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ORIGINAL RESEARCH PAPER

Selected rare and protected macrofungi (*Agaricomycetes*) as bioindicators of communities of xerothermic vegetation in the Nida Basin

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Abstract
Results of mycological investigations conducted in xerothermic grasslands of the Nida Basin in the years 1984–2013 are presented. Our research brings up to date the current knowledge on ecological requirements of threatened species of macrofungi. Strong affiliations between macrofungi and specific phytocenoses of the alliances *Festuco-Stipion* and *Seslerio-Festucion duriusculae* were detected. A considerable influence of the occurrence of certain species of steppe fungi on the composition of the mycobiota in the Nida Basin was identified.

Keywords
Gasteromycetes; bioindicators; Nida Basin; thermophilous fungi; correspondence analysis

This issue of Acta Mycologica is dedicated to Professor Maria Lisiewska and Professor Anna Bujakiewicz on the occasion of their 80th and 75th birthday, respectively.

Introduction

Rare species of steppe plants derived from warmer climatic zones of Southern and Southeastern Europe occur in xerothermic communities developing in the Nida Basin. The majority of these species is either threatened or endangered, such as, e.g., *Stipa capillata*, *S. joannis*, *Inula ensifolia*, *Thymus marschallianus*, *Cirsium pannonicum*, *Scorzonera purpurea* [1–3]. The occurrence of suitable habitats and xerothermic vegetation has contributed to the formation of a rich biota of thermophilous and steppe species of macrofungi (*Agaricomycetes*). Many very rare species and species of special value to Poland's mycobiota have been identified to date. These are often strictly protected species or species of red-listed macrofungi [4,5].

Species of gasteroid fungi, i.e., fungi having similar morphology, species clearly attached to xerothermophilic habitats, were prioritized for selection in our studies. This group of fungi belongs to the following genera: *Disciseda* (*D. bovista*, *D. candida*), *Gastrosporium* (*G. simplex*), *Geastrum* (*G. campestre*, *G. minimum*, *G. schmidelii*) and *Tulostoma* (*T. brumale*, *T. kotlabae*, *T. melanocyclum*, *T. squamosum*). These species exhibit primarily strong biocoenotic affinities with phytocoenoses of the alliances *Festuco-Stipion* and *Seslerio-Festucion duriusculae* [6,7]. In the xerothermic habitats in the Nida Basin, they form a special mycobiota that is not found elsewhere. The association *Tulostomato* (*brumali*)-*Gastrosporietum simplicis*, which exhibits a strong relationship with habitats of xerothermophilic grasslands of the alliance *Festuco-Stipion*, is a good example of such a specialized mycoassociation. Species of the genera *Tulostoma* and *Gastrosporium simplex* are the main components of this mycoassociation [6–8]. Due to high ecological specialization and a close relationship between fungi examined by us and specific plants of steppe origin, many of these species can be treated as important bioindicators of threatened and endangered habitat types of xerothermic vegetation in Poland [9,10]. The occurrence of the species identified in our study indicates that such communities are persistent and have typically developed phytocoenoses. The bioindicator value of fungi in a variety of plant communities has been noted by, e.g., Kornaś [11], Bujakiewicz [12–14], Barkman [15], Kałucka [16].

Multidimensional methods were used in our study to assess changes in the species composition of fungi in selected xerothermic communities. Species defined in the literature as thermophilous, xerothermic and steppe fungi related to the communities of the class *Festuco-Brometea* [6,8] were chosen for statistical analyses.

Specific aims of the study are:

(***i***) to analyze the occurrence of ten selected rare and protected species of fungi in chosen communities of xerothermic vegetation in the Nida Basin by correspondence analysis;

(***ii***) to analyze in detail fruitbody productivity in xerothermic communities using statistical methods;

(***iii***) to identify bioindicator species within fungi examined by us whose occurrence indicates an undisturbed type of communities of xerothermic vegetation.

Material and methods

The results presented in our study are based on investigations conducted in two stages. The first stage comprised investigations carried out from June 1984 until November 2013 at plots that were burnt annually. The second stage comprised investigations carried out from October 2010 until November 2013 at plots that were not burnt. Communities of xerothermic vegetation of the class *Festuco-Brometea* in selected subregions of the Nida Basin were examined. Investigations were conducted in protected areas such as Natura 2000 sites, nature reserves (Krzyżanowice, Skorocice) and landscape parks (Nida Landscape Park, Szaniec Landscape Park, Kozubów Landscape Park).

