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THE SURVIVAL OF MICROFUNGI IN THE NESTS OF TREE-SPARROW [PASSER MONTANUS L.] IN THE NEST-BOXES OVER THE WINTER SEASON

by

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Abstract

At the mycological examination of eleven nest-boxes of the Tree-Sparrow (*Passer montanus* L.) after the winter season a significant increase of the total number of fungi was ascertained in comparison with the investigation of the same boxes in the previous summer; especially the cellulolytic fungi increased (genera *Penicillium*, *Scopulariopsis*, *Chrysosporium* et al.) but also the potentially zoopathogenic (ascertained *Aspergillus fumigatus*, *Candida albicans*, *Mucor pusillus* et al.) and toxinogenic fungi (e.g. *Asp.flavus*); a moderate-statistically insignificant-decrease in the number of isolates and species of keratinolytic fungi took place (in spring found *Arthroderma ciferrii*, *A. quadrifidum* and *Aphanoascus fulvescens*). In some fungi not only survival but also colonization of the substrate in the winter and early-spring period were proved. As main factors conditioning the survival of fungi in the nest-boxes over the winter were ascertained the composition of the substrate, its temperature and humidity. The limiting abiotic factor is before all the low temperature, inhibiting the development of nonpsychrophilic fungi. On the base of various changes of the physical and chemical conditions of the environment an attempt of explaining the dynamics of some ascertained fungi in accordance with literary statements is presented. The proved overwintering of some potentially pathogenic fungi in the microhabitat supplies to the studies of this kind an epidemiologic and epizootologic importance.

Introduction

The previous paper dealt with the occurrence of fungi in the nests of some species of free-living birds in Czechoslovakia in the breeding season (23). The present report is devoted to an ecologically important problem which fungi and to what extent are able to survive in nest-boxes over the winter season.

Material and methods

The investigation was realized on locality no. 1 (Bzenec) by means of examination of lining material of eleven selected nest-boxes of the Tree-Sparrow (*Passer m. montanus* (L.)), namely in summer (1 July, 1970) and repeatedly in the same boxes after the conclusion of the winter season (1 April, 1971). The methods of sampling and treatment of samples are

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described in our previous papers (21, 23) as well as the characteristics of the macrohabitat and the climatic conditions in the first half of 1970 (23); a survey of the weather in the remaining period is given in table 1.

Table 1. Climatic conditions in the examined area
(Data from the State Hydrometeorological Institute, Brno)

	1970					1971		
Months:	VIII	IX	X	XI	XII	I	II	III
Temperature of the air (°C):								
average	17.9	13.3	8.8	7.0	0.4	−2.8	1.2	1.7
absol. maximum	29.3	28.0	23.6	19.5	9.0	11.0	11.0	21.3
absol. minimum	5.0	−2.4	−5.4	−2.8	−14.0	−22.0	−10.0	−15.0
Mean humidity of the air:								
relative (%)	78	73	80	80	89	85	83	76
absolute (g/m^3)	11.9	8.5	7.0	6.2	4.5	3.4	4.4	4.2
Precipitation (mm.)	27.2	15.8	40.4	60.3	31.3	12.0	19.2	24.8
No. of days with a snow cover higher than 1 cm.	0	0	0	0	10	14	3	9
Sunshine (hours)	186	194	115	39	22	68	59	108

Some of the other conditions which could affect the occurrence of fungi in the nest-boxes (i.e. in microhabitat) are expressed in further Tables (table 2, 3, 4).

Table 2. Characteristics of individual nest-boxes

Box no.	Internal volume of the box (cm^3)	Approximative volume of the nest material (cm^3) 1.IV.1971	Number of breedings in the period: 1.IV.–1.VII.1970 successful	1.IV.–1.VII.1970 unsuccessful	2.VII.–31.VIII.1970 successful	2.VII.–31.VIII.1970 unsuccessful	Roosting of tree-sparrows in the box in period 1.IX.1970 to 30.III.1971
106	3100	2300	1	0	0	1	+
119	3200	1100	1	0	0	1	−
157	3200	3000	2	0	0	1	+
308	1500	800	1	1	1	0	+
322	4400	3500	2	0	0	1	+
338	3700	2500	2	0	1	0	+
536	900	200	1	1	1	0	−
539	900	100	1	0	1	0	−
540	900	700	2	0	1	0	+
542	900	500	1	1	1	0	−
544	900	600	2	0	1	0	+

