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Seasonal fruit body production of macrofungi in Mediterranean vegetation

Abstract

Perini, C., Barluzzi, C. & De Dominicis, V.: Seasonal fruit body production of macrofungi in Mediterranean vegetation. – Bocconea 5: 359-373. 1996. – ISSN 1120-4060.

The fluctuation of macrofungal production in mediterranean vegetation types such as juniper scrub and evergreen oak woods has been studied. The fruiting period is concentrated in the autumn months. A general critical low in summer is due to drought. By comparison, submediterranean vegetation such as chestnut coppices show a second critical low in winter, due to harsh temperatures.

Introduction

Fungi are dependent on green plants but are in turn necessary for the existence and functioning of phytocoenoses. They are essential components of the ecosystem and very closely reflect its state. Furthermore, fungi indicate local factors more sensitively than plants, and can serve to reveal imminent ecosystem changes. For instance, many ectomycorrhizal species are good indicators of air pollution (Fellner 1989; Arnolds 1992). Nevertheless, knowledge of the relationship between fungal communities and their environment is still very scanty.

The first efforts date back to the end of the 19th Century when Henning (1888) in Sweden and Brinkmann (1897) in Germany published notes on fungal relations to vascular plants. Many others followed, listing fungal species in the context of specific phytocoenoses. Haas (1932) began a systematic study of mycocoenoses, with accurate observation of the various environmental parameters. A few years later Leischner-Siska (1939), in agreement with Lange (1923), concluded that areas rich in fungi are poor in floristic composition, and that fungi are more sensitive to ecological variations than phanerogams. The study of the ecology and sociology of macrofungi has considerably developed since the early fifties, and several traditions have developed: the phytosociological school of Tüxen focused on the role of fungi in different vegetation types (Jahn & al. 1967; Pirk & Tüxen 1957), while the Belgian Darimont (1973) analysed uniform

microhabitats inside a specific vegetation, and Barkman (1973, 1976) in the Netherlands discussed the fungal communities of a given vegetation from a phytocoenological point of view. From the seventies onward, numerous mycocoenological research projects were carried out in different European countries, e.g. by Lisiewska (1974) and Bujakievicz (1981, 1982a, b) in Poland, Bohus & Babos (1973) in Hungary, Smarda (1973) in Czechoslovakia, Bon & Géhu (1973) in France, Losa Quintana (1974), Garcia Pérez & al. (1982) and Honrubia & al. (1982) in Spain, Jansen (1981) and Arnolds (1981, 1982) in Holland.

As in the rest of Europe, mycocoenological research in Italy started about the end of the seventies. For the past 15 years our Department has studied some of the most important vegetational aspects of central southern Tuscany. Mycocoenological research points out the qualitative and quantitative composition of the fungal community of a specific phytocoenosis. The data obtained pertain not only to the fungal flora but also to the autoecology of species. Since macrofungi are fugacious and influenced by climatic conditions, observations must be made monthly and through several (2-4) years before more or less complete results are obtained.

This paper will examine the fluctuation of fungal production in mediterranean vegetation, such as juniper scrub and evergreen oak woods, and aims at pointing out the existence of different patterns in similar situations.

Methods

The data here presented are the result of mycocoenological research, limited to macrofungi, carried out in evergreen oak woods in the inland (De Dominicis & Barluzzi 1983), in the coastal region (Perini & al. 1989), in chestnut coppices (Barluzzi & al. 1992), and in juniper scrub on sandy dunes (in progress).

The climatic data of Siena, Grosseto, and Cotorniano (Siena) published by the Ministero Lavori Pubblici (Anonymous 1951-1980) are presented graphically according to the model of Walter & Lieth (1960).

Permanent plots, homogeneous from the point of view of their vegetation and other environmental parameters (exposure, geology, etc.), were selected for each vegetation type. The number of fruit bodies of each species was counted or estimated during each survey, for several years. The observed number is extrapolated to a standard area size (in our case 1000 m^2) in order to enable comparison of plots of different sizes. For further information on the mycocoenological methods used, see Barluzzi & al. (1992).

The number of species observed and the approximate number of fruit bodies collected in the various types of vegetation are graphically presented. The approximate number of fruit bodies has been calculated by an ordinal transformation of the density value according to Arnolds (1981).

