

DO HONEYBEES USE THE FUNGAL SPORES AS NUTRITIONAL SUPPLEMENTS? AN ANATOLIAN SAMPLE

Gulsah Yil¹

Received 25.05.2026.

Revised 13.08.2026.

Accepted 02.09.2026.

Keywords:

Honey, Fungal Spore,
Malatya, Anatolia

ABSTRACT

Honey is one of the most requested food products worldwide. The beneficial biochemicals are primarily provided by plants that honeybees visit to collect nectar and pollen. Pollen was considered to be the most important nutritional source of honey but in studies conducted in recent years fungal spores are accepted as supplement of bee products. When fungal spores are added to the pollen diet, they increase the nutritional value and ensure that the bee colony lives longer. Additionally it is possible to utilize bees in engineering applications-as spatially distributed bioindicators- to interpret ecological conditions. . For this reason this study was conducted in 13 districts of Eastern Anatolia (Malatya) during 2020. The 35 honey samples were provided from local stationary beekeepers. The honeys were prepared to examine microscopic for determining the diversity of fungal spores. 35 fungal spore type and hypha fragments were specified. *Cladosporium* (13.484 %), *Aspergillus/Penicillium* (6.682 %), *Uredinales* (6.592 %), *Metschnikowia* (5.692 %), *Puccinia* (5.649 %) spores were determined as most frequent spore types in samples. Kuluncak (KC-1) sample represented with the highest percentage (4.891%), Puturge (PT-3) sample represented with the lowest percentage (1.985%) in all districts of study area.



© 2026 Published by Faculty of Engineering

1. INTRODUCTION

Honey is known as the oldest sweet historically and has already been demanded around the world. Because of this request honey standardization has gained importance. The physical characteristics like colour, taste, pH, viscosity are affected substantially by pollen and spore chemicals (Anklam, 1998; Shaw, 1990). Melissopalynological studies have been carrying out for years all around the world for identifying microscopic elements (fungal spores, yeasts, pollen ... etc.) in honey to determine the ecological, botanical and geographical origin of honey.

Fungal spores come into honey in three ways. The first way is originated airborne with contamination (Pérez-Atanes et al., 2001). Weather conditions such as air humidity, air velocity, temperature, precipitation could affect the fungal spore concentration and composition in the air (Grinn-Gofroń & Bosiacka, 2015; Modro et al., 2009; Pasanen et al., 1991). The seconder way is the reason of honeydew in beehives (Pérez-Atanes et al., 2001). The last way is “active” mode; the bees collect the fungal spores vice polen grains (Parish et al., 2020). The bees collect the fungal spores instead of pollen could be explained by scarcity of botanical sources, wealthy nutritional compounds of fungal spores, the attractive fragrance and appearance and the morphological

¹ Corresponding author: Gulsah Yil
Email: gulsah.saatcioglu@ozal.edu.tr

similarity of some fungal spores and pollen grains (Parish et al., 2020; Shaw, 1990).

The bees utilize the fungal spores in lieu of pollen grains at the lack of flowering period for nutritional value (Lang, 1901; Parish et al., 2020). The fungal spore supplemented pollen diet of honey bees had shown the nutritiousness of fungal spores prolong the life of the worker bees (Parish et al., 2020). According to Modro et al. (2009) the crude protein, organic material and total carbohydrate values of fungal spores are quite rich. The bees can collect the fungal elements from vegetative parts of the plants while foraging for nectar (Seijo et al., 2011). The fungal spores as pellets are transported by pollen baskets on the honey bee legs like pollen grains and the spores that carried by this way, could be on honeycomb cells and all other surfaces (Lang, 1901; Modro et al., 2009; Seijo et al., 2011). The filamentous fungi is, by the virtue of its high nutrient content, accepted as future food and many studies has carried through on this trajectory (Barzee et al., 2021).

Metschnikowia T. Kamienski is yeast as a member of ascomycetes and in anaerobic conditions it shows pseudo hyphal growth (Vicente et al., 2020). *Metschnikowia* taxa could be observe on flowers or fruits and disperse to new habitats entomologically especially by honey bees (*Apis mellifera* L.) (Gruß, 1917–1918; Hong et al., 2001). The existence of this taxon in honeys was indicated by Magyar et al. (2005) firstly. *Metschnikowia* cells are a useful tool for distinguish blossom honey and honeydew honey (Escuredo et al., 2012; Seijo et al., 2011).

The studies about determining of fungal spores in honey samples are less by the side of pollen studies (Dimou et al., 2006; Escuredo et al., 2012; Mura-Mészáros & Magyar, 2017; Seijo et al., 2011; Terrab et al., 2019). This examination is conducted for defining the fungal spore content of Malatya (Southeast Anatolia) honeys to approach the ecological sources of honeys.

The filamentous fungi is, by the virtue of its high nutrient content, accepted as future food and many studies has carried through on this trajectory (Barzee et al., 2021). Various organisms serve as bioindicators in fields such as environmental monitoring and ecotoxicology, and this data has been utilized for many years, particularly within framework of environmental engineering. These organisms include lichens (Fрати et al., 2007), mussels (Nguyen Thanh Kim et al., 2025), and earthworms (Fründ et al., 2010). Honey bees can also serve as bioindicators for identifying environmental markers. They provide insight into the botanical, geographical and ecological characteristics of the areas where they forage for nectar, pollen, resin and fungal spores to produce bee products (Cunningham et al., 2022; Shindler et al., 2013).

2. MATERIALS AND METHODS

2.1 Study Area

Malatya is located in the Eastern Anatolia Region. There are 13 districts of Malatya and Arapgir, Arguvan, Hekimhan, Kuluncak are located in northern, Darende, Akcadag, Dogansehir are located in western, Dogansehir, Yesilyurt, Battalgazi and Puturge are located in southern, Doganyol, Kale and Yazihan are located in eastern of the city (Figure 1). Karakaya Dam surrounds the east of city and Akcadag Plateaus from west. Yama Mountain is in north, Nurhak Mountains places in south of Malatya.

The phytogeographical regional features of Malatya flora included Irano-Turanian (42.18%), Mediterranean (7.82%) and Euro-Siberian (3.84%) elements and In terms of species wealthy the largest families are analysed as Asteraceae, Fabaceae, Brassicaceae, Lamiaceae, Poaceae (Karakuş, 2016). According to previous studies some of fungal genera in the study area had been recorded as; *Peronospora*, *Pleospora*, *Puccinia*, *Uromyces*, *Ustilago*, *Botrytis*, *Cladosporium*, *Helminthosporium* (Bahçecioğlu & Gjærum, 2004; Bahçecioğlu & Yıldız, 2001; Kabaktepe et al., 2015; Tamer et al., 1987).

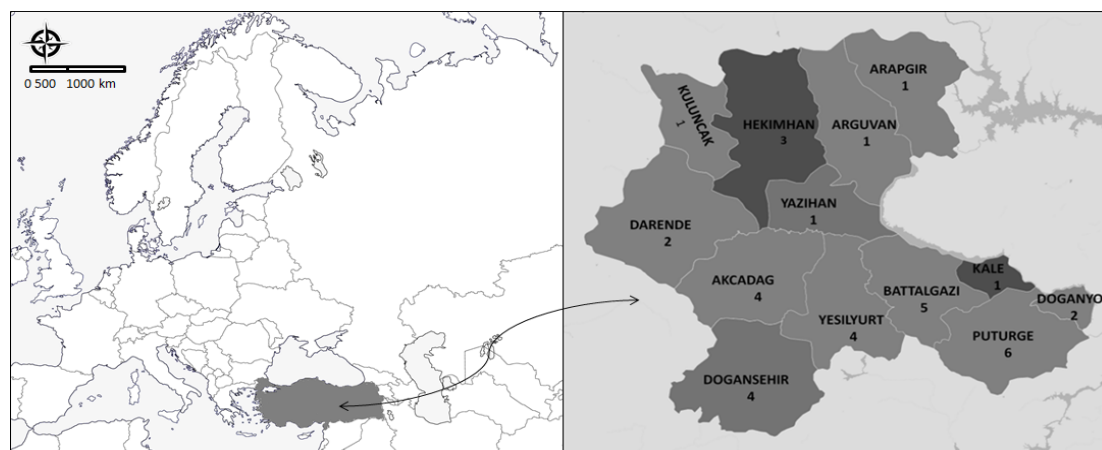


Figure 1. Study area and the sample quantities, provided of districts.
(https://en.wikipedia.org/wiki/File:A_general_map_of_Eastern_Europe.svg)

