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Influence of forest age on fungal trophic groups in different forest ecosystems (Tuscany – Italy)

A. LAGANÀ, V. DE DOMINICIS & C. PERINI*

Dip. Sc. Ambientali "G. Sarfatti", Univ. degli Studi,
Via P.A. Mattioli 4
53100 Siena (Italy)
° Via Sansedoni 9, 53100 Siena (Italy)

Summary – The results of research into the effect of forest age on macrofungal trophic groups are reported for various types of Mediterranean forest ecosystems in Tuscany (Italy). The research was conducted in two periods: mycocoenological surveys were performed in the study areas since the '70es by some of the authors of this paper, and after 10-20 years were repeated in the same plots. Statistical analysis demonstrate that the number and especially the percentage of symbiont taxa are negatively correlated with forest age, while the number and the percentage of lignicolous saprotrophic taxa are positively correlated with this parameter. A significant negative correlation was also found between forest age and percentage, but not number, of humicolous saprotrophs.

Epigeous macromycetes / mycorrhizal / lignicolous / correlations / Tuscany (Italy)

INTRODUCTION

Many studies (Dighton & Mason, 1985; Hintikka, 1988; Jansen, 1991; Keizer & Arnolds, 1994; Mason *et al.*, 1987; Ricek, 1981) have shown that forest age influences the composition of the fungal community, especially symbionts, and community changes occurring in time. However, only few of these studies were based on statistical analysis. Clearly, forest age is not the only parameter that determines the mechanisms of succession of fungal communities in a forest; others include soil composition, land use, composition of autotrophic communities, etc.

Studies conducted in central Europe (Fellner, 1993; Schlechte, 1987; 1991) indicate that the percentage of mycorrhizal fungi with respect to total macrofungi present in a forest is correlated with forest health status: in an attempt to give a measure of this dependence, they indicate a sort of "forest health status categories", i.e. percentage is greater than 40% in unpolluted areas, 20-40% in areas with acute disturbance, and less than 20% in areas with lethal disturbance of forest ecotrophic stability. According to Fellner (1993), the number of lignicolous taxa increases significantly in polluted areas. Laganà *et al.* (1999) showed that this relation cannot be readily generalised beyond the area in which it was observed, and that the number of taxa in the various trophic groups in a given area is also correlated with other parameters.

* Corresponding author: phone: +39 0577 232871; fax: +39 0577 232860; e-mail: lagana@unisi.it

These considerations prompted the present research, in which relations between macrofungi and forest age are analysed and demonstrated statistically in various types of forest ecosystems in southern Tuscany, in order to assess the influence of forest age on the richness of taxa in the various trophic groups, at least in this area.

MATERIALS AND METHODS

The present study is part of a project to evaluate changes in these forest ecosystems over a 10-20-year period (Laganà *et al.*, 1999; 2000a; 2000b; unpublished); so, the data on epigeous macrofungi and forest age, considered for the various forest communities (inland and coastland evergreen oak woods, natural and planted fir woods, chestnut coppices), belong to two study periods. Mycocoenological research were carried out in these and other woods since the last '70es by some of the authors of this paper; for details see tab. 1 and related publications: De Dominicis & Barluzzi (1983), Perini *et al.* (1989), Barluzzi *et al.* (1992), Perini *et al.* (1995). Observations were repeated in the period 1999-2000 in 11 permanent plots of variable size. No or only sporadic surveys were performed in these plots in the period between the two researches.

All plots are in forest ecosystems of Tuscany; fig. 1 is a map showing the study areas, while tab. 1 gives certain details of each permanent plot.

As far as possible, reference was made to the literature (Perini *et al.*, 1989) to determine the age of the forest communities investigated in the past. As far as possible, informations on forest management were acquired from public and private owners. With regard to present age, the study areas were visited in spring 1999 to measure the age of plants on site. In conifer woods, cores were obtained for growth ring count from trunks of several specimens of *Abies alba* Miller (one per plant) using a Presler drill; for broadleafs, a few specimens were cut down and growth rings counted in the stump.