The fungal species have been subdivided into three functional groups on the basis of life strategy (Trappe 1962; Arnolds 1984, 1985, 1988; Derbsch & Schmitt 1987): ectomycorrhizal, saprotrophic, and facultative parasites. The saprotrophic fungi have again been subdivided according to their substrate preference into three groups (Arnolds 1988): those growing on humus, on litter, and on wood. Litter fungi also include species growing on mosses, on dung, and on twigs less than 1 cm in diameter.

Climatic data

For a general description of the climatic conditions of the areas studied, thermo-pluviometric diagrams of Grosseto (8 m a.s.l.), Siena (369 m a.s.l.), and Cotorniano (530 m a.s.l.) are provided (Fig. 1). The Grosseto diagram shows a marked summer drought, and temperature peaks in July and August, with a monthly average around 23°C. High rainfall coincides with the coolest months; the highest monthly precipitation average is registered in November, with 93.8 mm. Autumn and winter are mild, and the average temperature never falls below 7.5°C.

As one moves inland and reaches higher levels (Siena and Cotorniano, respectively) summers become milder and winters harsher. Summer drought gradually decreases: from May to August in Grosseto, while it is limited to the month of July in Cotorniano.

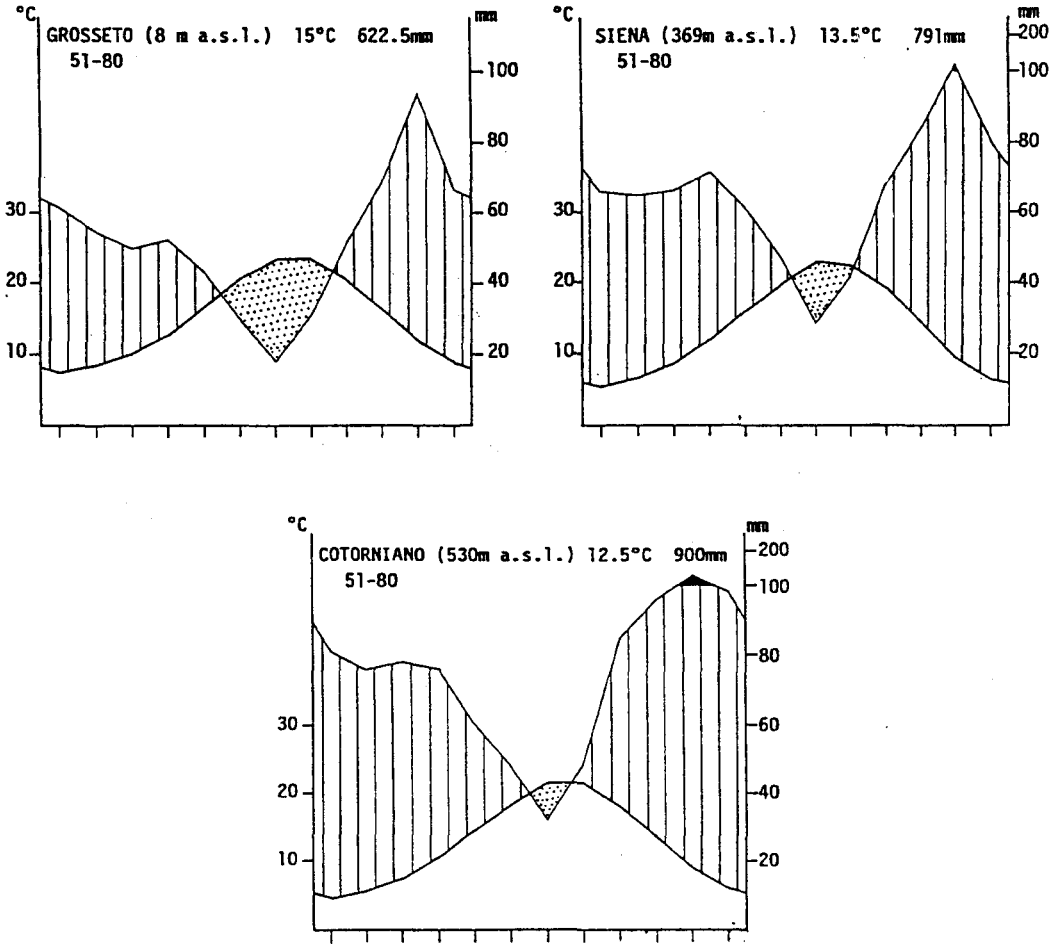

Fig. 1. Thermo-pluviometric diagrams of Grosseto, Siena, and Cotorniano.

