MYCOCOENOLOGY IN *ABIES ALBA* MILLER WOODS OF CENTRAL-SOUTHERN TUSCANY (ITALY)

ANGELA LAGANÀ, ELENA SALERNI, CARLA BARLUZZI
CLAUDIA PERINI AND VINCENZO DE DOMINICIS

Dip. Scienze Ambientali – Univ. degli Studi
Via P.A. Mattioli, 4 – I-53100 Siena (Italy)
Phone: +39 0577 232871; Fax: +39 0577 232860; e-mail: lagana@unisi.it

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ABSTRACT

Numerous reports indicate that fir woods in central and northern Europe have recently been damaged by increasing pollution. It has been demonstrated that fungi can be good bioindicators of forest health status. In polluted areas the production of fruit bodies generally declines and the fungal biodiversity, especially of symbiotic species, is reduced. Here we report the results of a survey of the fungal and plant communities in woods of *Abies alba* Miller in central-southern Tuscany, already studied in the past. Certain changes were observed in the study areas, but they seem more likely to be due to other factors than pollution, such as the weather conditions, the age and natural evolution of the forests towards their climax.

KEY WORDS: mycocoenology, fir woods, central Italy.

INTRODUCTION

Abies alba Miller has a vast fragmented distribution in Europe: it is found throughout the Alps and eastward, extends as far as the Dinarske, Balkans and Carpathian mountains. To the north, it is found in the Jura and Vosges. *A. alba* is found sporadically in the Pyrénées and in many small isolated stations along the Apennine range as far as Aspromonte (Bernetti 1987).

In the early 1970s, many specimens of *A. alba* began to decline in Bavaria and the Black Forest. By 1984, 84% of specimens in Germany showed some degree of damage. As the phenomenon spread to other parts of Europe and to other types of trees (both conifers and broadleafs), reference began to be made to damage of a new type, that involving not only vascular plants but also other components of forest ecosystems. The cause of this damage was identified as atmospheric pollution. In fact, forests are constantly exposed to mixtures of pollutants from ubiquitous sources (industry, towns, motorways). In Italy, the first signs of forest decline of the new type appeared towards the end of the 1970s, and regarded the Casentino fir forests (Bottacci et al. 1988).

Many studies carried out in various forest ecosystems in central and northern Europe (Arnolds, 1987; Schlechte 1987; Fellner 1993) have shown that in declining and degraded forests, the fungal component is also influenced. Jakucs (1988) and Arnolds (1991) demonstrated that the fungal community, especially ectomycorrhizal fungi, showed signs of damage 5-10 years before vascular plants.

It was therefore decided to monitor fungal communities in *A. alba* forests in the Mediterranean area. Four of the forest stands in which Perini et al. (1995) had already doné mycocoenological research between 1986 and 1989 were chosen, and the studies were repeated in the autumn of 1998. The aim of the study was to evaluate changes in the fungal community 10 years after the previous studies and to define their possible causes.

MATERIALS AND METHODS

The research was carried out in four fir woods (one natural and one artificial in the Nature Reserve of the Casentino Forests, stand 1 and stand 2; one natural and one artificial in the Pigelleto of Mt. Amiata, stand 3 and stand 4), chosen from those studied previously by Perini et al. (1995). Table 1 shows the main parameters of these forest stands.

The stations were surveyed once a month from August to December in 1998. All species of macrofungi (fungi that produce fruit bodies visible to the naked eye and which are greater than 1 mm in size; Arnolds 1981) were recorded and counted by standard methods (Arnolds, 1981; Jansen, 1981; Perini and Barluzzi 1987) during each survey. We did not consider hypogean basidiomycetes, or corticioids and poroids species with resupinate and pileate fruit bodies. The species were collected, dried and deposited in the Herbarium Universitatis Senensis (Siena). A summary of the results is shown in Table 2.

Nomenclature was used mostly according to Arnolds et al. (1995). Other sources (Kuhner and Romagnesi 1953; Bon 1980; Moser 1983; Julich 1989; Brandrud et al. 1990-1994; Courtecuisse and Duhem, 1994) were used for species not in-

TABLE 1. Information about the studied plots (pf = fine and coarse-grained Pietraforte sandstone, intercalated with silts and shales; ma = marnoso-arenacea formation, i.e. turbiditic sandstone alternating with grey marly-schist).

