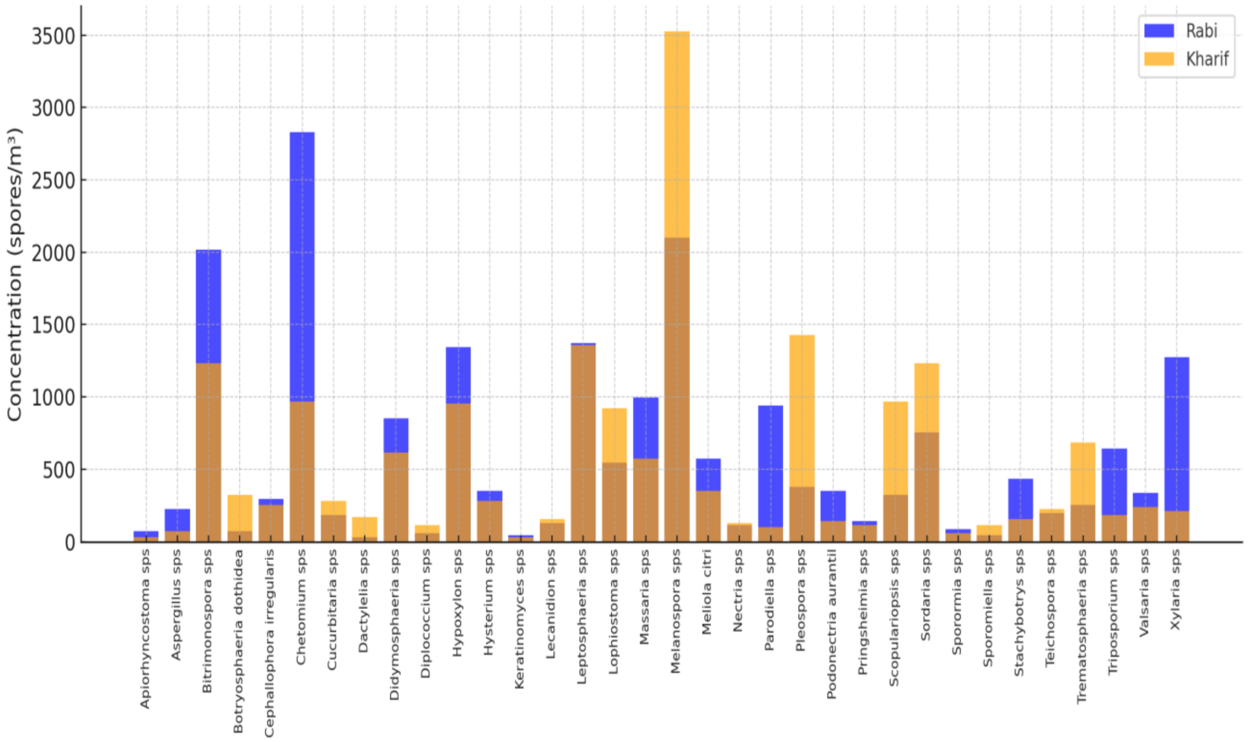

Figure 1 Spore concentrations of each fungus during Rabi and Kharif season.

During the Rabi season (October 2022 to February 2023), the fungal spores with the highest contributions to total concentrations were *Chetomium sps* (3.57%), *Melanospora sps* (2.65%), *Bitrimonospora sps* (2.55%), *Leptosphaeria sps* (1.73%), and *Hypoxylon sps* (1.7%). These species collectively accounted for a significant portion of the fungal load, with *Chetomium sps* standing out as the most dominant spore in the season. This distribution suggests that these fungi flourish in the conditions typical of the Rabi season, such as lower humidity and reduced precipitation.