Table 3. Changes in the composition of nest material

Sort of material in the lining	Summer (1.VII.1970)	Spring (1.IV.1971)
Number of boxes examined	11	11
Plant material	no. of boxes	
Stalks and leaves of grasses[1]	6	10
Inflorescence of Calamagrostis epigeios	6	9
Stalks of various dicotyledonous plants	10	2
Leaves of various dicotyledonous plants	0	1
Twigs	0	1
Small roots	3	0
Plant fibres (bast)	4	4
Needles of Pinus silvestris	1	7
Moss	7	10
Animal material		
Feathers:		
Passer montanus	2	10
Gallus gallus domest.	11	4
Phasianus colchicus	2	2
Garrulus glandarius	1	3
Dendrocopos major	1	1
Hair:		
Oryctolagus cuniculus	1	0
horse hair	2	0
Follicular scales:		
Passer montanus	7	9
Droppings:		
Passer montanus	1	7
Remainders of insects	0	1
Average number of structural components in one nest	5.9	7.6

[1] Mainly Calamagrostis epigeios, less frequently Poa pratensis var. angustifolia, Brachypodium silvaticum, Scleropodium undulatum and Festuca sulcata var. hirsuta.

Results

Direct microscopic observation

In the samples of the nest lining taken in spring a direct microscopic examination of various randomly selected parts of all eleven samples was carried out. As 'active fungi' (the criterium was the presence of a viabile mycelium) were ascertained: *Scopulariopsis candida*, *Aspergillus repens*, *Chaetomium* sp., *Cladosporium herbarum*, *Scopulariopsis brevicaulis*, *Penicillium janthinellum*, *Chrysosporium pannorum*, *Arthroderma ciferrii*, *Penicillium cyclopium* and *Scopulariopsis acremonium* (rank according to the decreasing frequency of the occurrence). An expressive colonization affinity to the substrate over the winter season and in early spring was manifested mainly in *Scop. candida*, *Asp. repens*, *Pen. janthinellum* and *Chrys. pannorum*.

Table 4. Changes in humidity and pH of the nest material

	% of water in the sample		pH of the sample	
Box no.	1.VII.1970	1.IV.1971	1.VII.1970	1.IV.1971
106	10.6	17.5	6.6	6.7
119	6.5	15.2	6.3	6.7
157	8.4	13.6	6.6	6.7
308	11.4	17.6	6.6	6.9
322	10.6	22.5	6.9	7.1
338	8.4	14.3	6.7	7.0
536	11.4	12.8	6.8	7.0
539	15.2	19.2	7.0	6.9
540	9.8	12.2	6.5	6.7
542	10.5	16.1	6.6	7.3
544	10.2	14.6	6.8	6.9
Average:	10.27	15.96	6.67	6.90
t-value: [1]	6.53		3.71	
Difference:	highly significant ($P < 0.001$)		highly significant ($P < 0.005$)	

[1] paired characters.

Isolation of the fungi

A survey of isolated fungi is given in table 5. We were surprised to find that in spring samples the total number of fungi was significantly (chi-square test) greater as compared with the summer sampling (average number of isolated fungal species per one nest was in summer 7.6, while in spring 10.8). With a higher frequency of occurrence in spring than in summer the following fungi were found by isolation: *Asp. repens*, *A. versicolor*, *Candida albicans*, *Chrys. pannorum*, *Pen. cyclopium*, *P. implicatum*, *P. janthinellum*, *Scop. brevicaulis*, *S. candida*, *S. koningii* and *Torulopsis* sp., when some further ones are left out which were not found at all in summer.

On the contrary, more often occurred in summer than in spring: *Asp. flavus*, *Cten. serratus*, *Fusarium* sp., *Pen. frequentans*, *Phoma* sp., *Rhiz. nigricans* et al.

A substantial part of all isolates is represented by two physiological groups of fungi forming the main synusies of the fungal microcommunity of the nest-boxes of the Tree-Sparrow.