	St. 1	St. 2	St. 3	St. 4
Plot surface (sqm)	500	800	360	900
Altitude (m)	1210	1115	770	860
Slope (°)	12	3	15	2
Exposure	N	S	N	N
Geological substratum	ma	ma	pf	pf
Vegetation	natural fir	artif. fir	natural fir	artif. fir
Past tree cover (%)	60	70	90	70
Present tree cover (%)	70	70	100	70
Past shrub cover (%)	40	50	70	70
Present shrub cover (%)	30	25	50	65
Past herb cover (%)	60	70	20	10
Present herb cover (%)	60	80	40	25
Mean annual temperature (°C)	9°/11°	9°/11°	11°/13°	11°/13°
Maean annual rainfall (mm/year)	1250-2300	1250-2300	550-700	550-700
Latitude	43°48'38'' N	43°48'18'' N	47°43'35'' N	47°43'30'' N
Longitude	11°51'05'' E	11°51'45'' E	11°39'46'' E	11°39'24'' E

cluded in this list, indicated with an asterisk in Table 2. Abbreviations of authors names are from Brummitt and Powell (eds. 1992).

The abundance of each species was expressed as mDCv (maximum density of carpophores per visit) as proposed by Arnolds (1981). The letters in the first column of the table indicate the trophic group, mostly according to Arnolds et al. (1995). Two trophic groups or a question mark were given for species that was difficult to classify exactly.

Vascular plants were also surveyed again by the method of Braun-Blanquet (1964). Species nomenclature was according to Pignatti (1982). These data are still being processed.

Mychorrizal ratio (i.e. the percentage of mycorrhizal species with respect to number of macromycete species) was calculated in each stand for both the research periods; according to Fellner (1985, 1987) and Schlechte (1987, 1991), the mycorrhizal ratio is useful to evaluate forest health status.

Statistical analysis, involving Pearson's χ^2 and cluster analysis (performed with the programme PC SYNTAX), was carried out. The index

$d = 1 - s$,

where "s" is the Jaccard (1901) index, was used as dissimilarity measure and the mean link as clustering function.

RESULTS AND DISCUSSION

Phytosociological investigations in both study periods indicated changes in floristic composition, especially in the stands 2 and 4. *Fagus sylvatica* L. cover increased together with mesophilous and nemorose species (*Carex sylvatica* Hudson, *Melica uniflora* Retz., Salvia glutinosa L., *Senecio fuchsii* Gmelin, *Veronica montana* L., *Viola reichenbachiana* Jordan), while nitrophiles and ruderal species decreased (*Rubus hirtus* W. et K., *R. idaeus* L., *Urtica dioica* L.), especially at the stand 2. No relevant change was found at the stand 1.

The fungal species found in 1998 totalled 108 (Table 2) compared to the previous 193 species (Perini et al. 1995). This large difference was confirmed by the high value of the dissimilarity index (d = 0.74). However 1998 was climatically unfavourable for fungi, with severe summer drought delaying fruiting and penalizing species that fruit at the end of summer (only 9 species found in September). For example, in the Casentino stands, the mean summer temperature was 21.1°C in 1998 and 18.1°C in 1986; rainfall in the same period was 81.5 mm and 498.4 mm respectively.

Among the 108 species found in 1998 (Table 2), 63 had been reported by Perini et al. (1995), while 130 of the species reported by these authors were not found in the present studies. Forty five were species (written in bold character in table 2) found in 1998 but not in the previous period, i.e. *Cortinarius odorifer* and *Russula adulterina*, which Marchand (1971-1986) and Romagnesi (1967) cited as typical for montane coniferous forests. Other noteworthy species in this group were *Inocybe furfurea, I. griseolilacina, Lactarius ichoratus, L. mitissimus, Russula luteotacta* and *R. romellii*, which according to many authors are linked to broadleaf or more specifically to beech woods (Lisiewska 1963; Romagnesi 1967; Marchand 1971-1986; Stangl 1991; Sarnari 1998). An interesting case is *Xerula pudens*, regarded as thermophilous and xerophilous by Heinemann and Darimont (1956), Darmont (1973), Trendel and Carbiener (1975-1976-1977), but quite the contrary according to our observations. Most of the species found for the first time in 1998 have a broad ecological range, for example *Clitocybe nebularis, Cortinarius duracinus, C. rufoolivaceus, Entoloma rhodopolium, Hygrocybe virginea, Inocybe flocculosa, I. rimosa, Mycena rosea, Psilocybe fascicularis* and *Russula fragilis*.