2.2 Microscopy

The 35 honey samples were collected from local beekeepers of all 13 districts of Malatya (Eastern Anatolia) in 2020. The districts and the sample numbers are Akcadag (AK)/4, Arapgir (AP)/1, Arguvan (AR)/1, Battalgazi (BG)/5, Darende (DR)/2, Dogansehir (DS)/4, Doganyol (DY)/2, Hekimhan (HK)/3, Kale(KL)/1, Kuluncak (KC)/1, Puturge (PT)/6, Yazihan (YZ)/1, Yesilyurt (YY)/4. Louveaux et al. (1978) methodology was used for preparing to honey samples for prepare to examination. According to the procedure a ten gram sample taken from each honey was dissolved in distilled water at 45°C and centrifuged for 10 minutes at 3500 rpm using Nüve NF200 desktop centrifuge. The supernatant was then removed. Basic fuchsin-stained glycerin-gelatin was added the sample. The sediment was transferred to a slide in this state, covered with a 22X22 lamella, and prepared for examination. In each sample, fungal spores were counted by scanning the entire area of the 22X22

mm lamella under a Nikon Eclipse E100 microscope using a 100X magnification oil-immersion objective. The morphological spore identification was based on (Domsch et al., 1980; Ellis & Ellis, 1998; Grant Smith, 2000; St-Germain & Summerbell, 1996; Watanabe, 2002) and our references. The statistical analysis of dominant fungal taxa has done according to One-Way Anova Test (Figure 5-6, Table 2-3).

3. RESULTS

Accordingly the districts of Malatya city 35 fungal taxa and hypha fragments determined in 35 honey samples examined in 2020 (Table 1). Kuluncak (KC-1) sample represented with the highest percentage (4.891 %), Puturge (PT-3) sample represented with the lowest percentage (1.985%) in study area, Eastern Anatolia (Malatya) (Table 1, Figure 2). Undetermined fungal spores, with 1.717% percentages, shown as “Others” in Table 1.

Table 1. The fungal spore concentrations according to the locations (%)

TAXA/SAMPLE	KC1	KL1	AR-1	AP1	AK1	AK2	AK3	AK4	HK1	HK2	HK3	DS1	DS2	DS3	DS4	YZ1	DY1	DY2
<i>Agroclybe</i>	0.025	0.036	0.036	0.016	0.005	0.008	0.030	0.030	0.044	0.038	0.014	0.033	0.008	0.003	0.003	0.005	0.019	0.036
<i>Alternaria</i>	0.183	0.090	0.128	0.033	0.139	0.107	0.074	0.049	0.098	0.115	0.041	0.145	0.046	0.063	0.071	0.303	0.120	0.074
<i>Anthrinium</i>	0.008	0.000	0.011	0.000	0.033	0.030	0.016	0.025	0.027	0.033	0.014	0.019	0.008	0.003	0.030	0.016	0.030	0.011
<i>Asp./Pen.</i>	0.435	0.213	0.170	0.202	0.159	0.336	0.183	0.030	0.123	0.066	0.254	0.323	0.107	0.126	0.098	0.623	0.046	0.057
<i>Botrytis</i>	0.413	0.172	0.139	0.038	0.060	0.049	0.098	0.046	0.033	0.391	0.120	0.197	0.052	0.131	0.090	0.139	0.074	0.044
<i>Chaetomium.</i>	0.011	0.030	0.022	0.016	0.033	0.005	0.016	0.011	0.019	0.003	0.036	0.074	0.057	0.044	0.066	0.036	0.014	0.030
<i>Cladosporium</i>	1.195	0.435	0.049	0.339	0.044	0.984	0.703	0.254	0.046	0.514	0.235	0.079	0.046	0.489	0.585	0.049	0.052	0.036
<i>Coprinus</i>	0.085	0.022	0.036	0.046	0.025	0.016	0.057	0.038	0.019	0.030	0.022	0.063	0.049	0.027	0.044	0.033	0.066	0.079
<i>Curvularia</i>	0.044	0.057	0.038	0.033	0.044	0.038	0.036	0.027	0.049	0.060	0.041	0.085	0.074	0.077	0.063	0.060	0.036	0.030
<i>Drechslera</i>	0.077	0.052	0.036	0.060	0.063	0.044	0.049	0.030	0.044	0.038	0.036	0.044	0.030	0.060	0.071	0.038	0.074	0.033
<i>Epicoccum</i>	0.033	0.038	0.041	0.030	0.038	0.044	0.038	0.030	0.033	0.036	0.030	0.030	0.041	0.044	0.033	0.030	0.044	0.033
<i>Fusarium</i>	0.038	0.049	0.060	0.046	0.025	0.038	0.011	0.016	0.005	0.025	0.044	0.057	0.052	0.044	0.049	0.066	0.019	0.036
<i>Ganoderma</i>	0.060	0.052	0.063	0.057	0.066	0.060	0.071	0.071	0.068	0.063	0.057	0.060	0.074	0.071	0.057	0.063	0.057	0.074
<i>Geotrichum</i>	0.112	0.071	0.090	0.046	0.098	0.036	0.066	0.101	0.068	0.120	0.115	0.057	0.079	0.074	0.085	0.098	0.093	0.090
<i>Myxomycetes</i>	0.150	0.044	0.063	0.101	0.041	0.052	0.036	0.049	0.074	0.066	0.079	0.060	0.085	0.090	0.057	0.038	0.046	0.066
<i>Helminthosporium</i>	0.090	0.085	0.104	0.087	0.101	0.079	0.063	0.098	0.115	0.057	0.077	0.071	0.101	0.057	0.107	0.066	0.090	0.082
<i>Hypha</i>	0.142	0.118	0.022	0.033	0.049	0.038	0.057	0.052	0.074	0.090	0.104	0.046	0.131	0.098	0.139	0.118	0.052	0.044
<i>Leptosphaeria</i>	0.120	0.139	0.090	0.170	0.183	0.213	0.194	0.202	0.085	0.079	0.068	0.098	0.090	0.085	0.093	0.109	0.079	0.057
<i>Melanospora</i>	0.000	0.027	0.005	0.000	0.008	0.030	0.025	0.011	0.019	0.014	0.003	0.025	0.016	0.008	0.022	0.019	0.011	0.025
<i>Metschnikowia</i>	0.703	0.380	0.077	0.457	0.049	0.484	0.416	0.052	0.202	0.208	0.224	0.178	0.134	0.115	0.090	0.093	0.074	0.087
<i>Nigrospora</i>	0.038	0.057	0.071	0.068	0.044	0.033	0.033	0.041	0.052	0.044	0.060	0.063	0.052	0.057	0.060	0.046	0.036	0.036
<i>Paecilomyces</i>	0.005	0.046	0.036	0.057	0.077	0.025	0.049	0.038	0.052	0.060	0.623	0.016	0.030	0.038	0.036	0.049	0.057	0.074
<i>Peronospora</i>	0.036	0.057	0.046	0.041	0.033	0.049	0.055	0.038	0.052	0.057	0.044	0.063	0.060	0.055	0.038	0.044	0.041	0.057
<i>Phytomyces</i>	0.066	0.041	0.057	0.044	0.060	0.057	0.055	0.046	0.055	0.057	0.066	0.052	0.057	0.060	0.046	0.057	0.060	0.052
<i>Pleospora</i>	0.057	0.046	0.090	0.066	0.052	0.046	0.057	0.049	0.046	0.036	0.038	0.087	0.093	0.082	0.090	0.079	0.071	0.057
<i>Fern</i>	0.066	0.044	0.000	0.057	0.052	0.041	0.057	0.049	0.254	0.385	0.375	0.052	0.063	0.049	0.052	0.060	0.093	0.112
<i>Puccinia</i>	0.336	0.052	0.074	0.090	0.131	0.178	0.224	0.591	0.044	0.049	0.066	0.172	0.153	0.131	0.107	0.202	0.052	0.038
<i>Stemphylium</i>	0.038	0.044	0.036	0.044	0.038	0.041	0.052	0.046	0.038	0.049	0.046	0.036	0.055	0.038	0.049	0.044	0.036	0.049
<i>Torula</i>	0.033	0.057	0.038	0.049	0.093	0.090	0.071	0.038	0.060	0.068	0.066	0.077	0.085	0.063	0.071	0.033	0.085	0.074
<i>Trichothecium</i>	0.003	0.011	0.003	0.005	0.003	0.008	0.011	0.016	0.005	0.008	0.005	0.016	0.005	0.003	0.014	0.005	0.019	0.011
<i>Ulocladium</i>	0.074	0.148	0.115	0.172	0.046	0.038	0.057	0.060	0.093	0.071	0.079	0.087	0.077	0.101	0.052	0.118	0.126	0.139
<i>Uredinales</i>	0.030	0.049	0.238	0.254	0.044	0.087	0.126	0.046	0.235	0.213	0.189	0.457	0.503	0.369	0.391	0.470	0.153	0.224
<i>Ustilago</i>	0.085	0.046	0.071	0.087	0.071	0.052	0.066	0.077	0.063	0.049	0.052	0.041	0.052	0.074	0.066	0.079	0.068	0.044
<i>Venturia</i>	0.030	0.049	0.066	0.060	0.044	0.052	0.038	0.060	0.071	0.036	0.036	0.038	0.046	0.033	0.052	0.057	0.049	0.066
<i>Xylaria</i>	0.005	0.003	0.016	0.014	0.008	0.005	0.011	0.003	0.008	0.014	0.008	0.003	0.005	0.016	0.011	0.008	0.000	0.000
<i>Zygophiala</i>	0.030	0.027	0.041	0.033	0.036	0.044	0.036	0.049	0.038	0.030	0.033	0.033	0.030	0.036	0.033	0.030	0.027	0.049
<i>Others</i>	0.036	0.011	0.057	0.014	0.030	0.019	0.025	0.011	0.016	0.036	0.098	0.052	0.066	0.060	0.041	0.085	0.077	0.068
Total	4.891	2.901	2.335	2.969	2.124	3.560	3.262	2.485	2.431	3.308	3.497	3.089	2.715	2.975	3.062	3.472	2.146	2.174