The synusy of the cellulolytic fungi is formed by a complex of the most important decomposers of the nest. In summer the cellulolytic fungi were ascertained in 9 out of 11 nest-boxes with an average number of 2.5 isolates per one nest. The order of the individual genera according to their frequency was: *Chaetomium*, *Fusarium*, *Phoma*, *Alternaria*, *Scopulariopsis*, *Aspergillus*, *Cladosporium*, *Doratomyces*, *Penicillium*. In spring were found cellulolytic micromycetes in all eleven nest-boxes, average number of isolates being 6.1 per one nest-box (the difference vs.

the summer sampling is highly significant). The order of individual genera in spring was: *Penicillium*, *Scopulariopsis*, *Chrysosporium*, *Chaetomium*, *Aspergillus*, *Cladosporium*, *Gliocladium* and *Trichoderma*, that is to a considerable extent different from the summer occurrence. The dominancy of the cellulolytic species of the fungal genera *Penicillium*, *Scopulariopsis* and *Chrysosporium* (*C. pannorum*) is – when compared with the summer sampling – striking.

The synusy of the keratinolytic fungi is equally expressively developed. These microfungi were found in summer as well as in spring in all eleven nest-boxes, with the average number of 2.0 isolates (in summer) and 1.7 isolates (in spring) per one box.

The sequence according to frequency was in summer: *Arthr. ciferrii*, *Aphan. fulvescens*, *Cten. serratus*, *Arthr. tuberculatum*, *A. quadrifidum* and *A. uncinatum*, while in spring: *A. ciferrii*, *A. fulvescens*, *A. quadrifidum* and *Arach. citrinus*. The species spectrum is therefore poorer after the winter season than in summer and also the average number of isolates is to a certain degree lower, but this difference does not manifest itself to be statistically significant.

Potentially zoopathogenic fungi (in this way those fungi are considered which were described as causal organisms of even only sporadic mycoses of homoiothermous animals including man) were ascertained in summer as well as in spring in all 11 nest-boxes, with the average number of 2.6 (in summer), respectively 4.4 (in spring-the increase is statistically significant) isolates per one box. The order of the more important zoopathogens was in summer: *Asp. flavus*, *A. amstelodami*, *Scop. brevicaulis* and *Asp. fumigatus*, while in spring *S. brevicaulis*, *Cand. albicans*, *A. fumigatus* and *M. pusillus*.

Toxinogenic fungi, i.e. species known to produce mycotoxins in victuals and fodder, were equally found relatively often: their average number per one nest-box was in summer 1.3 and in spring 2.5; this increase was significant. In summer the most frequent species of this veterinary important group were *Aspergillus flavus* (producer of aflatoxin) and *Rhizopus nigricans*, while in spring *Pen. cyclopium*, *Scop. brevicaulis* and *Asp. repens*.

Discussion

I. *List of the main changes of the substrate and environment*

Scanning the differences of the macro- and microhabitat between summer and spring in order to try to explain the changes in the composition of the mycoflora of the nest boxes (see par. III.) it is necessary to see again tables 1 to 4 and to realize moreover some further facts. It follows from the comparison that between the 1st and 2nd sampling the following physical and chemical changes of the substrate occurred:

a) an expressive decrease of the average temperature by about 16 °C in consequence of the decrease of the air temperature to the average value of about +2 °C in March.

Table 5. A survey of isolated fungi

	Groups of fungi	Sampling	
		1.VII.1970	1.IV.1971
Number of boxes examined		11	11
Fungal isolates alltogether		83	19
From these: cellulolytes	C, (C)	28	67
keratinolytes	K, (K)	22	19
zoopathogens	P, (P)	29	48
toxinogens	T, (T)	14	27
Zygomycetes		5	4
Absidia glauca Hagem		1	0
Mucor hiemalis Wehmer	(P), T	0	2
M. pusillus Lindt	P, T	0	1
Mucor sp. (sect. Genevensis)		0	1
Rhizopus nigricans (Ehrenb.) Ehrenberg	(P), T	4	0
Endomycetes		11	12
Aureobasidium pullulans (De Bary) Arnaud	(P)	2	1
Candida albicans (Robin) Berkhout	P	0	4
Candida sp.		1	1
Rhodotorula sp.		3	0
Saccharomyces sp.		3	0
Torulopsis sp.		2	6
Ascomycetes		25	22
Aphanoascus fulvescens (Cooke) Apinis	K, (P)	5	5
Arachniotus citrinus Massee et Salmon	(K)	0	1
Arthroderma ciferrii Varsavsky et Ajello	K	10	11
A. quadrifidum Dawson et Gentles	K	1	2
A. tuberculatum Kuehn	K, (P)	2	0
A. uncinatum Dawson et Gentles	K, (P)	1	0
Chaetomium cochliodes Palliser	C	0	1
C. funicolum Cooke	C	1	1
C. indicum Corda	C	1	0
Chaetomium sp.	C	1	1
Ctenomyces serratus Eidam	K	3	0
Fungi imperfecti		42	81
+Alternaria alternata (Fries) Keissler	C, (T)	2	0
+Alternaria sp.		1	0
+Arthrinium phaeospermum (Corda) Ellis		1	0
+Aspergillus amstelodami (Mangin) Thom et Church	P	2	0
+A. flavus Link ex Fries	P, T	4	0
+A. fumigatus Fresenius	C, P, T	1	1
+A. niger van Tieghem	(P), T	1	0
+A. ochraceus Wilhelm	C	0	1
+A. repens (Corda) De Bary	(P), T	0	4
+A. versicolor (Vuillemin) Tiraboschi	(C), (P)	3	7
Cephalosporium coremioides Raillo		0	1
Chrysosporium pannorum (Link) Hughes	C, (P)	0	5
Chrysosporium sp.		0	2