Among the 130 species that used to be present at the study sites, but were not found in 1998, there are some of the mycorrhizal taxa cited as "declining" by Arnolds (1991) for The Netherlands: *Cortinarius erythrinus* (Fr.) Fr., *Hydnum repandum* L.: Fr., *Lactarius piperatus* (L.: Fr.) Pers. On the contrary, the symbiotic species *Cortinarius lividoochraceus, C. paleaceus, Hygrophorus pudorinus, Inocybe geophylla,* ecc., reported by the same author as "declining" or "extinct", were found in both research periods in Tuscan *A. alba* woods. Arnolds (1991) considered *Cantharellus cibarius* Fr.: Fr. as very sensitive to many anthropogenic factors, so probably suitable for myco-bioindication purposes; in Tuscan fir woods this fungus (present in the period 1986-1989 and not found in 1998) seems to be desappeared. Fellner (1989) selected as a bioindicator of air pollution in spruce forests *Russula mustelina* Fr., but this taxon was never found in the studied stands. The majority (79%) of the species present in the past and absent in 1998 in Tuscan fir woods are saprotrophs; so, the high number of taxa that seems to be disappeared in the study stands may depend on other factors than air pollution, that

TABLE 2. Synthesis of mycocoennological investigations performed once a month in 1998 in the four plots studied (TG = trophic group; M. = mycorrhizal species; Sh = humus decomposers; Sl = litter saprotrophs; Sw = lignin decomposers; P = parasites).

TG	SPECIES	St. 1	St. 2	St. 3	St. 4
M	*Lactarius salmonicolor* R. Heim & Leclair*	2	4	3	3
M	*Hygrophorus pudorinus* (Fr.: Fr.) Fr.	4	1	1	
M	*Inocybe geophylla* (Fr.: Fr.) P. Kumm. var. *lilacina* (Peck) Gillet	1	3	3	
M	*Laccaria amethystina* (Huds.--) Cooke	1	3	3	
M	*Laccaria laccata* s. l.	3	3		4
M	*Russula delica* Fr. ss. str.	1	2		3
Sw	*Pluteus cervinus* (Schaeff.) P. Kumm.	1	2		1
Sw(Sl)	*Galerina stylifera* (G. F. Atk.) A. H. Sm. & Singer	1		3	4
Sw	*Mycena vitilis* (Fr.) Quél.	1		4	1
Sl	*Mycena epipterygia* (Scop.: Fr.) Gray	2		1	1
M	*Inocybe geophylla* (Fr.: Fr.) P. Kumm.		4	4	3
M	*Cortinarius lividoochraceus* (Berk.) Berk.		2	3	3
Sl	*Mycena pura* (Pers.: Fr.) P. Kumm.		1	2	3
Sw	*Xerula melanotricha* Dörfelt*		2	2	2
M	***Russula fragilis* (Pers.: Fr.) Fr. ss. str.**		2	2	1
Sw	*Panellus mitis* (Pers.: Fr.) Singer	2	3		
Sw	*Xylaria hypoxylon* (L.: Fr.) Grev.	4		5	
Sl(Sw)	*Mycena leptocephala* (Pers.: Fr.) Gillet	2		2	
Sw(Sl)	***Tubaria hiemalis* Bon**	2		2	
M	*Inocybe fuscidula* Velen.		4	5	
M	*Cortinarius dionysae* Rob. Henry*		3	4	
M	*Russula chloroides* (Krombh.) Bres.		5	1	
M	*Cortinarius infractus* (Pers.: Fr.) Fr.		4	2	
M	***Inocybe flocculosa* (Berk--) Sacc.**		4	1	
M	***Russula urens* Romell.**		1	1	
Sw	*Pseudohydnum gelatinosum* (Scop.: Fr.) P. Karst.*	4			4
M	*Russula cyanoxantha* Schaeff.: Fr.	1			1
M	*Russula queletii* Fr. ss. str.		4		3
M	***Russula adulterina* Fr.**		1		1
Sh	*Mycena zephirus* (Fr.: Fr.) P. Kumm.			4	3
M	*Amanita phalloides* (Fr.: Fr.) Link			4	2
M	*Amanita rubescens* Pers.: Fr.			2	2
M	*Russula puellaris* Fr.			2	2
Sl	*Mycena galopus* (Pers.: Fr.) P. Kumm.			1	3
Sw	*Gymnopilus sapineus* (Fr.: Fr.) Maire	6			
Sw	*Psilocybe fascicularis* (Huds.: Fr.) Noordel.	6			
Sw	***Mycena epipterygia* (Scop.: Fr.) Gray var. *lignicola* A. H. Smith**	5			
Sw	*Calocera viscosa* (Pers.: Fr.) Fr.	3			
M	***Cortinarius cinnamomeus* (L.: Fr.) Fr. ss. str.**	3			
M	*Tricholoma saponaceum* (Fr.: Fr.) P. Kumm.	3			
M	***Boletus ferrugineus* Schaeff.**	2			
Sw	*Galerina badipes* (Fr.) Kuhner	2			
Sw	*Galerina marginata* (Batsch) Kühner ss. str.	2			
Sw	*Gerronema strombodes* (Berk. & Mont.) Singer*	2			
Sl	*Mycena aurantiomarginata* (Fr.: Fr.) Quél.	2			
M	***Russula albonigra* (Krombh.) Fr.**	2			
M	***Russula melliolens* Quél.**	2			
Sh	***Hygrocybe virginea* (Wulfen: Fr.) P. D. Orton & Watling**	1			
Sw(Sl)	*Psilocybe aeruginosa* (M. A. Curtis: Fr.) Noordel ss. str.	1			
M	***Cortinarius elegantior* Fr.***		5		
Sh(M)	***Clavulina rugosa* (Fr.) J. Schröt.**		4		
M	*Inocybe cervicolor* (Pers.) Quél.		4		
M	***Cortinarius rufoolivaceus* (Pers.: Fr.) Fr.***		3		
M	***Lactarius ichoratus* (Batsch) Fr.**		3		
Sl(P?)	*Collybia tuberosa* (Bull.: Fr.) P. Kumm.		2		
Sl	*Mycena sanguinolenta* (Alb. & Schwein.: Fr.) P. Kumm.		2		
Sw	***Xylaria longipes* Nitschke**		1		
Sw	*Bisporella citrina* (Batsch: Fr.) Korf & Carpenter			5	
Sh(M)	*Clavulina coralloides* (L.: Fr.) J. Schröt. ss. str.			5	
Sw	*Mycena erubescens* Höhn.			5	
M	***Inocybe furfurea* Kuhner**			4	
Sl	*Mycena rosea* (Bull.--) Gramberg			4	
Sl	***Clitocybe nebularis* (Batsch: Fr.) P. Kumm.**			3	
M	*Cortinarius trivialis* J. E. Lange			3	
Sh	***Entoloma hebes* (Romagn.) Trimbach**			3	
Sh(M?)	***Entoloma rhodopolium* (Fr.: Fr.) P. Kumm. ss. str.**			3	