Table 1. The fungal spore concentrations according to the locations (%) (Continued)

TAXA/SAMPLE	PT1	PT2	PT3	PT4	PT5	PT6	YY1	YY2	YY3	YY4	DR1	DR2	BG1	BG2	BG3	BG4	BG5	TOT.
<i>Agrocye</i>	0.022	0.005	0.046	0.044	0.030	0.038	0.036	0.011	0.022	0.008	0.036	0.030	0.027	0.019	0.038	0.014	0.005	0.820
<i>Alternaria</i>	0.077	0.167	0.038	0.066	0.049	0.063	0.087	0.071	0.077	0.057	0.066	0.041	0.052	0.230	0.208	0.186	0.079	3.494
<i>Anthrinium</i>	0.005	0.003	0.003	0.011	0.003	0.005	0.011	0.019	0.011	0.022	0.005	0.008	0.033	0.003	0.011	0.022	0.005	0.495
<i>Asp./Pen.</i>	0.090	0.197	0.126	0.066	0.128	0.243	0.131	0.339	0.235	0.167	0.046	0.036	0.148	0.101	0.517	0.254	0.306	6.682
<i>Botrytis</i>	0.060	0.148	0.066	0.090	0.049	0.044	0.057	0.060	0.074	0.126	0.090	0.175	0.055	0.156	0.118	0.107	0.194	3.956
<i>Chaetomium.</i>	0.008	0.003	0.008	0.038	0.030	0.060	0.005	0.025	0.033	0.003	0.016	0.005	0.057	0.041	0.033	0.071	0.052	1.012
<i>Cladosporium</i>	0.880	0.476	0.189	0.796	0.044	0.090	0.828	0.265	0.481	1.096	0.342	0.049	0.241	0.262	0.249	0.320	0.741	13.484
<i>Coprinus</i>	0.060	0.036	0.044	0.036	0.038	0.022	0.033	0.022	0.046	0.016	0.055	0.038	0.063	0.068	0.052	0.030	0.022	1.438
<i>Curvularia</i>	0.052	0.033	0.046	0.049	0.055	0.044	0.038	0.041	0.033	0.027	0.087	0.030	0.049	0.063	0.074	0.052	0.071	1.736
<i>Drechslera</i>	0.046	0.057	0.036	0.033	0.044	0.046	0.033	0.030	0.052	0.041	0.066	0.057	0.044	0.038	0.046	0.036	0.052	1.635
<i>Epicoccum</i>	0.038	0.030	0.044	0.033	0.030	0.038	0.033	0.033	0.030	0.036	0.036	0.030	0.038	0.044	0.033	0.036	0.030	1.236
<i>Fusarium</i>	0.046	0.030	0.016	0.049	0.055	0.044	0.046	0.060	0.052	0.057	0.033	0.027	0.022	0.011	0.025	0.008	0.014	1.277
<i>Ganoderma</i>	0.060	0.055	0.068	0.066	0.057	0.063	0.060	0.060	0.068	0.066	0.057	0.066	0.055	0.063	0.060	0.063	0.066	2.198
<i>Geotrichum</i>	0.079	0.071	0.057	0.052	0.046	0.060	0.096	0.090	0.087	0.079	0.071	0.085	0.109	0.104	0.098	0.079	0.090	2.857
<i>Myxomycetes</i>	0.077	0.071	0.085	0.098	0.096	0.090	0.060	0.082	0.079	0.098	0.093	0.115	0.079	0.109	0.085	0.098	0.077	2.690
<i>Helminthosporium</i>	0.104	0.071	0.063	0.066	0.057	0.112	0.115	0.068	0.077	0.057	0.063	0.090	0.101	0.098	0.079	0.093	0.085	2.931
<i>Hypha</i>	0.066	0.107	0.036	0.046	0.085	0.066	0.153	0.126	0.118	0.030	0.041	0.074	0.055	0.060	0.090	0.101	0.068	2.729
<i>Leptosphaeria</i>	0.049	0.060	0.052	0.052	0.090	0.079	0.112	0.126	0.107	0.142	0.134	0.172	0.123	0.104	0.156	0.085	0.120	3.921
<i>Melanospora</i>	0.003	0.011	0.008	0.019	0.011	0.019	0.016	0.011	0.025	0.019	0.005	0.008	0.014	0.016	0.014	0.022	0.022	0.511
<i>Metschnikowia</i>	0.077	0.079	0.101	0.038	0.205	0.336	0.060	0.046	0.085	0.079	0.131	0.066	0.079	0.085	0.074	0.068	0.060	5.692
<i>Nigrospora</i>	0.038	0.052	0.060	0.071	0.066	0.063	0.030	0.041	0.038	0.052	0.049	0.066	0.057	0.068	0.060	0.071	0.055	1.829
<i>Paecilomyces</i>	0.025	0.016	0.030	0.036	0.025	0.033	0.038	0.057	0.071	0.036	0.049	0.041	0.036	0.052	0.046	0.038	0.041	2.040
<i>Peronospora</i>	0.046	0.063	0.060	0.041	0.049	0.063	0.060	0.049	0.057	0.060	0.046	0.030	0.044	0.038	0.063	0.057	0.066	1.761
<i>Phytomyces</i>	0.057	0.066	0.060	0.055	0.041	0.052	0.046	0.038	0.049	0.052	0.057	0.055	0.041	0.030	0.046	0.036	0.044	1.815
<i>Pleospora</i>	0.085	0.098	0.104	0.079	0.057	0.038	0.074	0.079	0.063	0.057	0.066	0.068	0.060	0.079	0.055	0.068	0.063	2.340
<i>Fern</i>	0.041	0.057	0.071	0.077	0.104	0.118	0.208	0.189	0.200	0.224	0.216	0.060	0.052	0.068	0.036	0.066	0.046	3.694
<i>Puccinia</i>	0.057	0.052	0.063	0.230	0.046	0.429	0.085	0.150	0.118	0.131	0.071	0.391	0.265	0.186	0.227	0.208	0.249	5.649
<i>Stemphylium</i>	0.049	0.038	0.057	0.052	0.052	0.049	0.038	0.046	0.041	0.052	0.044	0.036	0.038	0.049	0.049	0.038	0.044	1.553
<i>Torula</i>	0.052	0.077	0.046	0.036	0.044	0.082	0.057	0.066	0.077	0.068	0.041	0.071	0.046	0.044	0.052	0.085	0.055	2.149
<i>Trichothecium</i>	0.003	0.008	0.016	0.005	0.008	0.003	0.011	0.005	0.014	0.005	0.014	0.005	0.003	0.011	0.003	0.003	0.003	0.273
<i>Ulocladium</i>	0.063	0.049	0.046	0.071	0.066	0.057	0.057	0.041	0.063	0.060	0.052	0.044	0.049	0.038	0.055	0.036	0.046	2.548
<i>Uredinales</i>	0.071	0.101	0.038	0.112	0.098	0.118	0.052	0.044	0.063	0.131	0.107	0.265	0.254	0.235	0.271	0.295	0.257	6.592
<i>Ustilago</i>	0.036	0.052	0.055	0.066	0.060	0.074	0.041	0.049	0.066	0.071	0.041	0.049	0.036	0.057	0.060	0.074	0.038	2.067
<i>Venturia</i>	0.066	0.052	0.071	0.052	0.036	0.030	0.046	0.066	0.038	0.046	0.041	0.049	0.036	0.033	0.041	0.046	0.038	1.670
<i>Xylaria</i>	0.008	0.011	0.014	0.008	0.008	0.005	0.005	0.005	0.003	0.005	0.003	0.005	0.005	0.003	0.003	0.005	0.005	0.243
<i>Zygophiala</i>	0.038	0.046	0.036	0.052	0.030	0.038	0.041	0.033	0.036	0.030	0.036	0.033	0.038	0.033	0.049	0.033	0.030	1.266
<i>Others</i>	0.016	0.033	0.025	0.019	0.036	0.033	0.057	0.077	0.087	0.090	0.079	0.060	0.071	0.057	0.066	0.046	0.063	1.717
Total	2.652	2.581	1.985	2.808	2.029	2.849	2.961	2.622	2.873	3.401	2.485	2.532	2.575	2.759	3.240	2.950	3.303	100