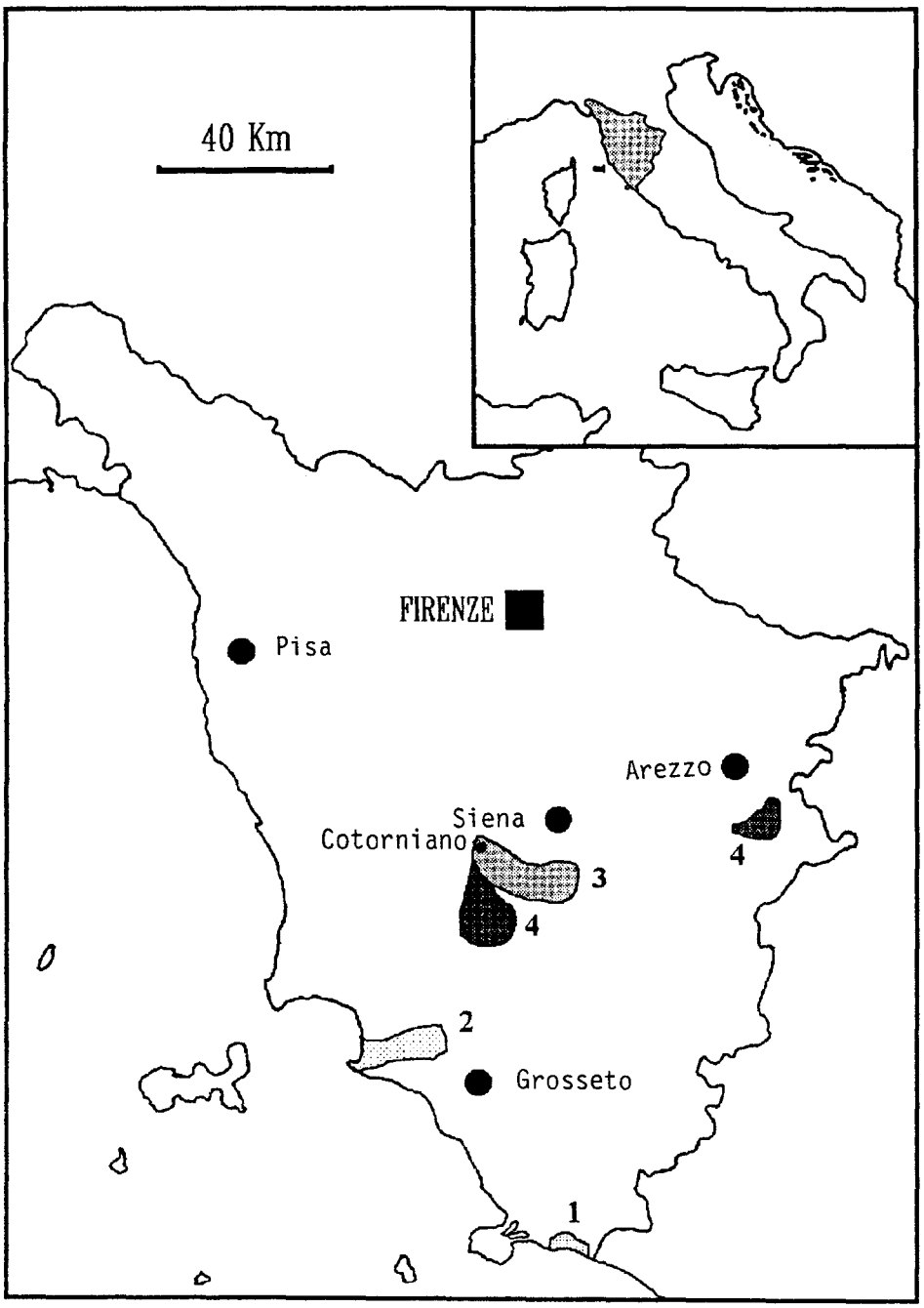

Fig. 2. Map of the areas studied, indicating the main vegetation communities: **1**, juniper scrub; **2**, evergreen oak woods of the Maremma coast; **3**, evergreen oak woods of the Siena hills; **4**, chestnut coppices.