Six communities of xerothermic vegetation were examined: three of the alliance *Cirsio-Brachypodion pinnati* (*Adonido-Brachypodietum pinnati*, *Inuletum ensifoliae*, *Seslerio-Scorzoneretum purpureae*), two of the alliance *Festuco-Stipion* (*Koelerio-Festucetum rupicolae*, *Sisymbrio-Stipetum capillatae*) and one of the alliance *Seslerio-Festucion duriusculae* (*Festucetum pallentis*) [3]. A total of 33 permanent research plots were established. Three research plots were established in the community *Sisymbrio-Stipetum capillatae* in the first stage of research, i.e., in the years 1984–2013. Thirty research plots, five in each of the six communities, were established in the years 2010–2013. Plot sizes were determined by the size of a homogenous vegetation patch and corresponded with the standards of an area of a phytosociological relevé used in these types of communities (from 30 m^2 to 150 m^2). Phytosociological relevés were performed with the commonly used Braun-Blanquet method at all permanent plots. Investigations were conducted regularly every two weeks after snow receded until a new snow cover appeared. In total, each plot was observed 15 times per year. All fruitbodies of selected gasteroid fungi were collected and counted each time during mycological observations. To avoid double counting of fruitbodies, all fruitbodies of fungi under consideration were collected.

Fungal fruitbodies were identified taxonomically in the laboratory. Mycological studies were used to determine the fungi: Pilát [17], Rudnicka-Jezierska [18], Sarasini [19], Wright [20]. A light microscope, a scanning electron microscope and standard chemical reagents were used for analysis (10% KOH, IKI). Spores, basidia and capillitial threads whose size and shape are taxonomically important were measured with a light microscope. All microscopic characters were observed with an immersion lens. Examinations using a scanning electron microscope were performed in the Department of Environment Protection and Modelling, Jan Kochanowski University in Kielce, Poland. Sampled material (soil samples containing spores) was transferred on a special sticky aluminium disc and sputter coated with 24-carat gold. Spores were photographed at 3000, 5000, 10 000 and 12 000 × magnifications.

Statistical method

The indicator species analysis was conducted with the indicator value index (IndVal) [21,22]. The IndVal is the product of two components called *A* and *B*. Quantity *A* is defined as the mean abundance of the species in the target site group divided by the sum of the mean abundance values over all groups. Quantity *B* is defined as the relative frequency of the occurrence (presence–absence) of the species inside the target site group.

Statistical significance of the relationship between the species and the site group was tested using a permutation test where the *P*-value <0.05 was considered significant.

The relationship between site groups and fungi species was also studied by correspondence analysis.

All computations were performed with package R, version 3.1.2 (R Core Team; http://www.R-project.org)

The nomenclature of fungi was accepted after Wojewoda [23] while that of plants after Mirek et al. [24].

Detailed data regarding the number of fruitbodies of individual species of fungi in selected plant communities is given in Tab. 1. Phytosociological features and a list of collected fruitbodies of the fungi examined in the study based on the community *Sisymbrio-Stipetum capillatae* are presented in Tab. 2. Tab. 3 contains the IndVal and its components.

Exiccata are deposited in the Fungarium (KTC) of the Faculty of Mathematics and Natural Sciences, Jan Kochanowski University in Kielce, Poland.

Results and discussion

Xerothermic communities and fruitbody productivity: an analysis

The most favorable growth conditions for fruitbodies of fungi examined by us were noted in the community *Festucetum pallentis*. A total of 837 fruitbodies of all species

Tab. 1 The number of fruitbodies of selected species of gasteroid fungi in communities of xerothermic vegetation.

	T. sq.	T. mel.	T. kot.	T. bru.	G. schm.	G. min.	G. cam.	G. sim.	D. can.	D. bov.
Fp	402	100	5	127	141	56	65	17	22	2
Sc	63	118	1	105	83	153	38	169	31	9
Sp	2	0	2	11	75	0	39	49	0	0
K	34	14	9	76	0	0	0	0	0	0
I	0	0	0	0	0	0	19	0	0	0
A	24	17	0	7	1	0	0	0	0	0

Abbreviations: Fp – *Festucetum pallentis*; Sc – *Sisymbrio-Stipetum capillatae*; Sp – *Seslerio-Scorzoneretum purpureae*; K – *Koelerio-Festucetum rupicolae*; I – *Inuletum ensifoliae*; A – *Adonido-Brachypodietum pinnati*; T. sq. – *Tulostoma squamosum*; T. mel. – *Tulostoma melanocyclum*; T. kot. – *Tulostoma kotlabae*; T. bru. – *Tulostoma brumale*; G. schm. – *Geastrum schmidelii*; G. min. – *Geastrum minimum*; G. cam. – *Geastrum campestre*; G. sim. – *Gastrosporium simplex*; D. can. – *Disciseda candida*; D. bov. – *Disciseda bovista*.