Data on macrofungi was gathered during monthly surveys (January 1998-December 1999); during each excursion, the fungal species fruiting and the number of carpophores found were recorded. Exsiccata are in the *Herbarium Universitatis Senensis* (SIENA). Assignment of the species found to trophic groups (M = mycorrhizal; Sh = humicolous saprotrophs; Sl = litter saprotrophs; Sw = lignicolous saprotrophs; Sc = coprophiles; Li = lichenized; P = parasites) was based on Arnolds *et al.* (1995); for taxa not considered in that work the authors used more recent texts and monographs or personal observations. In addition, data on vegetational composition, soil parameters, lichen communities were acquired (Laganà *et al.*, 1999; 2000b; 2002a; 2002b; 2002c).

Statistical analysis of the forest age and macrofungi data involved calculation of the Pearson product moment coefficient and Pearson's chi-square by means of the programme STATISTICA 5.0 (StatSoft Inc., 1997). Data for parasites, coprophiles and lichenized macromycetes (i.e. some *Omphalina* spp.) was not considered because few, if any, species belonging to these trophic groups were found in the plots.

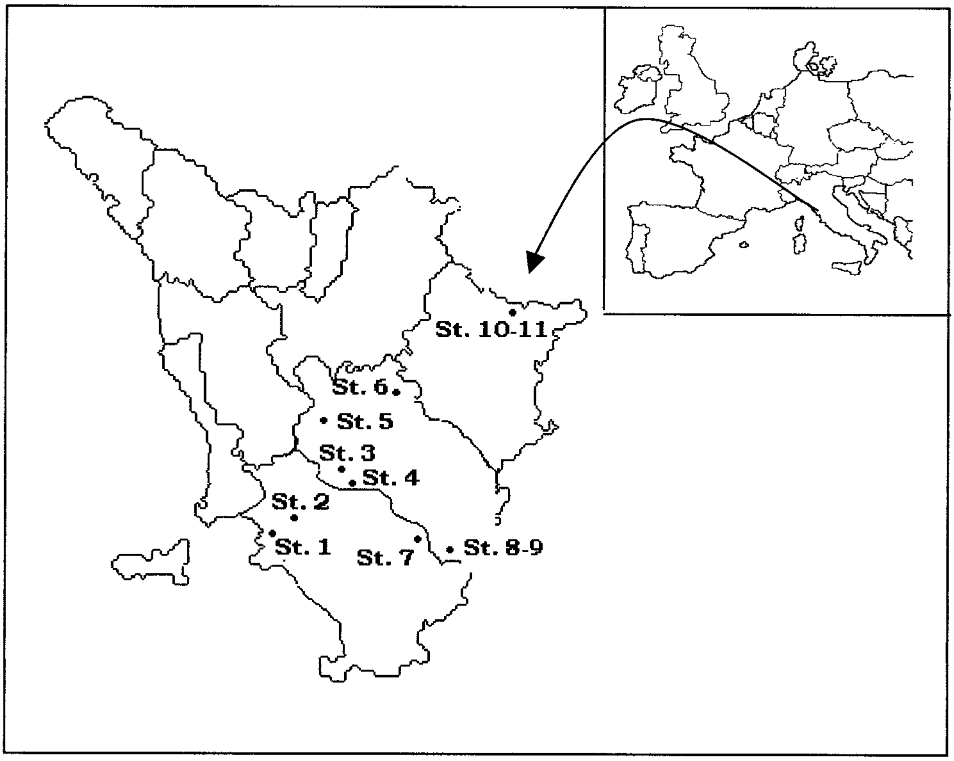


Fig. 1. Map showing the study areas (stt. 1 and 2 → evergreen oak woods along the Maremma coastline; stt. 3 and 4 → evergreen oak woods in the inland hills; stt. 5, 6 and 7 → chestnut coppices; stt. 8 and 9 → fir woods of Mt. Amiata; stt. 10 and 11 → fir woods in the Foreste Casentinesi Natural Park).