+Cladosporium cladosporioides (Fresenius) De Vries	C	1	1
+C. herbarum Link ex Fries	C	0	1
Doratomyces stemonitis (Persoon ex Fries) Morton et Smith	C	1	0
+Fusarium sp.	C	3	0
+Gliocladium roseum (Link) Bainier	C	0	1
+Malbranchea sp.		0	1
Monilia brunnea Gilman et Abbott		1	0
+Paecilomyces varioti Bainier		1	0
Papulaspora immersa Hotson		0	2
+Penicillium brevi-compactum Dierckx	C, T	0	1
+P. chrysogenum Thom	C	0	1
+P. citrinum Thom	(C)	1	0
+P. cyclopium Westling	C, T	0	9
+P. expansum (Link) Thom	C	0	2
+P. frequentans Westling	(C)	3	0
+P. funiculosum Thom	C, T	0	1
+P. implicatum Biourge	C	0	3
+P. janthinellum Biourge	C	0	4
+P. nigricans (Bainier) Thom	C	1	4
+P. oxalicum Currie et Thom	C	0	2
+P. waksmani Zaleski	(C)	1	0
+Penicillium sp.		2	2
Phialophora sp.		2	0
Phoma sp.	C	3	0
+Scopulariopsis acremonium (Delacroix) Vuillemin	C	0	1
+S. brevicaulis (Saccardo) Bainier	C, P, T	2	7
+S. candida (Guéguen) Vuillemin	(C), (P)	2	7
+S. koningii (Oudemans) Vuillemin	(C), (P)	0	4
+Sepedonium albo-griseum Balfour-Browne		0	2
+S. chrysospermum (Bulliard) Fries		0	1
+Stemphylium sp.		1	0
+Trichoderma viride Persoon ex Fries	C, T	0	1
+Trichothecium roseum Link		0	2
+Verticillium glaucum Bonorden	C	1	0
+Verticillium sp.		1	0

Note: Fungi marked '+' before their name belong systematically with great probability to the class Ascomycetes.

Groups of fungi: (according to the literature)

C = cellulolytes	(C) = weak cellulolytes
K = keratinolytes	(K) = weak keratinolytes
P = zoopathogens	(P) = weak zoopathogens
T = toxinogens	(T) = weak toxinogens

b) a statistically high significant raise of the average water content in the substrate (from 10.3 to 16.0%) before all in consequence of the relative humidity increase of the outdoor air (from 72% to 76–89%).

c) decomposition of the nest material by the activity of micro-organisms and the growth of the share of worse decomposible substances of vegetable origin (cellulose, xylans, lignin, tannic acid).

d) the decrease of chicken feathers and the loss of hair of mammals were compensated by a raised share of feathers of the Tree-Sparrow in the lining.

e) a totally longer contact time of the birds (breeding, roosting) with the nest-box material manifested itself by a significant raise in the quantity of their excreta in the nest-boxes, i.e. in a higher concentration of uric acid, urea and other low-molecular nitrogen substances.

f) this fact resulted in a small but significant raise of the alcality of the nest material (from the mean value pH 6.7 in summer to 6.9 in spring). The other changes may be assumed to be of inferior character.

We are conscious of the fact to make certain errors in point (a) when identifying the macroclimate of the area with the microclimate of the studied nest-boxes of the tree-sparrow.