Tab. 2 Phytosociological features and a list of collected fruitbodies of fungi examined by us: *Sisymbrio-Stipetum capillatae* (phytosociological data according to Braun-Blanquet method).

Sisymbrio-Stipetum capillatae **(Dziub. 1925) Medw.-Korn. 1959**	**Plots burnt regularly from 1984 until 2013**			**Undisturbed plots, observations in 2010–2013**				
Location	**Stawiany**			**Skorocice**			**Wola Zagojska**	
Day	12	11	13	12	12	12	12	12
Month	7	7	7	7	7	7	7	7
Year	1984	1984	1984	2011	2011	2011	2011	2011
Exposure	S	SW	S	S	S	S	S	SE
Inclination (°)	15	20	5	2	2	3	30	10
Cover of the herb layer c in %	90	90	85	90	85	95	80	100
Cover of the moss layer d in %	-	-	5	15	5	-	-	-
Relevé surface in m^2	60	150	50	70	50	30	100	100
Number of fungal fruitbodies collected								
Disciseda bovista	0	0	0	2	1	1	3	2
D. candida	0	0	0	5	2	3	9	12
Gastrosporium simplex	0	0	0	19	10	15	98	27
Geastrum campestre	0	0	0	3	3	8	9	15
G. minimum	0	0	0	19	20	70	28	26
G. schmidelii	0	0	0	8	7	36	15	17
Tulostoma brumale	0	0	0	1	3	8	26	67
T. kotlabae	0	0	0	0	0	0	1	0
T. melanocyclum	0	0	0	2	3	12	47	54
T. squamosum	0	0	0	2	7	14	15	25
Ch. *Sisymbrio-Stipetum, Festuco-Stipion:*								
Stipa capillata	5.5	1.2	4.4	4.5	4.5	4.4	4.4	5.5
Ch. *Festuco-Brometea:*								
Achillea pannonica	.	.	.	.	+	.	.	.
Agrostis vulgaris	.	.	.	.	+.2	.	.	.
Arenaria serpyllifolia	.	.	.	.	.	+	.	.
Avenastrum pratense	.	.	.	.	.	.	.	1.2
Anthyllis vulneraria var. *polyphylla*	+	+	+	1.2	1.2	1.2	.	2.2
Arabis hirsuta	.	.	.	+	1.1	+	.	+.2
Artemisia campestris	+	.	+	2.2	1.2	2.2	1.2	.
Artemisia vulgaris	.	.	.	.	.	.	.	+.2
Asperula cynanchica	+	+	1.2	1.2	1.2	1.2	+.2	1.2

Tab. 2 Continued

Sisymbrio-Stipetum capillatae **(Dziub. 1925) Medw.-Korn. 1959**	**Plots burnt regularly from 1984 until 2013**			**Undisturbed plots, observations in 2010–2013**				
Location	**Stawiany**			**Skorocice**			**Wola Zagojska**	
Astragalus danicus	0.2	1.1	+	.	.	+.2	+.2	1.2
Avenula pratensis	+	+	+	.	.	.	.	.
Calamintha acinos	.	.	.	+	+	+	.	+
Campanula sibirica	.	+	+	+	+	+	1.1	+
Carex glauca	.	.	.	.	1.2	.	.	.
Carex humilis	.	2.2	3.3	.	.	.	2.2	1.2
Carex montana	.	.	.	1.2	.	.	.	.
Carex tomentosa	.	.	.	.	.	+.2	.	.
Centaurea scabiosa	.	.	.	+	1.2	1.1	.	.
Centaurea stoebe	.	.	.	2.1	1.1	.	+.2	1.1
Cuscuta epithymum	.	.	.	+	.	.	.	.
Crepis praemorsa	.	.	.	.	+	.	.	.
Braychypodium pinnatum	.	.	.	+.2	.	+.2	.	.
Dactylis glomerata	.	.	.	.	.	+.2	.	.
Dianthus carthusianorum	.	.	.	+	.	.	.	.
Euphorbia cyparissias	0.2	+	+	1.1	+	+	1.2	1.2
Euphrasia stricta	.	.	.	+	.	.	.	.
Erigeon acer	.	.	.	.	+	.	.	.
Festuca pallens	.	.	.	.	.	+.2	.	.
Festuca rupicola	0.2	.	.	.	.	.	.	.
Festuca sulcata	.	.	.	1.2	1.2	1.2	1.2	2.2
Filipendula hexapetala	.	.	.	+	.	.	.	.
Helianthemum nummularium ssp. *obscurum*	2.2	1.1	.	.	.	.	.	.
Helianthemum ovatum	.	.	.	.	.	+.2	.	+.2
Hieracium bauhinia	.	.	.	1.2	.	+.2	.	+.2
Koeleria glauca	1.2	+	1.2	.	.	.	.	.
Koeleria macrantha	.	.	.	.	+	.	.	.
Leontodon hispidus	.	.	.	+.2	+	+	.	.
Linum hirsutum	.	.	.	.	.	.	.	+
Lotus corniculatus	.	.	.	+	+	+	.	.
Melampyrum arvense	.	.	.	.	+	.	.	.
Odontites lutea	.	.	.	.	.	+	.	.
Onobrychis viciaefolia	.	.	.	.	.	+	.	+