RESULTS AND DISCUSSION

In table 1 forest age results are shown. In both the research periods, the youngest woods were evergreen oak woods of the Siena hills (plots 3 and 4) and chestnut woods (plots 5, 6 and 7). The oldest were those of the Casentino Forest Park (plots 10 and 11). Age differences between the forests in the two study periods, recorded for each plot, generally coincided with the number of years between observations; the only exceptions were plots 3 and 7, an inland evergreen oak wood and a chestnut coppice. Information obtained from owners indicated that these plots had been regularly coppiced, more or less with the frequency established by forestry regulations. The other woods, both conifer and broadleaf, had not been cut; with regard to broadleaf woods, plot 1 is programmed for tall tree cover, whereas plots 2, 4, 5 and 6 are long overdue for coppicing.

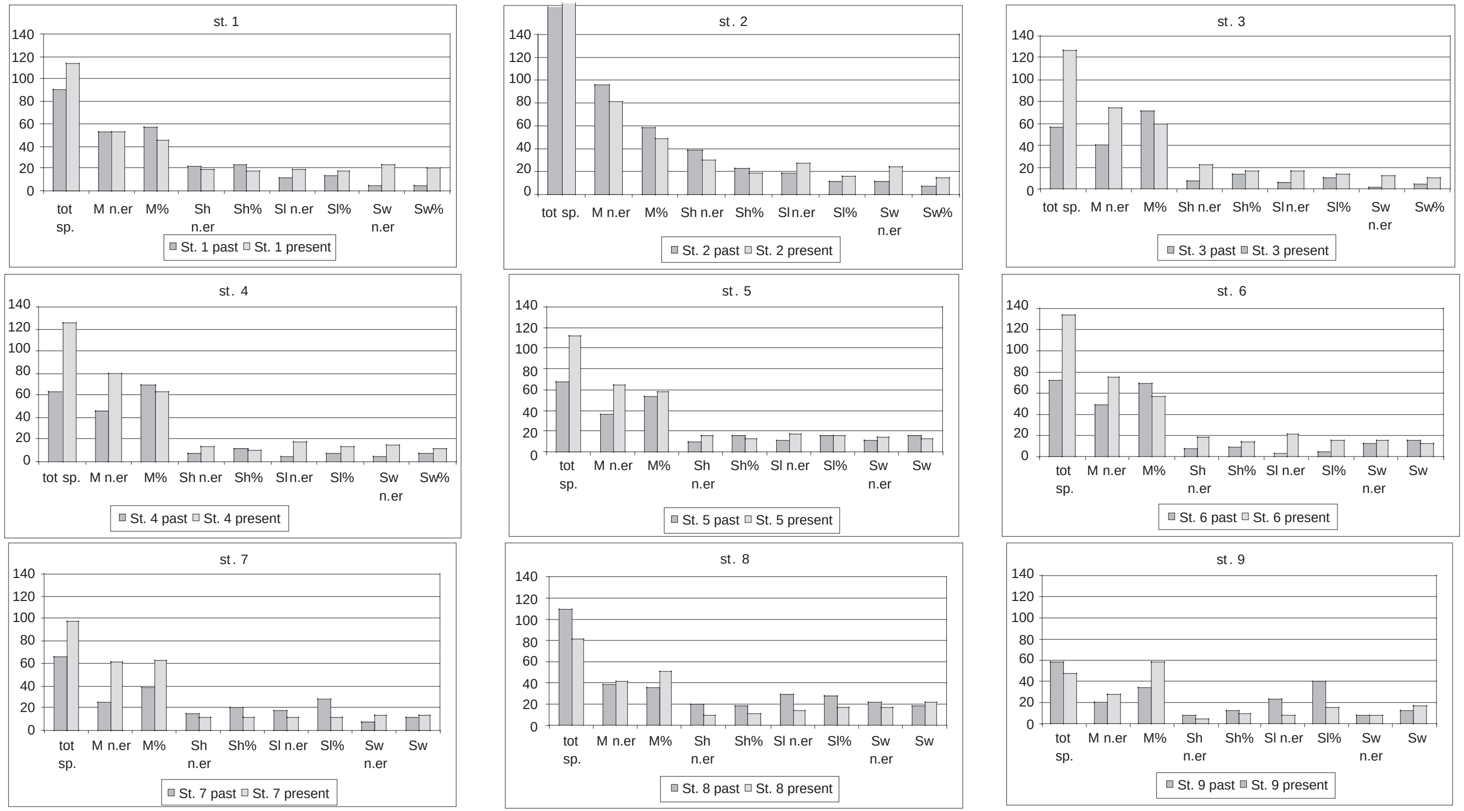
Figure 2 shows the total number of fungal species found in each plot and the number/percentage of taxa belonging to each trophic group in the two study periods. According to the criteria proposed by Fellner (1993) and Schlechte (1987;