In the Kharif season (June 2023 to October 2023), the fungal spore composition shifted, with *Melanospora sps* emerging as the dominant species, contributing 5.07% to the total fungal concentration. Other significant contributors included *Pleospora sps* (2.05%), *Leptosphaeria sps* (1.95%), *Sordaria sps* (1.77%), and *Bitrimonospora sps* (1.77%). This seasonal variation highlights the ability of *Melanospora sps* and *Pleospora sps* to grow well in the wetter and more humid conditions of Kharif. Notably, *Bitrimonospora sps* maintained a relatively consistent presence across both seasons, indicating its adaptability to varying environmental conditions of Rabi and Kharif.

During the Rabi season, fungal spores like *Chetomium sps* (3.57%) and *Bitrimonospora sps* (2.55%) showed higher concentrations, likely due to their resilience to lower humidity and minimal precipitation. Dry conditions during this season can reduce competition from moisture-dependent fungi, allowing these species to dominate. Studies have shown that *Chetomium sps* thrives in drier environments and exhibits efficient spore dispersal under such conditions (Gupta et al., 2015). Furthermore, the dominance of *Chetomium sps* during Rabi season could be utilized for its potential as a biological control agent, given its known antagonistic properties against plant pathogens (Kumar et al., 2016).

In contrast, the Kharif season, characterized by higher temperatures, humidity, and precipitation, supported the dominance of moisture-dependent fungi like *Melanospora sps* and *Pleospora sps*. The considerable increase in *Melanospora sps* (from 2.65% in Rabi to 5.07% in Kharif) aligns with findings by Paul et al. (2020), which demonstrated that higher humidity levels boost fungal sporulation and dissemination. The frequent precipitation events in Kharif likely contributed to the dispersal of waterborne fungal spores, as also suggested by Mallaiah and Rao (2013).

Influence of Meteorological factors:

Study was aimed to investigate the influence of meteorological conditions on the spore concentration. Different meteorological factors such as temperature, relative humidity and precipitation were month wise considered during study. In both seasons (Rabi and Kharif) meteorological conditions are totally different. Thus, this meteorological data was correlated with spore concentrations in order to investigate influence of weather conditions on spore concentration. Month wise meteorological data during study was given in Table 3 & 4.

Table 3: Month wise average meteorological data for first Rabi season (Oct 2022 to Feb 2023)

Rabi-I	Oct-22	Nov-22	Dec-22	Jan-23	Feb-23
Temperature (^{0}C)	24.46	22.68	23.57	23	25.16
Humidity (%)	78.1	71.99	66.48	48.46	26.75
Precipitation (mm)	4.6	0.01	0.03	0	-

Table 4: Month wise average Meteorological data for first Kharif season (June 2023 to Oct 2023)

Kharif - I	Jun-23	Jul-23	Aug-23	Sep-23	Oct-23
Temperature (^{0}C)	30.55	26.92	27.66	27.66	26.56
Humidity (%)	56.7	76.21	71.37	73.92	76.1
Precipitation (mm)	1.77	6.31	0.85	4.46	7.71

A comprehensive graphical representation of the meteorological conditions across Rabi and Kharif season was given in Figure 2. Fungal spore concentrations and their distribution are strongly influenced by seasonal meteorological factors such as temperature, humidity, and precipitation. The observed variations between the Rabi (October to February) and Kharif (June to October) seasons reflect the distinct ecological preferences of fungal species and their adaptability to environmental changes.