Tab. 2 Continued

Sisymbrio-Stipetum capillatae **(Dziub. 1925) Medw.-Korn. 1959**	**Plots burnt regularly from 1984 until 2013**			**Undisturbed plots, observations in 2010–2013**				
Location	**Stawiany**			**Skorocice**			**Wola Zagojska**	
Ononis spinosa	.	.	.	+	+	+	.	.
Peucedanum oreoselinum	.	.	+	.	.	.	.	.
Phleum phleoides	.	.	.	.	.	.	.	+.2
Plantago lanceolata	.	.	.	1.2	1.1	+	.	1.1
Plantago media	.	.	.	.	.	+.2	.	.
Poa angustifolia	.	.	.	.	1.2	.	.	.
Poa compressa	3.3	+	2.2	2.2	2.3	3.2	2.2	1.2
Potentilla arenaria	.	.	.	.	.	+.2	.	.
Salvia pratensis	.	.	.	+	+	1.2	+	.
Sanguisorba minor	.	.	.	.	.	+	.	.
Sanguisorba officinalis	+	1.2	1.2	.	.	.	.	.
Scabiosa canescens	.	.	.	+	.	+	.	.
Scabiosa ochroleuca	.	.	.	+	+	.	.	.
Sedum maximum	.	.	.	+	+.2	1.2	.	.
Sedum sexangulare	.	.	.	+	+	.	.	.
Silene otites	.	+	+	+	+	+	.	+
Seseli annuum	.	.	.	.	.	.	.	+.2
Sisymbrium polymorphum	.	.	.	.	+.2	1.2	.	.
Stipa joannis	.	.	.	+	+	.	.	.
Thalictrum minus	.	1.1	2.2	+	.	.	.	.
Thesium linophyllon	.	.	0.2	1.2	1.2	2.2	2.2	.
Thymus marschallianus	1.2	1.2	1.2	2.2	1.2	2.2	.	.
Thymus pannonicus	.	.	.	.	+	+	.	.
Trifolium montanum	1.1	+	+	+	.	.	.	1.2
Ch. *Trifolio-Geranietea sanguinei*:								
Anthericum ramosum	+	4.4	.	.	.	.	+.2	.
Galium boreale	.	.	.	.	1.2	+	.	.
Galium verum	2.3	+	1.1	1.2	.	+	.	1.2
Medicago falcata	+	+	+	+	1.2	1.2	+.2	.
Accompanying species:								
Galium verum	.	.	.	.	.	.	.	1.2
Gypsophila fastigiata	1.2	+	0.2	.	.	.	1.2	2.2
Pimpinella saxifraga	+	+	+	+	+	.	.	+

Tab. 2 Continued

Sisymbrio-Stipetum capillatae **(Dziub. 1925) Medw.-Korn. 1959**	**Plots burnt regularly from 1984 until 2013**			**Undisturbed plots, observations in 2010–2013**				
Location	**Stawiany**			**Skorocice**			**Wola Zagojska**	
Bryum argenteum d	.	.	0.2	.	.	.	.	.
Bryum caespiticium d	.	0.2	0.2	.	.	.	.	.