Rainfall, concentrated on autumn and peaking in November, increases on the whole: the annual average is 622 mm in Grosseto, 791 mm in Siena, and 900 mm in Cotorniano.

The typical mediterranean climate of the coast is favourable to evergreen sclerophyll growth; the submediterranean climate, which becomes almost continental on the higher hills, is suitable for broad-leaved deciduous forests; transitional conditions occur on the lower hills.

Observations

Juniper scrub on sandy dunes

A vegetation type in which junipers (*Juniperus phoenicea* L., *J. oxycedrus* subsp. *macrocarpa* (Sm.) Ball) predominate develops on sandy dunes along the coast. Eight plots were chosen between the Tyrrhenian sea and Lake Burano (c. 50 km S. of Grosseto; Fig. 2). According to Pedrotti & al. (1975, 1979), and Pedrotti & Cortini Pedrotti (1976), four of them belong to the *Juniperetum macrocarpae-phoeniceae* Pedrotti & Cortini Pedrotti 1976, the other four to the *Oleo-Lentiscetum* Horvat 1974.

The thermo-pluviometric diagram of Grosseto (Fig. 1) illustrates the climate of this area; indeed, the temperature and drought are very pronounced, as evidenced by the diagram.

The mycocoenological study of the juniper plots (about 900 m^2) is still in progress. 94 fungal species were noted from January 1988 to December 1991. As shown in the histogram of the species number of macrofungi (Fig. 3A), fruit body production starts with 35 species in October, peaks in the following month (71 species), regresses to its initial value in December, then steadily decreases from January to June when only two species were found (*Geaster pseudolimbatum* Hollós and *Xerocomus chrysenteron* (Bull.) Quél.). No macrofungi were noticed during the three summer months. For the approximate number of fruit bodies (Fig. 3B) the pattern is slightly different: production is high, with more than 10,000 fruit bodies, from October to January, then suddenly drops in February to less than 1000. The high numbers are mostly due to two small litter species, *Marasmius androsaceus* (L. : Fr.) Fr. and *Hemimycena delicatella* (Peck) Singer, and one lignicolous species, *Mycena meliigena* (Berk. & Cooke) Sacc.

Evergreen oak woods of the coastal region

Five plots (10,000 m^2) of *Quercus ilex* L. woods were studied (Perini & al. 1989) along the rocky coast and the hills facing the Gulf of Follonica N. of Grosseto (Fig. 2). These woods, belonging to the *Viburno-Quercetum ilicis* Rivas-Martínez 1975 subass. *ornetosum* Allier & Lacoste 1980, are situated altitudes ranging from 20 m to 250 m a.s.l., and at a distance of 50 m to 11 km from the sea. Again, the diagram for Grosseto (Fig. 1) is illustrative of the climate. 309 fungal species were noted from November 1981 to October 1984. As pointed out in a previous paper (Perini & al. 1993), many of them had previously been reported from mediterranean areas of Spain, France, and Morocco, and some are linked to xerothermic evergreen oak woods, e.g. *Clavariadelphus flavoimmaturus* R. H. Petersen, *Hymenoscyphus fructigenus* (Bull.) Gray,