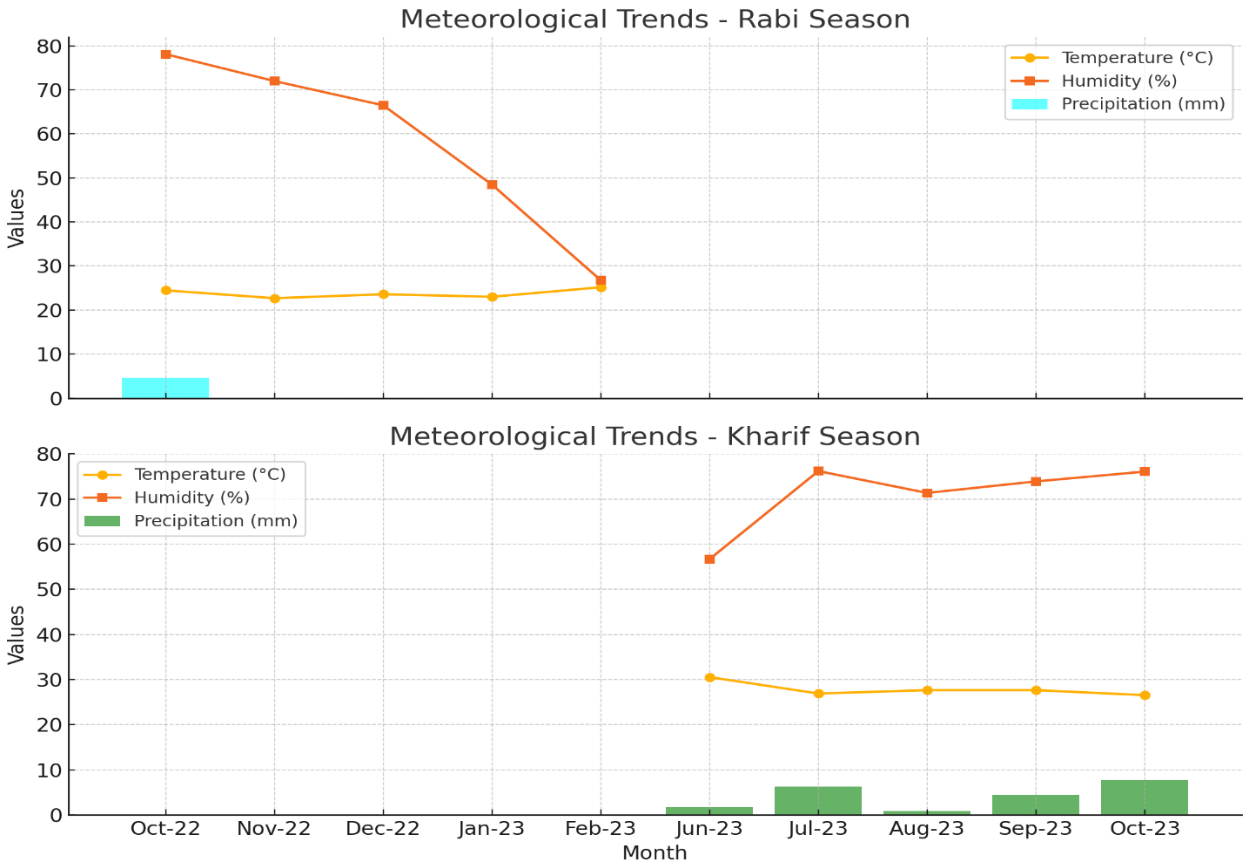

Figure 2 Meteorological trends showing temperature, humidity and precipitation during Rabi and Kharif season. The Rabi season has stable temperatures, ranging from 22.68°C in November to 25.16°C in February, with minimal variation (Table 3). Humidity showed a steady decline, starting at 78.1% in October and falling drastically to 26.75% by February (Table 3). This marked reduction in humidity was accompanied by negligible precipitation, with October being the only month with significant rainfall (4.6 mm) (Table 3). These dry and cooler conditions are consistent with the dominance of fungal spores like *Chetomium sps*, which are likely adapted to such environments.

In contrast, the Kharif season was characterized by higher average temperatures, ranging from 26.56°C in October to a peak of 30.55°C in June (Table 4). Humidity levels remained consistently high, fluctuating between 70% and 76%, creating a favorable environment for fungal growth. From Table 4, it can be seen that precipitation was also significantly higher during Kharif, which peaks in October (7.71 mm) and July (6.31 mm). This combination of warmth, humidity, and rainfall provided ideal conditions for fungal spores like *Melanospora sps* and *Pleospora sps* to flourish.