of fungi under investigation were collected at the five permanent plots established within the patches of this community, which is the highest number of fruitbodies collected. *Tulostoma squamosum*, which accounted for 48% of fruitbodies of all species of fungi examined by us, was the dominant species at the *Festucetum pallentis* plots. The number of fruitbodies of individual fungal species collected in the patches of *Seslerio-Scorzoneretum purpureae* phytoceoneses ranges quite considerably; a single dominant species, however, was not recorded. Very good conditions for the growth of fruitbodies of fungi investigated by us were also noted in the community *Sisymbrio-Stipetum capillatae*. A total of 770 fruitbodies were noted in the plots of this phytocoenosis, with *Gastrosporium simplex* as a dominant species. A large number of fruitbodies was also produced by *Geastrum minimum* in *Sisymbrio-Stipetum capillatae*, where 153 of its fruitbodies were collected. Neither *G. simplex* nor *Geastrum minimum* developed fruitbodies in the communities *Koelerio-Festucetum rupicolae* and *Inuletum ensifoliae*. The least favorable conditions for the development of fruitbodies of fungi examined by us were noted in the community *Inuletum ensifoliae*. Fruitbodies of only one species, *Geastrum campestre*, totaling 19 fruitbodies, were collected at the plots comprising phytocoenoses of this community. Detailed data regarding the number of fruitbodies of individual species in plant communities is given in Tab. 1.

The diversity of fruitbody production of macrofungi is plotted against xerothermic communities in figures below (Fig. 1a–f). As the box plots show (Fig. 1a,b,f), *G. simplex* has a narrow range of ecological requirements. Its fruitbodies produce white, long (ca. 50–200 mm) mycelial cords, rhizomorphs, which they use to entwine grass roots. *Gastrosporium simplex* is an obligatory parasite of grass roots, mostly of the genus *Stipa* but it has also been noted on roots of *Brachypodium*, *Bromus*, *Festuca*, *Koeleria* and *Sesleria* [17,25]. Many authors: Šmarda [26], Bujakiewicz [27], Łuszczyński and Łuszczyńska [28], Stasińska [29,30], stress its strong affiliation with communities of the alliance *Festuco-Stipion* but they also show that the species is exceptionally thermophilous, associated with dry, warm and sun-exposed sites where soil temperature often exceeds 39°C.

Gastrosporium simplex was also recorded most frequently in the communities *Sisymbrio-Stipetum capillatae* and *Festucetum pallentis* (Fig. 1a,b). The most numerous production of fruitbodies was recorded on roots of grasses of the genus *Stipa*, which also confirms its obligatory relationship with the host.

The mycobiota of extremely dry and warm habitats of xerothermic and psammophilous grasslands is differentiated by species of the genus *Tulostoma*: *T. brumale*, *T. kotlabae*, *T. melanocyclum* and *T. squamosum*. Species of this genus develop the mycelium and fruitbodies among tall herb vegetation, in south-facing sites. They prefer dry, sandy soils

Tab. 3 The IndVal and its components (abbreviations are as in Tab. 1).

Site group	Species	*A*	*B*	IndVal	*P*-value
Fp	T. sq.	0.7657	0.8000	0.6126	0.027
	T.bru.	0.3896	1.0000	0.3896	0.085
	G. schm.	0.4700	0.6000	0.2820	0.505
	D. can.	0.4151	0.6000	0.2460	0.204
K	T. kot.	0.5294	0.8000	0.4235	0.034
Sc	G. min.	0.7321	1.0000	0.7321	0.001
	G. sim.	0.7191	1.0000	0.7191	0.002
	D. bov.	0.8182	0.6000	0.4909	0.021
	T. mel.	0.4739	1.0000	0.4739	0.027
	G. cam.	0.2360	0.8000	0.1888	0.535