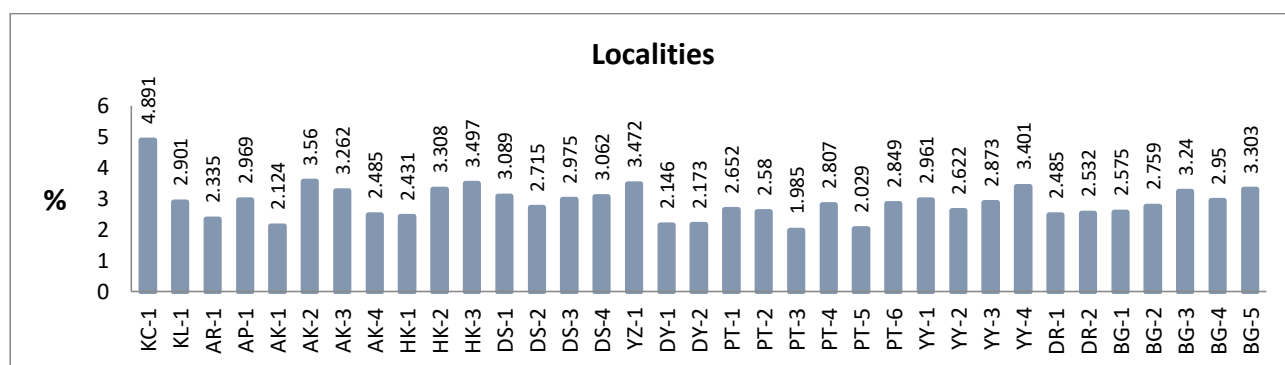


Figure 2. The fungal spore percentages according to localities

Most frequently fungal taxa were determined as *Cladosporium* (13.484%), *Aspergillus/ Penicillium* (6.682%), *Uredinales* (6.592%), *Metschnikowia* (5.692%), *Puccinia* (5.649%). The taxa with more than 5% were accepted as most frequent taxa. *Anthrinium* in Kale (KL-1) and Kuluncak (KC-1) samples, *Melanospora* in Kuluncak (KC-1) and Arapgir (AR-1) samples, Fern spores in Arapgir (AR-1) samples, *Xylaria* in Doganyol (DY-1, DY-2) samples, were not determined. Most frequent taxa, *Cladosporium*, exceeded 1% in Kuluncak (KC-1) and Yesilyurt-4 (YY-4) samples. *Metschnikowia* cells, blossom honeyindicator, were counted all samples (Figure 3, 4).

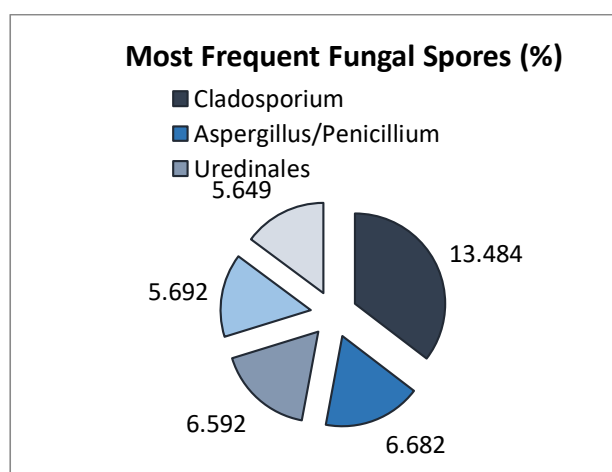


Figure 3. The fungal spore taxa with more than 5% percentages



Figure 4. Metschnikowia cells in honey sample

In Kuluncak sample the spores with concentrations over 0.100 were calculated as; *Alternaria*, *Aspergillus / Penicillium*, *Botrytis*, *Cladosporium*, *Geotrichium*, *Myxomycetes*, *Leptosphaeria*, *Metschnikowia*, *Puccinia*

and Hypha fragments (Table 1). When the total percentages of the samples belonging to the districts are evaluated, it could be analyzed that Hekimhan (HK-1-2-3) district has the highest concentration totally (Figure 2). Taxa with a rate above 0.100 in these districts were listed as; *Alternaria*, *Helminthosporium*, *Metschnikowia*, Fern spores, *Uredinales*, *Geotrichium*, *Cladosporium*, *Aspergillus/Penicillium*, *Botrytis*, *Paecilomyces*, Hypha fragments.

3.1 Statistical Analysis

The statistical analysis has done according to One-Way Anova Test (Figure 5, Table 2). *Cladosporium* was parted at first. Polynomial linear test was performed the rest dominant fungal spore taxa (*Aspergillus/Penicillium*, *Uredinales*, *Metschnikowia*, *Puccinia*). The results showed in Figure 6, Table 3. All of statistic values are greater than 0.5. Consequently the statistical data are compliant with total counts and places.