TABLE 2. cont.

TG	SPECIES	St. 1	St. 2	St. 3	St. 4
Sh	***Entoloma serrulatum* (Fr.: Fr.) Hesler**			3	
M	*Hygrophorus discoxanthus* (Fr.) Rea			3	
M	***Lactarius mitissimus* (Fr.: Fr.) Fr.**			3	
Sl/**Sw**	*Mycena pelianthina* (Fr.: Fr.) Quél.			3	
Sw(P?)	*Xerula radicata* (Relhan: Fr.) Dörfelt			3	
M	***Amanita pantherina* (DC.: Fr.) Krombh.**			2	
Sl	*Clitocybe fragrans* (With.: Fr.) P. Kumm.			2	
Sl	*Collybia butyracea* (Bull.: Fr.) P. Kumm.			2	
M	***Cortinarius aleuriosmus* R. Maire***			2	
M	***Cortinarius bulliardi* (Pers.: Fr.) Fr.**			2	
M	***Cortinarius dibaphus* Fr. var. *nemoreus* Rob. Henry***			2	
M	***Cortinarius duracinus* Fr.**			2	
M	***Cortinarius odorifer* Britzelm.***			2	
M	*Cortinarius paleaceus* Fr. ss. str.			2	
Sl(Sw)	***Mycena abramsii* (Murrill) Murrill**			2	
Sw	*Mycena crocata* (Schrad.: Fr.) P. Kumm.			2	
M	***Russula olivacea* (Schaeff.) Pers.**			2	
M	***Inocybe griseolilacina* J. E. Lange**			1	
M	***Inocybe rimosa* (Bull.: Fr.) P. Kumm.**			1	
M	*Lactarius chrysorrheus* Fr.			1	
M	***Lactarius subumbonatus* Lindgr.***			1	
Sh	*Lyophyllum deliberatum* (Britzelm.) Kreisel			1	
Sl	*Mycena sepia* J. E. Lange			1	
M?	***Ramaria* cfr. *formosa***			1	
M	***Russula luteotacta* Rea**			1	
M	***Russula romellii* Maire**			1	
Sw(P?)	***Xerula pudens* (Pers.) Singer**			1	
Sl	*Clitocybe trullaeformis* (Fr.: Fr.) Quél.				5
M	*Russula nigricans* (Bull.--) Fr.				5
M	***Cortinarius* cfr. *brunneus* (Pers.: Fr.) Fr. var. *glandicolor* (Fr.: Fr.) Lindstrom & Melot**				4
M	***Amanita gemmata* (Fr.) Bertillon**				3
Sh	*Lycoperdon* cfr. *perlatum*				2
M	*Boletus chrysentheron* (Bull.) ss. str.				1
M	***Cantharellus tubaeformis* Fr.: Fr.**				1
Sl	*Collybia erythropus* (Pers.: Fr.) P. Kumm.				1
M	***Cortinarius cristallinus* Fr. ss. str.**				1
M	***Cortinarius malicorius* Fr.***				1
M	*Inocybe assimilata* (Britzelm.) Sacc.				1
M	***Inocybe* cfr. *pseudoasterospora* Kuhner & Bours.**				1
Sw	*Megacollybia platyphylla* (Pers.: Fr.) Kotl. & Pouzar				1
Sh(Sw)	***Psathyrella multipedata* (Peck) A. H. Sm.**				1
M	***Russula violeipes* Quél. fm. citrina Quél.**				1