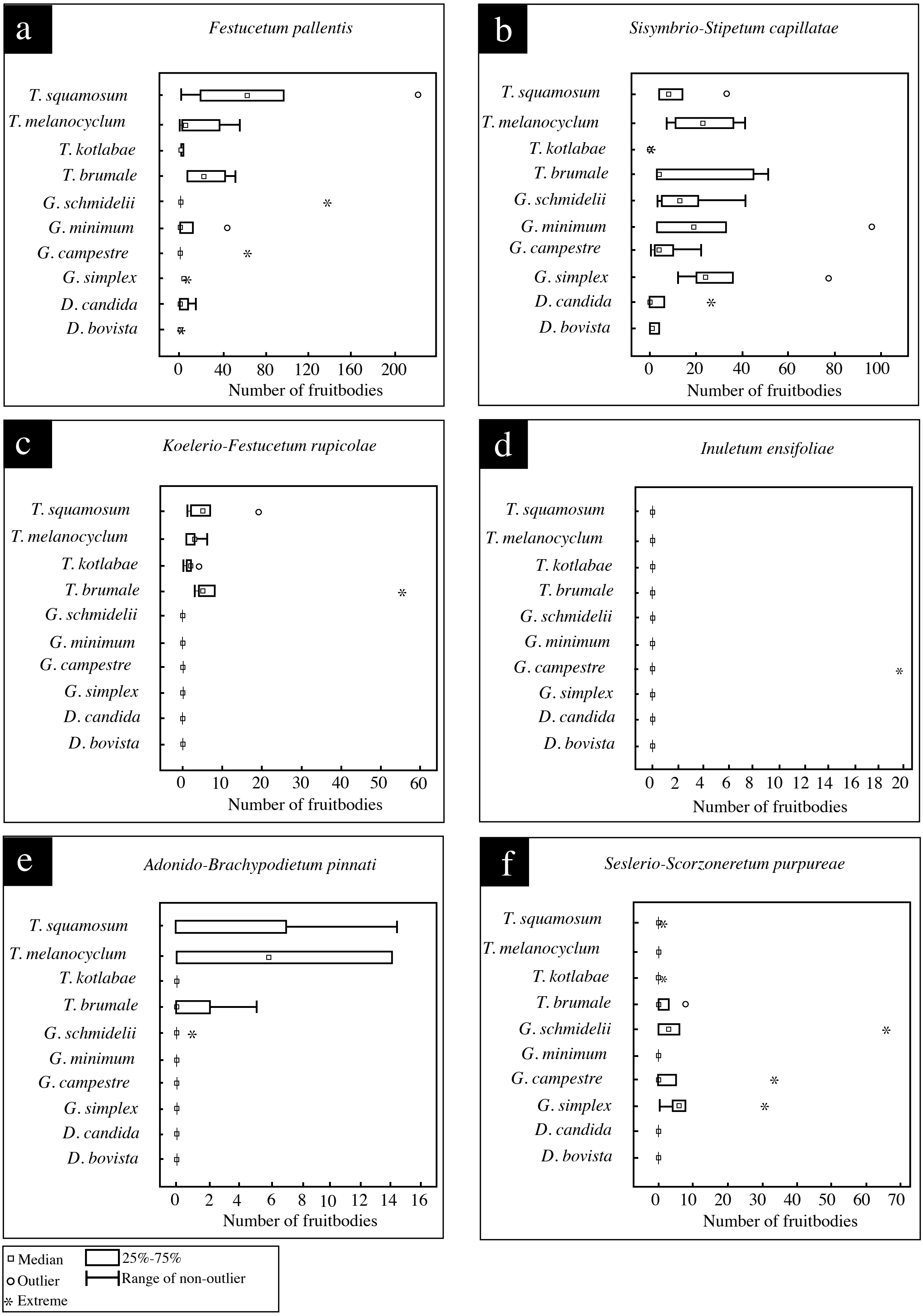

Fig. 1 The number of fruitbody production of Basidiomycetes in communities of xerothermic vegetation in the Nida Basin in the years 2010–2013.

rich in calcium carbonate [17,18]. In our study, fruitbodies of fungi belonging to the genus *Tulostoma* were collected on south-facing slopes, in summit parts, strongly insolated, where mean soil temperatures often exceeded 35°C in summer months. Fruitbodies of these fungi were most frequently recorded on soils such as shallow clay rendzina. The closest biocoenotic affiliation with phytocoenoses of the associations *Festucetum pallentis*, *Sisymbrio-Stipetum capillatae* and *Koelerio-Festucetum rupicolae* was recorded for *Tulostoma squamosum* and *T. melanocyclum* (Fig. 1a–c). *Tulostoma brumale* can also be a characteristic species of the above-mentioned grasslands as fruitbody abundance is considerably higher in them.