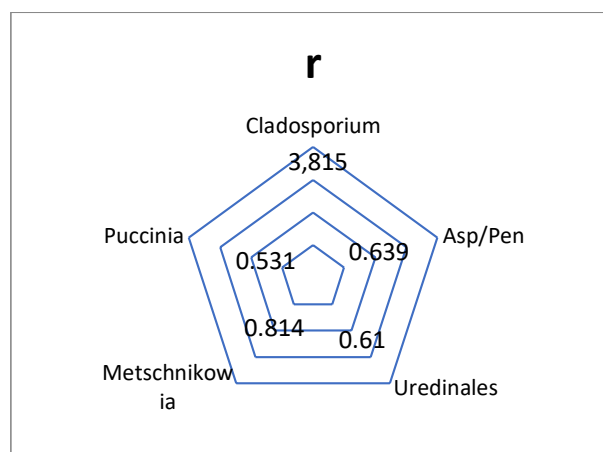


Figure 5. Graphical range of statistical data

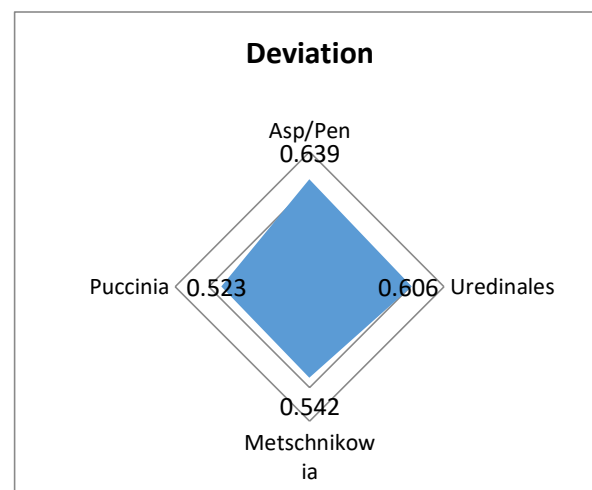


Figure 6. Graphical range of deviation data

Table 2. Statistical data according to One-Way Anova Test

Taxa	<i>Cladosporium</i>	<i>Aspergillus/Penicillium</i>	Uredinales	<i>Metschnikowia</i>	<i>Puccinia</i>
<i>r</i>	3.815	0.639	0.610	0.814	0.531

Table 3. Deviation data according to Polynomial Linear Test

Taxa	<i>Aspergillus/Penicillium</i>	Uredinales	<i>Metschnikowia</i>	<i>Puccinia</i>
Deviation	0.639	0.606	0.542	0.523

4. DISCUSSION

Fungal organisms are heterotrophs and termed as biotrophs, saprotrophs and necrotrophs (Carris et al., 2012). Fungi are wide diverse taxa in ecosystem and effects humankind health (Abrego et al., 2020). With urbanization the fungal communities are disturbed so both airborne and soil fungus are rare in urban than natural areas (Abrego et al., 2020). Soil fungi involved in biological cycling in terrestrial systems via remnants, pathogens and symbiosis with plant organisms (Peng et al., 2020; Smith & Read, 2008; Zeilinger et al., 2016).

In beehives habitat (honey, bee pollen, bee bread) fungus are living as saprophytes with all kind of bees and it is accepted that the entry of fungus in the beehive occurs mostly with collection of pollen by bees (Barbosa et al., 2018). Honey bees prefer fungus when the nutritional sources (pollen and nectar) insufficient because the fungal pellets have high protein content (Modro et al., 2009). The fungal spores' nourishment value is below than pollen but fungal spores could be used as supplemented food for bees because of simple accessibility (Eltz et al., 2002; Oliveira & Morato, 2000). According to another hypothesis; some fungal spores; like *Puccinia*, *Uromyces*; collect by bees because of yellow-orange colours and size that appears similar pollen grains (Shaw, 1999).

There are some similar studies about fungal spore content of honey around the world. In Galicia- Spain, 30 honey samples were analysed and founded that *Cladosporium*, *Aspergillus/Penicillium*, Basidiospores were constituted 80% of the total fungal spore count (Pérez-Atanes et al., 2001). In Greece, Dimou et al. (2006) examined *Abies cephalonica* and *Pinus sp.* honeys and identified six fungal genera; *Alternaria*, *Cladosporium*, *Coleosporium*, *Fumago*, *Heterosporium*, *Stemphylium*. In Northwest Spain *Metschnikowia* spores was found more than 50% in of microscopic analyses of honeys and some plant pathogens as *Leptosphaeria*, *Stemphylium* and *Urediniospores* were examined (Seijo et al., 2011). Another study in same area was conducted for distinguish blossom and honeydew honeys, *Metschnikowia* cells, *Cladosporium*, *Penicillium* spores were identified as most common spores in honeys (Escuredo et al., 2012). Mura-Mészáros and Magyar (2017) examined honey samples mostly provided from Italy and Greece and found 34 fungal spore types. Terrab et al. (2019) analysed oak honeydew honeys in Spain and identified *Alternaria*, *Cladosporium*, *Drechslera*, *Geotrichium*, *Phthomyces*, *Stemphylium*, *Torula*, *Ulocladium* and *Venturia* spores.

Cladosporium; is a saprobic and ubiquitous fungi, spread out all around the world and isolated from any organic items, mainly plant material and soil (Bensch et al., 2012; Ellis, 1971; Ellis, 1976). *Cladosporium* is accepted as plant pathogen, secondary invader, on necrotic parts of herbal fragments but according to former studies *Cladosporium* species defend plants by secondary metabolites to biotic and abiotic stresses (Ellis, 1971; Răut et al., 2021). This fungus exists on leaves, stems, fruits of different plants like *Asteraceae*, *Fabaceae*, *Poaceae* (Bensch, 2015; Bensch et al., 2012; Marin-Felix et al., 2017; Schubert, 2005; Xu et al., 2021). These taxa occurs prevalence in Malatya provinces (Karakuş, 2016). In a study conducted in Minas Gerais, Brazil, it was shown that the fungus *Cladosporium* was collected for honey by *Apis mellifera* L. (Modro et al., 2009). *Cladosporium* spores had also isolated from Turkish (Çınar, 2020), Polish (Felsöciová et al., 2012), Croatian (Kiš et al., 2018) honey samples. Research findings have been published indicating that adding *Cladosporium* and *Botrytis* spores to a diet extends the lifespan of bees (Parish et al., 2020). It has been found that *Ganoderma* fungal extracts exhibit therapeutic properties in lesions in the midgut of bees (Ansaloni et al., 2026).

Aspergillus/Penicillium; are saprophytic, cosmopolitan taxa and exist in air, soil and other materials like bees, ants, flowers, leaves, shells (Leite Júnior et al., 2012; Pitt, 1994; Taniwaki et al., 2015). Bees cannot procure some sterols thus they are obliged to take sterols exogenously (Ferreira-Caliman et al., 2012). According to Peterson et al. (2003), *P. brocae* synthesizes exogenous sterols; hence the bees and *Penicillium* fungi maintain a mutualistic habit.

Uredinales; are obligate parasites, phytopathologic fungi live on Pteridophyta, Pinophyta, Magnoliophyta (Pardo-Cardona, 2000; Yepes & De Carvalho Júnior, 2013). These spores evolve mostly humid areas (Mendgen, 1997) likely this study. In Doganşehir samples this taxon reached the higher concentration with the climatic conditions of the district. According to According to Maurizio (1950) Uredineae spores increase life expectancy by using as a varied nutriment for broods. Uredinales spores had examined by Pérez-Atanes et al. (2001) in Galicia honeys.

Metschnikowia; ascomycetous yeast disperse on flowers and fruits and is transported by insects to new niches (Hong et al., 2001). To Brysch-Herzberg (2004) there is a mutualistic relationship between *Metschnikowia* cells

and bees, the essence of *Metschnikowia* cells enhances the attractiveness of nectar for bees.

Puccinia; is a pathogenic fungi and Leguminosae, Liliaceae, Orchidaceae, Gymnosperms and ferns host this taxon (Hiratsuka & Sato, 1982). *Puccinia* spores examined in Galicia honeys as well (Pérez-Atanes et al., 2001). *Puccinia* fungus infects Brassica flowers and the infection causes pseudoflowers with yellowish and clumped leaves, these pseudoflowers has a mellifluent excretion that appeal to bees (Raguso & Roy, 1998). Brassicaceae family is prevalent plant group of the study areas and this taxon with rust infected individuals would increase its pollination by enhanced bee foraging.