There are, however, some papers on the base of which it is possible to justify this procedure. The presence of birds affects strongly especially the temperature (as well as the moisture) of the lining. Therefore during the breeding season the microclimate of the hollow nests is to some extent really independent from the macroclimate, especially in the hatching time and the period of parental care as was ascertained e.g. in nests of *Delichon urbica* (7). In nest-boxes of *Parus major* the temperature of the lining in the hatching period was on the average by 6.5 °C and during the period of parental care even by 10 °C higher than the temperature of the outside air (33). On the other hand as far as the birds are not present in the box the dynamics of the nidoclimate is on the whole identical with the dynamics of the macroclimate. At the winter temperature measurements of hollows uninhabited by birds (29) was only observed that the temperature of the hollows becomes identical with the air temperature of the external environment as late as after a certain time. Finally in the case if the hollows are used by birds only for the roosting an increase of temperature in the hollow sets in after the arrival of the bird within 0.5 to 2 hours as much as by 6–8 °C, then the temperature continuously falls and is nearly equal to the external temperature in the morning (46). In nest boxes of Great Tit (*Parus major*) the difference was registrated on the average +5.3 °C in the evening after the arrival of the birds while in the morning only +1.0 °C in comparison with the external environment, the average difference being approximately +2 °C (33).

At the sampling on 1st July, 1970 in this study there were young in 3 nests, in 5 incubated eggs, one nest just before egg-laying and 2 nest-boxes were uninhabited. Over the winter, as has already been said before 7 nest-boxes were used by sparrows for roosting, while 4 remained empty even over night. If we use the data acquired by measuring the temperature in the nest-box of Great Tit (33), we may very roughly estimate the average error we made in point (a) by identifying the air temperature of the outer environment with the temperature of the nest lining: it is necessary to add to the mean air temperature in June (17.7 °C) 5.9 °C, while to the mean air temperature in March (+1.7 °C) 1.3°. If then average air temperature in March 1971 was lower when compared with that of June 1970 by 16°, the temperature of the lining in the boxes dropped by estimate by about 20° in the same term, i.e. still more. From this fact we deduce that the assertion sub (a) is generally correct.

II. *Influence of the nest volume and nest inhabitation from July to March on the mycoflora*

The question occurrs whether some differences between the boxes which fall into the abiotic or biotic sphere cannot misrepresent the achieved results. Some of these possible influences were therefore verified in detail, namely in samples taken after the winter (1 April, 1971).

Size of the boxes and the volume of the lining material

The boxes were separated into 2 categories:

a) with the internal volume of 1500 cm^3 or less, in which the lining material occupied a space less than 1000 cm^3 (altogether 5 boxes).

b) with the internal volume more than 1500 cm^3 in which the material occupied a space greater than 1000 cm^3 (6 boxes).

In both categories the average number of all isolates per one box was 10.8, so that no difference was found. Qualitative and quantitative differences in the occurrence of individual species of fungi in both categories could not be reliably evaluated with respect to the small number of examined boxes-this note concerns also the following influences mentioned in this paragraph.

Nesting in July (*P. montanus*)

Again two categories were selected:

a) boxes in which successful breeding was accomplished still after July 1st, 1970 (7 boxes).

b) boxes with unsuccessful or no breeding after July 1st (4 boxes).

The average number of all isolates in category (a) was 10.4 per one box, in category (b) 11.5. The difference is not statistically significant (chi-square test).

Roosting in the boxes (*P. montanus*)

On the whole 4 boxes were not used by the sparrows for regular roosting in the winter period. The average number of all isolates was with them 10.5 per one box. In 7 boxes it was proved that Tree-sparrows had roosted in them regularly in winter. The average number of isolates from these boxes was 11.0. Again, the difference is not significant.

In this way it was proved that the examined differences in the characteristics of boxes do not affect the number of fungi isolated from individual boxes to such an extent so that it would not be possible to carry out a summary comparative analysis of mycologic results of the summer and after-winter sampling.

III. *An attempt to explain qualitative and quantitative changes in the occurrence of some fungi in boxes in summer and after winter*

In the following text data are chosen from literary sources on the base of which in accordance with the knowledge of the main physical and chemical changes of the substrate, as adduced in paragraph I, it is possible to understand the changes in the number of some fungal species when comparing the summer (1.7.1970) and spring (1.4.1971) sampling.