Two species of the genus *Disciseda*: *Disciseda bovista* and *D. candida*, associated with Pontic-steppe vegetation, are appropriate species of the associations *Festucetum pallentis* and *Sisymbrio-Stipetum capillatae* [6,19,31–34]. Localities noted in our study confirm their affiliation with grasslands of the alliances *Festuco-Stipion* and *Seslerio-Festucion duriusculae*. Our results confirm the occurrence of the mycocoenosis of the association of fungi *Tulostomato* (*brumali*)–*Gastrosporietum simplicis* in the study area. Species of the genus *Geastrum* also characterize well thermophilous, easily warming areas of steppe grasslands. A strong affinity between *Geastrum campestre*, *G. minimum* and *G. schmidelii* and *Stipa grasslands* containing *Stipa capillata* and *S. joannis* as well as *Festuca* grasslands dominated by *Festuca pallens* and *F. rupicola* (Fig. 1b) was recorded in our study.

Several extreme data points, relating to *Gastrosporium simplex*, *Geastrum schmidelii*, *G. campestre*, *Tulostoma kotlabae* and *T. squamosum*, are noticeable in some diagrams (Fig. 1d–f). These values suggest that these species can also be identified with phytocoenoses belonging to the alliance *Cirsio-Brachypodion pinnati*, which would indicate a broader ecological scale of these taxa. However, local lithological–pedological conditions in the Nida Basin make the microhabitats in this seemingly homogenous type of communities highly mosaic. Without specialized pedological examinations, the richness of the microhabitats is not reflected in the floristic diversity of the communities, especially in the alliance *Cirsio-Brachypodion pinnati*. Small plots are often distinguished in floristically homogenous patches due to outcrops beneath upper soil layers. This local diversity can cause the development of fungi associated with xerothermophilic communities of the alliance *Festuco-Stipion* and not those associated with mesoxerothermic phytocoenoses of the alliance *Cirsio-Brachypodion pinnati*.

The results of mycological observations conducted in the phytocoenoses of *Sisymbrio-Stipetum capillatae*, successively burnt out since 1984, are very different. Not only is an impoverished species composition observed at these plots but also a total disappearance of the biota of macrofungi is noted (Tab. 2). Therefore, fungi examined by us are an important component of the biocoenosis. Their occurrence indicates its mature character and complex structure while its type remains undisturbed by burning.

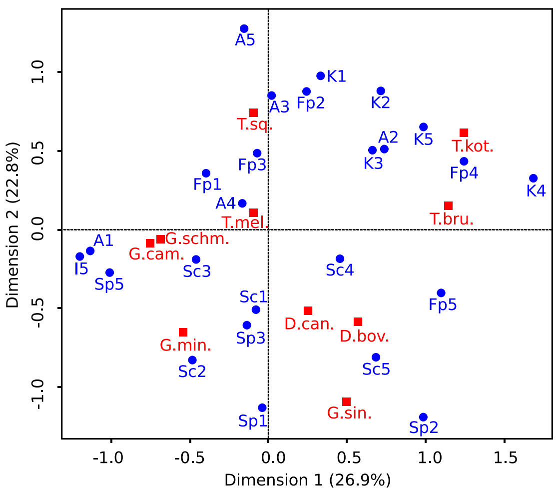

Fig. 2 The correspondence analysis based on all 30 plots in the years 2010–2013 (abbreviations are as in Tab. 1).

Determination of indicator species: statistical analysis

In our data, six out of ten of the species analyzed were significantly related to site groups. *Tulostoma squamosum* is an indicator of *Festucetum pallentis*, *Tulostoma kotlabae* is an indicator of *Koelerio-Festucetum rupicolae* and *Geastrum minimum*, *Gastrosporium simplex*, *Disciseda bovista* and *Tulostoma melanocyclum* are indicators of *Sisymbrio-Stipetum capillatae* (Tab. 3).

The highest values of IndVal were observed for *Geastrum minimum* and *Gastrosporium simplex*, which were significantly associated with *Sisymbrio-Stipetum capillatae*. The species of fungi *Gastrosporium simplex* and *Geastrum minimum* are mainly restricted to *Sisymbrio-Stipetum capillatae* ($A > 0.7$) and each of them occurs at all plots of *Sisymbrio-Stipetum capillatae*.

In the correspondence analysis based on all 30 plots, the first two dimensions accounted for only 49.7% of inertia (Fig. 2) and no clear clusters were found.