Table 1. Summary of stational and ecological data in each permanent plot (st. dim. = plot size; alt. = altitude; exp. = exposure; geol. subs. = geological substrate; AR = annual rainfall; MAT = mean annual temperature; dts = dominant tree specie; s = sandstone; cc = "calcare cavernoso" (limestone); cp = polygenic conglomerates; sc = polychromes sericitic schists; v = "verruvano (pebbles and red soils); pf = "Pietraforte" sandstone; ma = "Palombini-like" limestone and "Pietraforte" sandstone; Qi = *Quercus ilex*; Cs = *Castanea sativa*; Aa = *Abies alba*).

	st. dim. (sqm.)	*alt. (m)*	*exp.*	*slope (°)*	*geol. subs.*	*AR (mm)*	*MAT (°C)*	*dts*	*study period*	*past age*	*present age*
St. 1	2000	5	WNW	5	s	655	15.7	*Qi*	*1981-84*	28	46
St. 2	2000	150	S	10	s	821	13.3	*Qi*	*1981-84*	28	46
St. 3	2000	210	NE	15	cc	1036	14.3	*Qi*	*1977-79*	15	20
St. 4	2000	275	N	5	cp	927	13.6	*Qi*	*1977-79*	18	40
St. 5	2000	525	NNE	5	sc	952	14.1	*Cs*	*1979-82*	10	30
St. 6	2000	550	NE	15	s	845	14.2	*Cs*	*1979-82*	16	36
St. 7	2000	870	W	5	v	1002	12.5	*Cs*	*1979-82*	16	15
St. 8	360	770	N	15	pf	1270	11.3	*Aa*	*1986-89*	50	63
St. 9	900	860	N	2	pf	1270	11.3	*Aa*	*1986-89*	50	63
St. 10	800	1115	S	3	ma	1701	8.2	*Aa*	*1986-89*	72	85
St. 11	500	1210	N	12	ma	1701	8.2	*Aa*	*1986-89*	97	110

1991), forest health is currently good, since the percentage of mycorrhizal species was over 40% in most plots. The percentages of species in the different trophic groups recorded in each plot in the two study periods were quite different in some cases; Pearson's chi-square demonstrated that some differences were statistically significant (M $\chi^2 = 27.93$, $p < 0.01$; Sh $\chi^2 = 24.19$, p < ; Sl $\chi^2 = 61.13$, $p < 0.001$; Sw $\chi^2 = 31.92$, $p < 0.001$). According to the criteria of Fellner and Schlechte, the status of these forests has changed considerably in recent years, even if only in a few cases a real change in "health status categories" can be observed. For example plots 8-11 seems to be in a better condition actually in respect to past; in line with Fellner and Schlechte, the high mycorrhizal percentage (more than 40%) registered during the present researches could be considered as an indication for a good forest health status and a low impact of contaminants, while the low mycorrhizal ratio (< 40%) resulting from past studies seems to indicate acute disturbance of forest ectotrophic stability. This is quite strange, expecially for stt. 10 and 11 that are in a nature reserve with low human impact; however, at the beginning of 1998 we visited these plots to determine whether their appearance and their general status had changed since the mycocoenological studies 10 years before. Following the standards of Ferretti (1994), based on the analysis of tree crown conditions (tree defoliation percentage), the forests appeared to be much the same as before (similar tree defoliation percentage), which would be highly unlikely if the area was really exposed to contaminants.