The high humidity levels during Kharif, showed the dominance of *Melanospora sps* (5.07%) and *Pleospora sps*. (2.05%) which thrive in moist conditions. On the other hand, the decline in humidity during the Rabi season seems to favor spores like *Chetomium sps*, (3.57%) indicating its resilience to drier conditions (Table 2).

Thus, humidity emerged as a critical factor influencing fungal spore distribution. High humidity levels during the Kharif season created favorable conditions for fungal growth and sporulation, consistent with previous research indicating that fungal growth accelerates in environments with sustained relative humidity above 70% (Kim et al., 2018). Conversely, the decline in humidity during the Rabi season limited the growth of moisture-dependent fungi while promoting the proliferation of drought-tolerant species. Earlier studies have shown that high humidity levels are essential for the growth of moisture-dependent fungi like *Alternaria alternata*, with optimal growth at 100% relative humidity and a gradual decline as humidity decreases (Balai & Ahir, 2013). This inverse relationship between humidity and fungal spore types highlights the adaptability of different species to specific environmental conditions (Prentice & Capone, 2018).

Precipitation, another key factor, supports fungal proliferation, as evidenced by the higher spore concentrations in the Kharif season (Table 2). Increased rainfall likely contributes to the spread and reproduction of moisture-dependent spores like *Melanospora sps*. (5.07%). Conversely, spores thriving in the Rabi season, such as *Chetomium sps*, (3.57% during Rabi and 0.36% during Kharif) seem less reliant on precipitation and better suited to dry periods (Table 2).

Precipitation, however irregular in Rabi, was significant during Kharif and supported the growth and dispersal of spores like *Pleospora sps*. (0.48% in Rabi whereas 2.05% in Kharif). These results are in accordance with the observations of Sharma et al. (2017) and Kim et.al.,(2019). These studies illustrate how rainfall not only provides the moisture necessary for spore germination but also plays a crucial role in the dispersal of spores, thereby facilitating the spread of fungal pathogens.
Temperature, while less-variable across seasons, likely interacts with humidity and precipitation to influence fungal growth. The warmer conditions of the Kharif season, combined with high humidity and rainfall, create an optimal environment for many fungal species like *Melanospora, Pleospora.* Meanwhile, the cooler, drier conditions of Rabi restrict the growth of moisture-dependent spores like *Lophiostoma* (Rabi- 0.69% and Kharif- 1.33%), *Scopulariopsis* (Rabi- 0.41% and Kharif- 1.39%) but allow more drought-resistant species like *Xylaria* (Rabi- 1.61% and Kharif- 0.3%) to dominate (Table 2).
Temperature is relatively stable across seasons, played a synergistic role with humidity and precipitation. Warmer temperatures in Kharif enhanced the metabolic activity and sporulation of fungi, a relationship well established in studies on tropical fungal ecology (Smith & Read, 2008). The limited variability in temperature during the Rabi season suggests that other factors, such as precipitation, may have a greater influence during this period.
Thus, the concentration of fungal spores in Jowar fields is significantly influenced by the interplay of temperature, humidity, and precipitation. Fungal spores are emitted directly into the atmosphere during the fungal reproduction process when temperature and humidity conditions are favorable, and their emission can also be triggered by wind and rain (Elbert et al., 2007).

CONCLUSION

The findings highlight the importance of understanding fungal ecology in the context of seasonal meteorological changes. Fungal spores such as *Melanospora sps* and *Pleospora sps* could pose a higher risk of plant infections during the Kharif season, especially in humid and rain-prone regions. Furthermore, the dominance of *Chetomium sps* during Rabi could be utilized for its potential as a biological control agent, given its known antagonistic properties against plant pathogens. This underscores the need for timely monitoring and management strategies in agricultural systems to mitigate fungal infections. In the context of Jowar fields, meteorological factors (temperature, humidity and precipitation) collectively determine the prevalence and diversity of airborne Ascomycetes, which can impact crop health and yield.

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