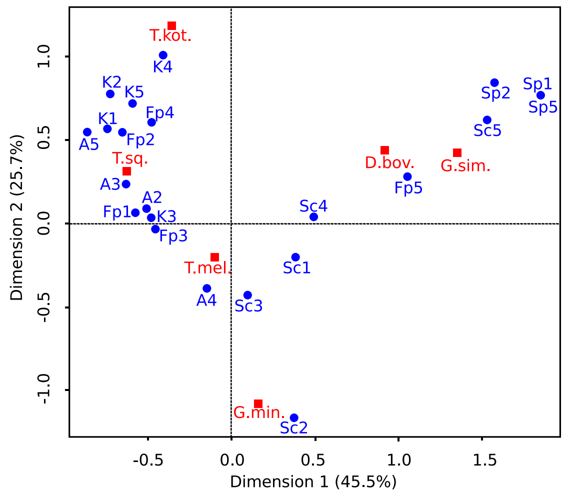

Fig. 3 The correspondence analysis based on 6 species related significantly to site groups by IndVal analysis (abbreviations are as in Tab. 1).

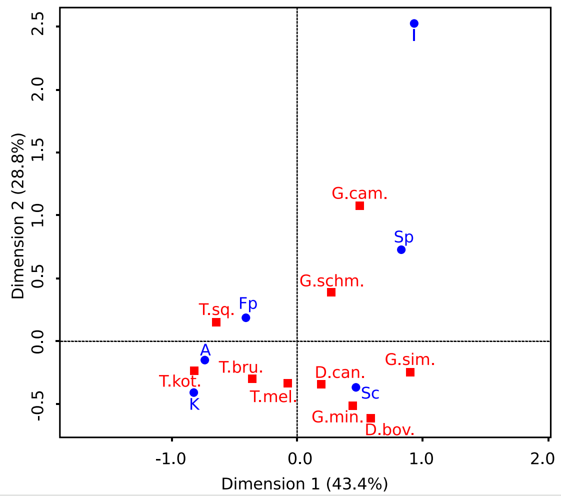

Fig. 4 The correspondence analysis on the accumulated abundances across the plots within communities of xerothermic vegetation (abbreviations are as in Tab. 1).

When we restricted our analysis to those six species that were significantly related to site groups by IndVal analysis, the first two dimensions accounted for 71.2% of inertia (Fig. 3) but clear clusters were still not observed.

We also conducted a correspondence analysis on the accumulated abundances across the plots within *Festucetum pallentis*, *Sisymbrio-Stipetum capillatae*, *Seslerio-Scorzoneretum purpureae*, *Koelerio-Festucetum rupicolae*, *Inuletum ensifoliae* and *Adonido-Brachypodietum pinnati*. The results are presented in Fig. 4. *Koelerio-Festucetum rupicolae*, *Adonido-Brachypodietum pinnati* and *Festucetum pallentis*, which were dominated by species of group *Tulostoma*, can be seen on the left whereas *Sisymbrio-Stipetum capillatae*, *Seslerio-Scorzoneretum purpureae* and *Inuletum ensifoliae*, which were dominated by species of group *Geastrum* and/or *Disciseda*, can be seen on the right.

Conclusions

The following conclusions can be drawn from our studies: (***i***) observations conducted at burnt plots of *Sisymbrio-Stipetum capillatae* showed a complete disappearance of macrofungi. The occurrence of the taxa studied by us at the plots uninfluenced by burning indicates the persistent, undisturbed type and the complex structure of the alliance *Sisymbrio-Stipetum capillatae* as well as the alliances *Festucetum pallentis* and *Koelerio-Festucetum rupicolae*. Therefore, the above taxa are of indicator value for these phytocoenoses. These species are: *Tulostoma kotlabae*, *T. melanocyclum*, *T. squamosum*, *Disciseda bovista*, *Gastrosporium simplex* and *Geastrum minimum*; (***ii***) further research into the occurrence of some species of fungi in the phytocoesnoses of the alliance *Festuco-Stipion* and *Seslerio-Festucion duriusculae* and outside them is needed to assess fully ecological requirements and to define their optimum; (***iii***) *Tulostoma kotlabae*, *T. melanocyclum*, *T. squamosum*, *Disciseda bovista*, *Gastrosporium simplex* and *Geastrum minimum* were statistically significant species. This may be indicative of special attachment of these fungi to the habitats of xerothermic vegetation examined by us; (***iv***) based on our research, we propose to accept *Tulostoma kotlabae*, *T. melanocyclum*, *T. squamosum*, *Disciseda bovista*, *Gastrosporium simplex* and *Geastrum minimum* as typical of Natura 2000 habitats (6210). The above species are associated with mature and undisturbed types of relict xerothermic communities such as *Sisymbrio-Stipetum capillatae* and *Festucetum pallentis*.

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