Bees primarily collect fungal spores in the lack of pollen grains, but for now known that they also collect fungal spores in the presence of pollen grains (Shaw, 1999). The protein content of pollen grains is not sufficient for bee requirements occasionally and they need the fungal spore ingestion as a complementary food because of the high protein substance (Huang et al., 2015; Kleinschmidt & Kondos, 1976; Shaw, 1999; Shu et al., 1954). Relatively high protein content of spores provides resistance to abnormal conditions (Huang et al., 2015; Wyatt et al., 2013). *Cladosporium* produces protein form metabolites for adaptation new habitats (Räut et al., 2021). According to a Single Cell Protein study *Aspergillus* has 24.49%, *Penicillium* has 35% crude proteins (Amar et al., 2017). Enzymes that break down the host plant cell wall and protein substances related to plant defence were isolated from Uredinales (Deising et al., 1995; D'Silva & Heath, 1997). In a study about *Metschnikowia* presents the protein content of this cell connected with protect the structure against environmental stress like temperature, osmotic pressure...etc (Ariño, 2002; Pawlikowska et al., 2020). Yuan et al. (2021) revealed that some enzymes found in *Puccinia* increase virulence by inducing oxidative stress of the host.

Fungal spores found in agricultural lands are also directly transported by pollinators; in particular, when carried by bees, they end up inside the hive and also found in bee products (Belhadj et al., 2015). From this perspective, the identification and quantification of fungal spores in bee products support the thesis that bees are important bioindicators from an environmental engineering standpoint. Fernandes et al. (2023), has shown that *Alternaria* and *Cladosporium* fungal spores are present in large quantities not only in the air but also in the soil, and it is known that these fungi are highly damaging to agricultural crops. According to Sobieraj et al. (2026) *Alternaria* and *Cladosporium* spores was found at ground level approximately airborne in agricultural areas. Fungal spores such as *Aspergillus*/*Penicillium*, *Alternaria*, *Drechslera* and *Verticillium* have been isolated from bee pollen collected by bees from agricultural fields (Belhadj et al., 2015).

5. CONCLUSIONS

The fungal spores increase the nutriment value of honeys as a aliment supplement. Determining the fungal diversity of honeys is an important approach to know ecological origin of honey. In this study Eastern Anatolia (Malatya) honeys were examined for fungal spores. 35 fungal spores and hypha elements were determined. *Cladosporium*, *Aspergillus*/*Penicillium*, Uredinales, *Metschnikowia* and *Puccinia* spores were found dominant. This study constitutes a preliminary investigation conducted on honey collected from a limited region. The scope of the study can be expanded, the range of bee products examined can be broadened, and bees, when approached from an environmental engineering perspective, are among the organisms that function as bioindicators in nature. Given these characteristics, they can utilized in numerous future studies, and this approach could also serve as a stepping Stone toward biosensor technologies.

References:

- Abrego, N., Crosie, B., Somervuo, P., Ivanova, N., Abrahamyan, A., Abdi, A., Hämäläinen, K., Junninen, K., Maunula, M., Purhonen, J., & Ovaskainen, O. (2020). Fungal communities decline with urbanization—more in air than in soil. *ISME Journal*, 14, 2806–2815. <https://doi.org/10.1038/s41396-020-0732-1>
- Amar, Wazir, K., Shah, A., Ihsan, K., Khan, F., & Jamil, J. (2017). Nutritional assessment of single cell protein produced with *Aspergillus flavus* and *Penicillium chrysogenum*. *International Journal of Bioscience*, 11(5), 62–69. <https://doi.org/10.12692/ijb/11.5.62-69>
- Anklam, E. (1998). A review of the analytical methods to determine the geographical and botanical origin of honey. *Food Chemistry*, 63, 549–562. [https://doi.org/10.1016/S0308-8146\(98\)00057-0](https://doi.org/10.1016/S0308-8146(98)00057-0)
- Ansaloni, L. S., Domingues, C. E. C., Gregori, M., Gregori, A., & Gregorc, A. (2026). An assessment of the impacts of feeding four fungal extracts on the lifespan and midgut of newly emerged Carniolan honey bees (*Apis mellifera carnica*). *Insects*, 17(6), 594. <https://doi.org/10.3390/insects17060594>
- Ariño, J. (2002). Novel protein phosphatases in yeast. *European Journal of Biochemistry*, 269(4), 1072–1077. <https://doi.org/10.1046/j.0014-2956.2002.02753.x>
- Bahçecioğlu, Z., & Gjerum, H. B. (2004). New and rare rust fungi (Uredinales) from Anatolia (Turkey)-2. *Mycotaxon*, 90(1), 55–68.

- Bahçecioğlu, Z., & Yıldız, B. (2001). Malatya Yöresi Tarla Yabancı Otları Üzerinde Belirlenen Parazit Funguslar. *Cumhuriyet Üniversitesi Fen-Edebiyat Fakültesi Fen Bilimleri Dergisi*, 22(1), 3–12.
- Barbosa, R. N., Bezerra, J. D. P., Souza-Motta, C. M., Frisvad, J. C., Samson, R. A., Oliveira, N. T., & Houbraken, J. (2018). New *Penicillium* and *Talaromyces* species from honey, pollen and nests of stingless bees. *Antonie Van Leeuwenhoek*, 111, 1883–1912. <https://doi.org/10.1007/s10482-018-1081-1>
- Barzee, T. Y., Cao, L., Pan, Z., & Zhang, R. (2021). Fungi for future foods. *Journal of Future Food*, 1(1), 25–37. <https://doi.org/10.1016/j.jfutfo.2021.09.002>
- Belhadj, H., Harzallah, D., Dahamna, S., & Mouloud, G. (2015). A plausible role for pollen-residing molds in agricultural purposes. *Communications in Agricultural and Applied Biological Sciences*, 80, 559–562.
- Bensch, K., Braun, U., Groenewald, J. Z., & Crous, P. W. (2012). The genus *Cladosporium*. *Studies in Mycology*, 72, 1–401. <https://doi.org/10.3114/sim0003>
- Bensch, K., Groenewald, J. Z., Braun, U., Dijksterhuis, J., de Jesús Yáñez-Morales, M., & Crous, P. W. (2015). Common but different: The expanding realm of *Cladosporium*. *Studies in Mycology*, 82, 23–74. <https://doi.org/10.1016/j.simyco.2015.10.001>
- Brysch-Herzberg, M. (2004). Ecology of yeasts in plant-bumblebee mutualism in Central Europe. *FEMS Microbiology Ecology*, 50, 87–100. <https://doi.org/10.1016/j.femsec.2004.06.003>
- Carris, L. M., Little, C. R., & Stiles, C. M. (2012). Introduction to fungi. *The Plant Health Instructor*, 1, 1–30. <https://doi.org/10.1094/PHI-I-2012-0426-01>
- Çınar, A. (2020). The presence of mold in chestnut honey is a risk factor to health. *Fresenius Environmental Bulletin*, 29(12A), 11581–11587.
- Cunningham, S. A., Crane, M. J., Evans, M. J., Hingee, K. L., & Lindenmayer, D. B. (2022). Density of invasive western honey bee (*Apis mellifera*) colonies in fragmented woodlands indicates potential for large impacts on native species. *Scientific Reports*, 12(1), 3603. <https://doi.org/10.1038/s41598-022-07635-0>
- D'silva, I., & Heath, M. C. (1997). Purification and characterization of two novel hypersensitive response-inducing specific elicitors produced by the cowpea rust fungus. *Journal of Biological Chemistry*, 272, 3924–3927.
- Deising, H., Rauscher, M., Haug, M., & Heiler, S. (1995). Differentiation and cell wall degrading enzymes in the obligately biotrophic rust fungus *Uromyces viciae-fabae*. *Canadian Journal of Botany*, 73, 624–631. <https://doi.org/10.1139/b95-304>
- Dimou, M., Katsaros, J., Klonari, K., & Thrasyvoulou, A. (2006). Discriminating pine and fir honeydew honeys by microscopic characteristics. *Journal of Apicultural Research*, 45(2), 16–21. <https://doi.org/10.1080/00218839.2006.11101319>
- Domsch, K. H., Gams, W., & Anderson, T. H. (1980). *Compendium of soil fungi* (Vol. 1). Academic Press.
- Ellis, M. B. (1971). *Dematiaceous hyphomycetes*. Commonwealth Mycological Institute.
- Ellis, M. B. (1976). *More dematiaceous hyphomycetes*. Commonwealth Mycological Institute.
- Ellis, M. B., & Ellis, J. P. (1998). *Microfungi on miscellaneous substrates: An identification handbook*. Richmond Publishing.
- Eltz, T., Bruhl, C. A., & Gorke, C. (2002). Collection of mold (*Rhizopus* sp.) spores in lieu of pollen by the stingless bee *Trigona collina*. *Insectes Sociaux*, 12, 441–445. <https://doi.org/10.1007/s00040-002-8274-2>
- Escuredo, O., Fernández-González, M., & Carmen, S. C. M. (2012). Differentiation of blossom honey and honeydew honey from Northwest Spain. *Agriculture*, 2, 25–37. <https://doi.org/10.3390/agriculture2010025>
- Felšöciová, S., Kačániová, M., Hleba, L., Petrová, J., Pavelková, A., Džugan, M., & Grabek-Lejko, D. (2012). Microscopic fungi isolated from Polish honey. *Journal of microbiology, biotechnology and food sciences*, 2(3), 1040–1049.
- Fernandes, C., Casadevall, A., & Gonçalves, T. (2023). Mechanisms of *Alternaria* pathogenesis in animals and plants. *FEMS Microbiology Reviews*, 47(6). <https://doi.org/10.1093/femsre/fuad061>
- Ferreira-Caliman, F., Silva, C. I., Mateus, S., Zucchi, R., & Nascimento, F. S. (2012). Neutral sterols of cephalic glands of stingless bees and their correlation with sterols from pollen. *Psyche*, 2012, 1–7. <https://doi.org/10.1155/2012/982802>
- Fрати, L., Santoni, S., Nicolardi, V., Gaggi, C., Brunialti, G., Guttova, A., Gaudino, S., Pati, A., Pirintso, S. A., & Loppi, S. (2007). Lichen biomonitoring of ammonia emission and nitrogen deposition around a pig stockfarm. *Environmental Pollution*, 146, 311–316. <https://doi.org/10.1016/j.envpol.2006.03.029>
- Fründ, H. C., Graefe, U., & Tischer, S. (2010). Earthworms as bioindicators of soil quality. *Biology of Earthworms*, 16, 261–278. https://doi.org/10.1007/978-3-642-14636-7_16
- Grant Smith, E. (2000). *Sampling and identifying allergenic pollens and molds*. Blewstone Press.