Fungi isolated more frequently (or only) in spring:

Mucor hiemalis is a hygrophilic species with minimal relative humidity for the growth higher than 90% (34) which produces urease (12). These properties enable its more frequent occurrence in boxes over winter when the lining material is moister and contains more droppings.

Candida albicans and *Torulopsis spp.* are quite frequently found in bird droppings (6, 15, 26, 39) and these are hygrophilic fungi.

Arachniotus citrinus is associated with excrements (16).

Aspergillus repens is in mid-european conditions in the winter period the most abundant species of the genus *Aspergillus* in the atmosphere (1, 22). It is a relatively psychrophilic fungus with a minimum temperature for growth 4–7 °C (2, 34). Conspicuous is also its xerophily: for example conidia germinate already at a R.H. of 71–74% (18, 40), in dust particles from closed rooms it sporulates at a R.H. of 75% and generally in dust it is the dominant fungus at a R.H. 80–85% (8); on stored grain it grows even at a water content of 13–15% (34).

A. versicolor is aspergillus distributed geographically in the coolest areas (12) in consequence of its relative psychrophily (minimal temperature for the growth is 4–5 °C/34). It occurs quite frequently on hay, dry stalks (5) and mouldy straw (12); it strongly desintegrates pectins and xylans, less cellulose and insignificantly humic acids (12). The fungus is relatively xerophilic, growing at 75% of R.H. (34) and it germinates from 73–80% R.H. (18, 40); it grows on the grain also at 14% water in the substrate (12). The maximum frequency of spores of this species in the atmosphere was proved in spring (44), which together with the previous data probably conditions the higher frequency of the fungus in boxes in after-winter period.

Chrysosporium pannorum is a definitely psychrophilic fungus occurring even in the Alaska and in the alpine (12). Minimal temperature for the growth is lower than 0 °C, a weak growth is mentioned even at −10 °C (19); this fact conditions frequent occurrence in cold stored meat (3, 19, 27). The fungus has xylanase and cellulase (12) and maximal frequency of its occurrence in the soil was found in winter season (14). These properties explain the increased records frequency ascertained by us of *C. pannorum* in boxes after winter.

Gliocladium roseum is a hygrophilic fungus (8) relatively psychrophilic (minimal temperature for the growth is 4–8 °C/12), which produces cellulase, pectinase and xylanase (12) and occurs also in excrements

(5, 42). In the soil of Wisconsin it was most often found in January (17).

Papulaspora immersa is a coprophilic fungus (12).

Penicillium chrysogenum is a psychrophilic species, growing even at −4 °C (34).

P. cyclopium is also psychrophilic fungus, for the growth of which is stated minimal temperature lower than 5 °C (12). According to water demands it is mesophilic (minimal rel, humidity for germination is 81–84%/18, and for the sporulation 85%/8), it does not occur in an environment with a low water content. It decomposes intensively pectins, xylans, less strongly cellulose, and it very often occurs on hay and rotting vegetation in general (12).

P. expansum is definitely psychrophilic: minimal temperature for the growth is −3 °C (34). It was recorded on cold stored meat (3). According to its humidity demands the fungus is mesophilic: minimal R.H. for development is 82–85% (18, 34). Frequent occurrence on rotten plant substrate is explainable by its psychrophily and the ability of producing enzymes xylanase, pectinase and tannase (12).

P. janthinellum is frequent on rotten vegetable substrata in the last stage of decomposition (37), also on wood. Maximum occurrence in soil was ascertained in spring (14). The fungus produces pectinase and tannase (12).

Scopulariopsis brevicaulis is frequent on half-dry hay where it develops usually as soon as easily assimilable nutrients (monosaccharides etc.) have been exhausted (37), which is explainable by the enzymatic equipment of this fungus, which produces xylanase, cellulase, it grows on ligninsulphonate and decomposes slightly even wood (12, 31). This species is alcalophilic and often found in droppings of birds (22), it was ascertained in the excreta of seagulls even in Antarctic (11). The fungus can be designated as mesophilic according to the claim to humidity, because the minimum R.H. for its development is 85–90% (8, 18, 34).

S. candida is usually ascertained in wood (5), in birds' droppings (24) and substances of cellulose character (31).

Trichoderma viride is a pronounced hygrophilic fungus with higher claims to the water content in the substrate: minimum R.H. for its development is 91–96% (18, 34). On the other hand it shows a tolerance for low temperatures, while minimal temperature for the growth is 6 °C and the fungus was recorded in the alpine (12). It is known to be frequent in wood which it decomposes sometimes. Moreover it produces cellulase, pectinase and xylanase (12) and grows on excrements (42). In the atmosphere it was ascertained mainly in spring and in winter (1).