usually affects the mycorrhizal component of mycocoenoses (Schlechte 1987; Arnolds 1987, 1991; Fellner 1993). Moreover, the lack of fruit bodies of fungi does not mean that species are not present at the study site; some species, infact, do not produce the fruit bodies every year (Arnolds 1995).

Figures 1a and 1b present the percentage of each trophic group recorded in the two study periods (1986-1989 and 1998). Our results showed considerable differences. The percentage of mycorrhizal species increased with respect to all niche substrate groups of saprotrophs, except in the stand 1 where lignin decomposers taxa were more numerous in 1998 than in the previous period. When testing for statistically significant differences between the two study periods, we used the number of species belonging to each trophic group, rather than the percentages. The changes were significant only for the stands 1 and 2, both in the Nature Reserve of the Casentino Forests: for station 1, Pearson's $\chi^2 = 8.93$, $p<0.05$ (significant) and for station 2 $\chi^2 = 16.13$, $p<0.01$ (very significant).

Figures 2a and 2b show the dendrograms for the four stands in the two study periods. An evident change was found: in the period 1986-89 two main clusters corresponding to the two areas (Casentino and Mt. Amiata) were present, whereas the similarity in 1998 was between the artificial forests (st. 2 and 4), and to a lower degree with the natural fir forest of Mt. Amiata (station 3) and last of all stand 1.

CONCLUSIONS

The present results indicate that in the 10-year period since the research of Perini et al. (1995), the stations have undergone changes in vegetation, type and number of fungal species, frequency of the different trophic groups and mutual relations.

The high percentage of mycorrhizal species found in the stations suggests that the forests are in good health (Fellner 1985, 1987; Schlechte 1987, 1991). These authors regard the mycorrhizal ratio as an index of pollution: in unpolluted areas it ranges from 40-60%, in moderately polluted areas from 20-40% and in situations of lethal disturbance it is less than