- Grinn-Gofroń, A., & Bosiacka, B. (2015). Effects of meteorological factors on the composition of selected fungal spores in the air. *Aerobiologia*, 31, 63–72. <https://doi.org/10.1007/s10453-014-9347-1>
- Grüß, J. (1917–1918). Die Anpassungen eines Pilzes (*Anthomyces reukaufii*) an den Blütenbau und den Bienenrüssel. *Berichte der Deutschen Botanischen Gesellschaft*, 35, 746–762.
- Hiratsuka, Y., & Sato, S. (1982). Morphology and taxonomy of rust fungi. In K. Scott & A. K. Chakravorty (Eds.), *The rust fungi*. Academic Press.
- Hong, S. G., Chun, J., Oh, H. W., & Bae, K. S. (2001). *Metschnikowia koreensis* sp. nov., a novel yeast species isolated from flowers in Korea. *International Journal of Systematic and Evolutionary Microbiology*, 51, 1927–1931. <https://doi.org/10.1099/00207713-51-5-1927>
- Huang, M., Hebert, A. S., Coon, J. J., & Hull, C. M. (2015). Protein composition of infectious spores reveals novel sexual development and germination factors in *Cryptococcus*. *PLoS Genetics*, 11(8), 1–28. <https://doi.org/10.1371/journal.pgen.1005490>
- Kabaktepe, Ş., Karakuş, Ş., & Mutlu, B. (2015). New Puccinia (Puccinales, Basidiomycota) records for Turkey. *Hacettepe Journal of Biological Chemistry*, 43(1), 69–72. <https://doi.org/10.15671/HJBC.20154311206>
- Karakuş, Ş. (2016). *Malatya İli Florası* [Doktorska disertacija, Graduate School of Natural and Applied Science, Inonu University].
- Kiš, M., Furmeg, S., Tkalec, V. J., Zadavec, M., Lugomer, M. D., Koncurat, A., Benic, M., & Pavlicek, D. (2018). Characterisation of Croatian honey by physicochemical and microbiological parameters with mold identification. *Journal of Food Safety*, 38(5), 1–6. <https://doi.org/10.1111/jfs.12492>
- Kleinschmidt, G. J., & Kondos, A. C. (1976). The influence of crude protein levels of colony production. *Australasian Beekeeper*, 78, 36–39.
- Lang, W. H., Jr. (1901). Fungus spores as bee-bread. *The Plant World*, 4(3), 49–51.
- Leite Júnior, D. P., Yamamoto, A. C. A., Ribeiro De Souza Amadio, J. V., Martins, E. R., Leal Do Santos, F. A., Simões, S. A. A., & Hahn, R. C. (2012). Trichocomaceae: Biodiversity of *Aspergillus* spp and *Penicillium* spp residing in libraries. *The Journal of Infection in Developing Countries*, 6(10), 734–743. <https://doi.org/10.3855/jidc.2080>
- Louveaux, J., Maurizio, A., & Vorwohl, G. (1978). Methods of melissopalynology. *Bee World*, 59, 139–157. <https://doi.org/10.1080/0005772X.1978.11097714>
- Magyar, D., Gönczöl, J., Révay, Á., Grillenzoni, F., & Seijo-Coello, M. C. (2005). Stauro- and scoleococonidia in floral and honeydew honeys. *Fungal Diversity*, 20, 103–120.
- Marin-Felix, Y., Groenewald, J. Z., Cai, L., Chen, Q., Marincowitz, S., Barnes, I., Bensh, K., Braun, U., Camporesi, E., Damm, U., de Beer, Z. W., Dissanayake, A., Edwards, J., Giraldo, A., Hernández-Restrepo, M., Hyde, K. D., Jayawardena, R. S., Lombard, L., & Crous, P. W. (2017). Genera of phytopathogenic fungi: GOPHY 1. *Studies in Mycology*, 86, 99–216. <https://doi.org/10.1016/j.simyco.2017.04.002>
- Maurizio, A. (1950). The influence of pollen feeding and brood rearing on length of life and physiological conditions of the honeybee: Preliminary report. *Bee World*, 31, 9–12.
- Mendgen, K. (1997). The Uredinales. U K. Esser & P. A. Lemke (Ur.), *The Mycota: Vol. V. Plant relationships (Part B)*. Springer-Verlag.
- Modro, A. F. H., Silva, I. C., Message, D., & Luz, C. F. P. (2009). Saprophytic fungus collection by Africanized bees in Brazil. *Neotropical Entomology*, 38(3), 434–436. <https://doi.org/10.1590/S1519-566X2009000300022>
- Mura-Mészáros, A., & Magyar, D. (2017). Fungal honeydew elements as potential indicators of the botanical and geographical origin of honeys. *Food Analytical Methods*, 10, 3079–3087. <https://doi.org/10.1007/s12161-017-0862-x>
- Nguyen Thanh Kim, H., Duong, V.-H., Chu, T.-T., Pham-Thi, T.-X., Nguyen, X.-Q., Van Vu, S., Van, T. P., Ta, D.-T., Duong, D.-T., Tursunov, O., Priyadharshini, M., Musthafa, M. S., Hegedűs, M., Shahrokhi, A., & Kovács, T. (2025). Mussels as bioindicators for the rapid detection of heavy metal fluctuations in marine coastal waters: A case study of seasonal bioaccumulation monitoring and assessment of *Perna viridis* from the Gulf of Tonkin Coastline, Hai Phong, Vietnam. *Water*, 17(17), 2552. <https://doi.org/10.3390/w17172552>
- Oliveira, M. L., & Morato, E. F. (2000). Stingless bees (Hymenoptera, Meliponini) feeding on stinkhorn spores (Fungi, Phallales): Robbery or dispersal? *Revista Brasileira de Zoologia*, 17, 881–884. <https://doi.org/10.1590/S0101-81752000000300025>
- Pardo-Cardona, V. M. (2000). Relaciones florísticas y altitudinales de los Uredinales colombianos. *Biológico*, 62(1), 89–105.
- Parish, J. B., Scott, E. S., & Hogendoorn, K. (2020). Nutritional benefit of fungal spores for honey bee workers. *Scientific Reports*, 10, 15671. <https://doi.org/10.1038/s41598-020-72758-1>