Trichothecium roseum is also a quite hygrophilic fungus with a minimum R. H. for the development (86–96% (8, 18, 34, 40). It presents a certain affinity to lignin (32) and occurs also in excrements (42). In the atmosphere it was ascertained only in winter and in spring (44).

Fungi isolated more often (or only) in summer:

Rhizopus nigricans is 'sugar fungus' which dominates in the first stage of the plant decomposition, when the plant residues contain still a high

percentage of easily assimilable substances, first of all glycids. In the atmosphere spores were ascertained in summer and in autumn, while not in winter (44).

Arthroderma uncinatum was not recorded in spring which may be explained by three possible reasons. Some authors proved a significant decrease of this fungus in the soil and on plant remnants over the winter period (4, 28). It is found that *A. uncinatum* prefers more acid substrates: from the soil samples and from birds' nests with a higher pH than 6.0–6.2 a very small portion of the total number of strains is usually isolated (30, 35, 36). Another possible explanation is in the ascertainment that this fungus grows better on horse hair than on feathers (45): the hair of the mammals from the lining over the winter period disappeared.

Ctenomyces serratus shows an evident preference for hen feathers (45) expressive decrease of which was recorded after the breeding period in the lining of the examined boxes.

Alternaria alternata has the maximum occurrence of spores in the atmosphere in summer (1, 41, 44), and many strains loose their viability after being preserved in a refrigerator at +4 °C for a longer time (22). It is besides a fungus of the first stage of the decomposition of plant material ('early colonizer') (25).

Aspergillus flavus and *A. niger* are thermophilic species geographically distributed predominantly in tropical and subtropical areas. Both fungi occur abundantly on various substrates in south California with an average air temperature of 32 °C, while in middle California (average air temperature 25 °C) they are rare on the same substrata (38). Minimal temperature for their growth is 12 °C (2). Concerned are fungi taking part especially in the first phase of decomposition of plant material. The maximum occurrence of spores of *A. niger* in the atmosphere was ascertained in summer (44).

Penicillium frequentans is found especially in acid soils (12), which may contribute to the explanation of the disappearance of this fungus in the boxes over the winter period.

Some from the other isolated fungi

Arthroderma ciferrii grows well at +4 °C (13, 20), which is with regard to the sufficient quantity of keratin (feather) in the lining of hollow nests a warrant for survival over the winter period.

A. quadrifidum was found in the soil and on plants significantly more often in spring than in autumn (4, 28). On assumption of a convenient keratin material it is facilitated by the fact that *A. quadrifidum* grows very well at +4 °C (9, 13).

Cladosporium cladosporioides and *C. herbarum* are fungi psychrotolerant, occurring for instance also in alpine and polar areas. *C. herbarum*, growing even at −6° to −10 °C, can be the cause of decay of cold stored meat (3). Both fungi grow also on ligninsulphonate (12) and their survival over the winter in boxes is not surprising.

After this autecological analysis it is possible to attempt a synecological view and from this aspect to explain the changes of fungal community of the boxes. A statistically high significant increase in the number of cellulolytic fungi in spring is relatively well explainable by the raised portion of cellulose in the lining of the boxes. A higher number of cellulolytes in spring than in summer was ascertained in the soil by Úlehlová (43). In keratinolytic fungi, a statistically insignificant decrease of the number of isolated species was recorded after the winter period (in summer 6, in spring 4). This slight decrease and a certain narrowing of the species spectrum can be explained by the disappearance of hair from the lining, the smaller quantity of hen feathers and also perhaps by a decrease in temperature. With zoopathogenic and toxinogenic fungi a statistically significant rise in the number of isolates occurred over the winter season, which, as we suppose, could be explainable by an increased quantity of droppings in the boxes (i.e. a greater concentration of low mollecular nitrogen substances, especially uric acid). Many toxinogenic fungi are moreover cellulolytic so that their number with the growing proportion of cellulose in the substrate will grow as expected. A surprising and statistically evident rise of the total number of fungi is finally on the base of a presented autecologic and synecologic analysis explainable especially by the fact that over the winter season the number of cellulolytic fungi forming the substantial part of fungal community in boxes has grown.

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