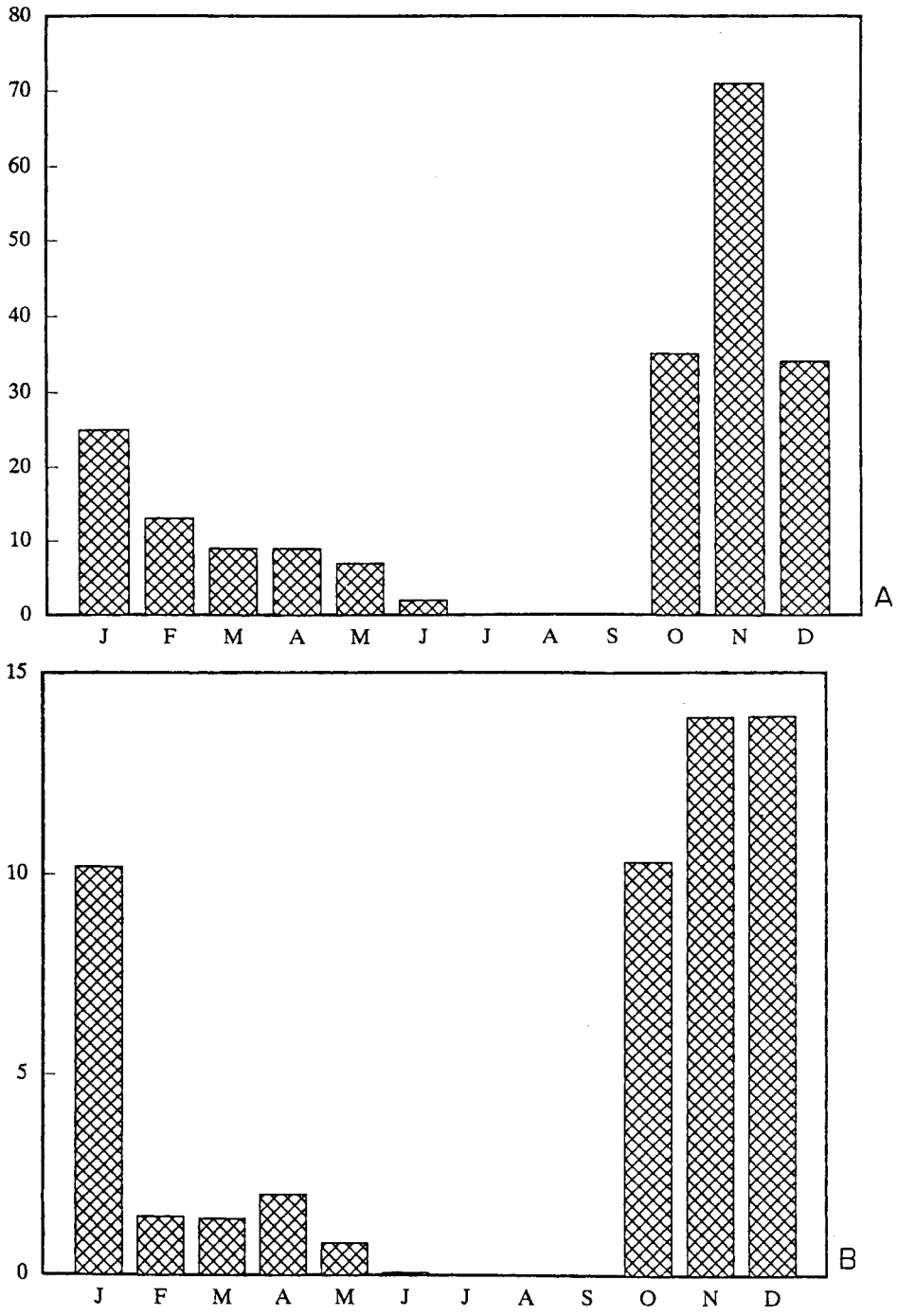

Fig. 3. Juniper scrub: total number of species (**A**) and approximate number of fruit bodies, by the thousand (**B**), collected on average in a given month, during the observation period.