- Pasanen, A. L., Pasanen, P., Jantunen, M. J., & Kalliokoski, P. (1991). Significance of air humidity and air velocity for fungal spore release into the air. *Atmospheric Environment. Part A. General Topics*, 25(2), 459–462. [https://doi.org/10.1016/0960-2771\(91\)90316-Y](https://doi.org/10.1016/0960-2771(91)90316-Y)
- Pawlikowska, E., Szymańska, M., Berłowska, J., & Kregiel, D. (2020). Lysates of *Metschnikowia* yeast with higher content of hydroxyproline. *BioResources*, 15, 3228–3236. <https://doi.org/10.15376/biores.15.2.3228-3236>
- Peng, W., Song, T., Du, H., Chen, H., Zeng, F., Liu, Y., Luo, Y., & Tan, W. (2020). Inconsistent diversity patterns of soil fungi and woody plants among habitat types in a karst broadleaf forest. *Forest Ecology and Management*, 474(118367), 1–10. <https://doi.org/10.1016/j.foreco.2020.118367>
- Pérez-Atanes, S., Seijo-Coello, M. D. C., & Méndez-Alvarez, J. (2001). Contribution to the study of fungal spores in honeys of Galicia (NW Spain). *Grana*, 40(4-5), 217–222. <https://doi.org/10.1080/001731301317223240>
- Peterson, S. W., Pérez, J., & Vega, F. (2003). *Penicillium brocae*, a new species associated with the coffee berry borer in Chiapas, Mexico. *Mycologia*, 95, 141–147. <https://doi.org/10.2307/3761973>
- Pitt, J. I. (1994). The current role of *Aspergillus* and *Penicillium* in human and animal health. *Journal of Medical and Veterinary Mycology*, 32(1), 17–32.
- Raguso, R. A., & Roy, B. A. (1998). 'Floral' scent production by *Puccinia* rust fungi that mimic flowers. *Molecular Ecology*, 7, 1127–1136. <https://doi.org/10.1046/j.1365-294x.1998.00426.x>
- Răut, I., Călin, M., Capră, L., Gurban, A. M., Doni, M., Radu, N., & Jecu, L. (2021). *Cladosporium* sp. isolate as fungal plant growth promoting agent. *Agronomy*, 11(392), 1–17. <https://doi.org/10.3390/agronomy11020392>
- Schubert, K. (2005). *Morphotaxonomic revision of foliicolous Cladosporium species (Hyphomycetes)*. Martin-Luther-University Halle-Wittenberg.
- Seijo, M. C., Escuredo, O., & Fernández-González, M. (2011). Fungal diversity in honeys from northwest Spain and their relationship to the ecological origin of the product. *Grana*, 50, 55–62. <https://doi.org/10.1080/00173134.2011.559555>
- Shaw, D. E. (1990). The incidental collection of fungal spores by bees and collection of spores in lieu of pollen. *Bee World*, 71, 158–176. <https://doi.org/10.1080/0005772X.1990.11099059>
- Shaw, D. E. (1999). Bees and fungi, with special reference to certain plant pathogens. *Australasian Plant Pathology*, 28, 269–282. <https://doi.org/10.1071/AP99044>
- Shindler, M., Diestelhorst, O., Härtel, S., Saure, C., Scharnowski, A., & Schwenninger, H. R. (2013). Monitoring agricultural ecosystems by using wild bees as environmental indicators. *Biodiversity and Ecosystem Risk Assessment*, 8(8), 39–51. <https://doi.org/10.3897/biorisk.8.3600>
- Shu, P., Tanner, K. G., & Ledingham, G. A. (1954). Studies on the respiration of resting and germinating uredospores of wheat stem rust. *Canadian Journal of Botany*, 32, 16–23.
- Smith, S. E., & Read, D. J. (2008). *Mycorrhizal symbiosis* (3. izd.). Academic Press.
- Sobieraj, K., Wieczorek, O., Delikta, M., Stawrakakis, K., Grewling, L., & Bogawski, P. (2026). Airborne *Alternaria* and *Cladosporium* spores at ground level: Influence of land use and harvesting activity. *Environmental Pollution*, 395, 127822. <https://doi.org/10.1016/j.envpol.2026.127822>
- St-Germain, G., & Summerbell, R. (1996). *Identifying filamentous fungi: A clinical laboratory handbook* (1. izd.). Star Publishing Company.
- Tamer, A. Ü., Gücin, F., & Altan, Y. (1987). Malatya (Pütürge) Yöresi Bitkilerinde Belirlenen Bazı Parazit Funguslar. U *Proceedings of the 8th National Biology Congress 1986* (Vol. 2, str. 202–207). Botanik Bildirileri Kitabı.
- Taniwaki, M. H., Pitt, J. I., Iamanaka, B. T., Massi, F. P., Fungaro, M. H. P., & Frisvad, J. C. (2015). *Penicillium excelsum* sp. nov. from the Brazil nut tree ecosystem in the Amazon basin. *PLOS ONE*, 10, Article e0143189.
- Terrab, A., Berjano, R., Sanchez, J. A., Pajuelo, A. G., & Díez, M. J. (2019). Palynological and geographical characterization of Spanish oak honeydew honeys. *Grana*, 58(1), 63–77. <https://doi.org/10.1080/00173134.2018.1509124>
- Vicente, J., Ruiz, J., Belda, I., Benito-Vázquez, I., Marquina, D., Calderón, F., Santos, A., & Benito, S. (2020). The genus *Metschnikowia* in enology. *Microorganisms*, 8(7), 1038. <https://doi.org/10.3390/microorganisms8071038>
- Watanabe, T. (2002). *Pictorial atlas of soil and seed fungi: Morphologies of cultured fungi and key to species* (2. izd.). CRC Press.
- Wyatt, T. T., Wösten, H. A. B., & Dijksterhuis, J. (2013). Fungal spores for dispersion in space and time. *Advances in Applied Microbiology*, 85, 43–91. <https://doi.org/10.1016/B978-0-12-407672-3.00002-2>
- Xu, Y. X., Shen, H. W., Bao, D. F., Luo, Z. L., Su, H. Y., & Hao, Y. E. (2021). Two new species of *Cladosporium* from leaf spots of *Paris polyphylla* in north-western Yunnan Province, China. *Biodiversity Data Journal*, 9, Article e77224. <https://doi.org/10.3897/BDJ.9.e77224>

- Yepes, M. S., & De Carvalho Júnior, A. A. (2013). Uredinales (rust fungi) biota of the Parque Nacional Do Itatiaia, Brazil: An analysis of composition, species diversity and altitudinal distribution. *Caldasia*, 35(1), 165–176.
- Yuan, P., Qian, W., Jiang, L., Jia, C., Ma, X., Kang, Z., & Liu, J. A. (2021). Secreted catalase contributes to *Puccinia striiformis* resistance to host-derived oxidative stress. *Stress Biology*, 22, 1–15. <https://doi.org/10.1007/s44154-021-00021-2>
- Zeilinger, S., Gupta, V. K., Dahms, T. E., Silva, R. N., Singh, H. B., Upadhyay, R. S., ... & Nayak S, C. (2016). Friends or foes? Emerging insights from fungal interactions with plants. *FEMS microbiology reviews*, 40(2), 182-207. <https://doi.org/10.1093/femsre/fuv045>

Gulsah Yıl

Malatya Turgut Ozal University,
Battalgazi Vocational School,
Plants and Animal Production
Department, Malatya,
Turkiye
gulsah.saatcioglu@ozal.edu.tr
ORCID 0000-0001-5124-7239