In an attempt to find an explanation for the detected changes in the proportion of fungal trophic groups, the data was analysed with forest age data, in order to assess if this parameter could have an influence on the trophic categories proportion; the relevance of other parameters was stated in other papers: for



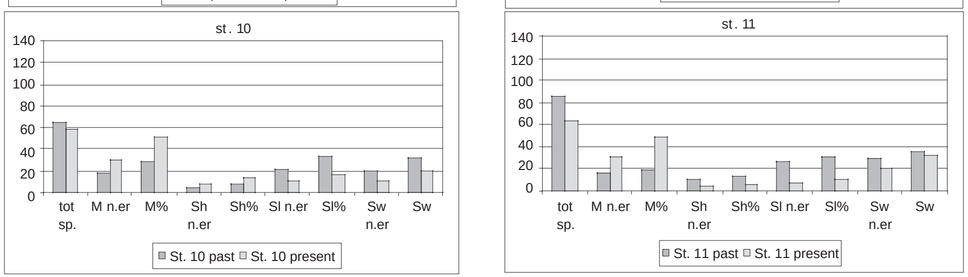


Fig. 2. Number of total species, number and percentage of taxa belonging to each considered trophic groups (M = mycorrhizal; Sh = saprotrophe on humus; Sl = saprotrophe on litter; Sw = saprotrophe on wood) for the two study periods in each studied plots.

altitude see Laganà *et al*. (1999), for soil pH and composition Laganà *et al*. (2002a), for temporal changes Laganà *et al*. (2002b), for climate Salerni *et al*. (2002).

The number and especially percentage of symbiont taxa were found to have statistically significant negative correlations with forest age ($r = -0.45$, $p < 0.05$; $r = -0.59$, $p < 0.01$, respectively); on the other hand, the number and percentage of lignicolous saprotrophs showed a significant positive correlation with forest age ($r = 0.60$, $p < 0.01$; $r = 0.83$, $p < 0.001$ respectively). A significant negative correlation was also found between forest age and percentage, but not number, of humicolous saprotrophs ($r = -0.45$, $p < 0.05$).

As mentioned in the introduction, much literature exists on the influence of forest age on fungal communities. In forests dominated by *Pinus sylvestris* L. in Finland, Hintikka (1988) found that the number of mycorrhizal species was low in young stands (5-15 years), increased in forests with ages of 20-30 years and decreased gradually in older stands. Ricek (1981) reported a similar trend in forests of *Picea abies* in Germany: an increase in the number of symbionts up to 20-25 years and a decrease in older forests. Jansen (1991) reported a similar pattern of mycorrhizal diversity in plantations of *Pseudotsuga menziesii* in Holland; unlike the previous authors, she found a decrease beginning after only 20 years. Dighton & Mason (1985) proposed a model of succession for the ectomycorrhizal component, showing an increase in species diversity up to canopy closure, followed by a rapid decline. Keizer & Arnolds (1994) studied roadside verges in Holland and reported a positive correlation between the number of symbiont taxa and the age of single trees with which they were linked. They found that the course of succession was not uniform in different habitats and that the most common process in forests was probably a sharp increase in mycorrhizal species richness in the first 30-40 years, followed by a more gradual decline during ageing. With regard to the relation between lignicolous macrofungi and plant age, Arnolds (1987) reported that forest ageing certainly contributes to an increase in fungi that grow on wood. The results obtained in the course of the present study are in line with the above, though obtained in forest ecosystems different from those studied by most of the European authors mentioned. We observed an increase in the number and percentage of mycorrhizal species in young (0-20 years) to intermediate forests, followed by a large reduction in forests older than 40 years of age. We found that lignicolous saprotrophs increased with increasing forest age. It could be interesting to count mycorrhizal root tips in order to evaluate real correspondence between belowground and aboveground situation; however, as reported by Jansen & De Nie (1988), Kottke & Agerer (1983), Arnolds (1991) positive correlations exists between the abundance of sporocarps and the proportion of mycorrhizas.

The here reported results, added to the ones in Laganà *et al*. (1999), Laganà *et al*. (2002a ; 2002b) and Salerni *et al*. (2002), are useful for understanding the mechanisms influencing the composition of fungal communities and their changes in time, at least in the studied area; the percentage (and number) of lignicolous species, and to a greater extent fruiting symbionts, has now been demonstrated to depend on forest age.

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