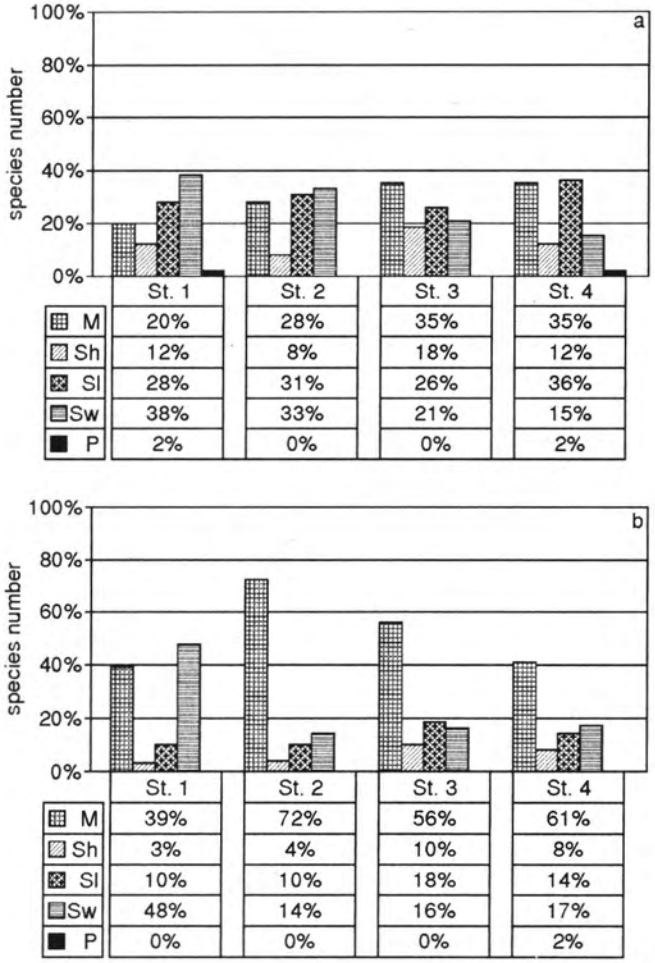

Fig. 1. Proportion of trophic groups in the four stands in the two periods of study (1a: 1986-89; 1b: 1998) (M = mycorrhizal species; Sh = saprotrophs on humus; Sl = saprotrophs on litter; Sw = saprotrophs on wood; P = parasites). Test for statistically significant differences between the two study periods (using the number of species belonging to each trophic group): stand 1 $\chi^2 = 8.93$, $p<0.05$; stand 2 $\chi^2 = 16.13$, $p<0.01$; stand 3 = NS; stand 4 = NS.

20%. In all stations this ratio was greater than 40%, the only exception being station 1 in which it was only slightly below 40%. According to this ratio, the health of these forests has improved since the previous study period. Statistical analysis confirmed that, at least in stations 1 and 2, the recorded changes were significant.

A partial explanation of these changes is based on climate. The summer of 1998 was much hotter and drier than the previous study period. This may be why many saprotrophs that normally fruit in September were absent. Another factor is the natural evolution of the forests. The phytosociological relevés showed considerable changes in floristic composition between the two periods, especially in station 2. The fact that the beech cover increased could have affected the mycorrhizal component, as suggested by the finding of many species typically linked to broadleaf forests, or specifically beeches, in 1998.

The results available so far suggest that the changes recorded can be ascribed more to the normal evolution of the forests, especially the artificial ones which tend to "naturalize", than to pollution.

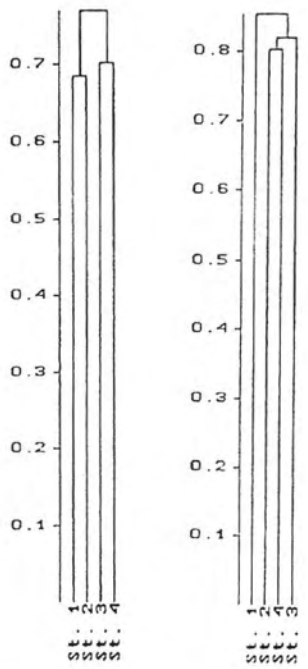

Fig. 2. Results of cluster analysis. 2a refers to Perini et al. (1995); 2b refers to 1998 investigations. d = 1 – s (where "s" is the Jaccard, 1901 index) was used as dissimilarity index, and the mean link was used as clustering function.

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MIKOCENOLOGIA W BORACH JODŁOWYCH W POŁUDNIOWEJ CZĘŚCI ŚRODKOWEJ TOKSANII (WŁOCHY)

STRESZCZENIE

Z licznych doniesień wynika, że bory jodłowe w środkowej i północnej Europie uległy ostatnio zniszczeniu na skutek narastających zanieczyszczeń środowiska. Stwierdzono, że grzyby mogą być dobrymi bioindykatorami stanu zdrowotnego lasów. Produkcja owocników w obszarach zanieczyszczonych na ogół się zmniejsza a bioróżnorodność grzybów, w szczególności gatunków symbiotycznych, ulega redukcji. Niniejsza praca prezentuje wyniki badań zbiorowisk grzybów i roślin w badanych już w przeszłości borach jodłowych w południowej części środkowej Toksanii. W badanych obszarach zaobserwowano też pewne zmiany nie spowodowane czynnikami antropogenicznymi, ale wywołane warunkami klimatycznymi, wiekiem oraz zmierzającą do klimaksu naturalną sukcesją lasów.

SŁOWA KLUCZOWE: mikocenologia, bory jodłowe, Włochy Środkowe.