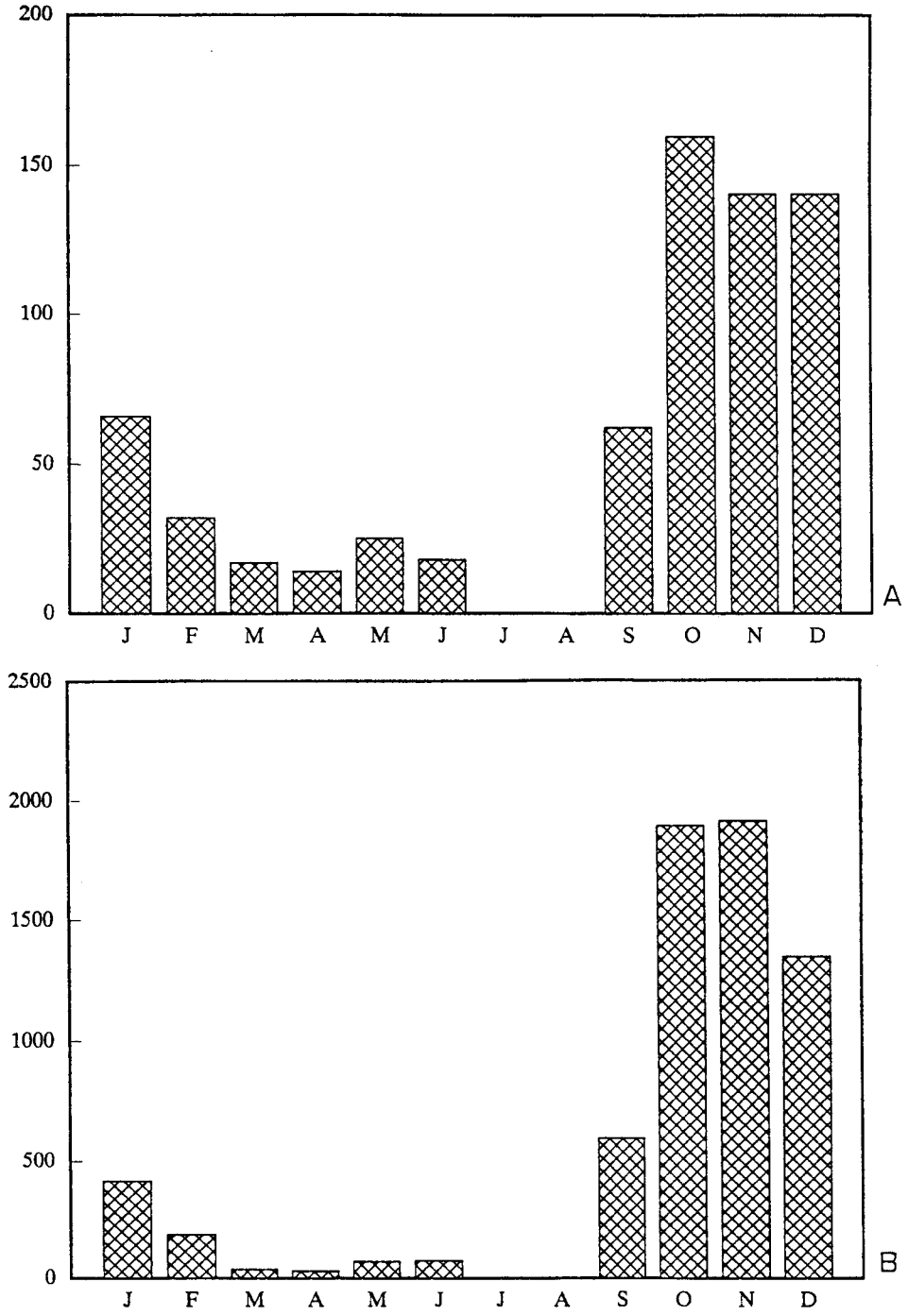

Fig. 4. *Quercus ilex* woods of the Maremma coastline: total number of species (**A**) and approximate number of fruit bodies, by the thousand (**B**), collected on average in a given month, during the observation period.

Mycena lenta (Maire) Kühner & Romagn., all very abundant; and *Cortinarius ionochlorus* Maire, *Lepiota rhodorrhiza* Romagn. & Locquin ex Orton, *Mycena algeriensis* Maire, *Russula seperina* Dupain, less abundant.

The total number of species and the approximate number of fruit bodies noted each month during the observation period are reported in Fig. 4A and 4B, respectively. Fructification in coastal evergreen oak woods (Fig. 4a) already begins in September (62 species), peaks in October (159 species), remains high for the following two months, with 140 species, then sharply drops to the September level in January (66 species) and decreases further from February to June, with a slight increase in May. The summer standstill lasts two months. The fruit body production pattern (Fig. 4B) is similar to that pattern of species number, exceeding the thousand during the autumn months and gradually decreasing in winter and spring.

Inland evergreen oak woods

Five plots (10,000 m^2) of *Quercus ilex* coppices were chosen in the region of "Colline Metallifere", S. of Siena (Fig. 2), between 210 and 450 m a.s.l. and at c. 50 km from the coast (De Dominicis & Barluzzi 1983). These woods show ectotonal features, with various deciduous oak woods growing at the next higher level. They are therefore assigned to the *Quercion ilicis* Br.-Bl. (1931) 1936 but not to a definite association.

For illustrating the climate the diagram of Siena (Fig. 1) may be used, considering that local fluctuations may result from differences in exposure, altitude, distance from the coast, etc. During our mycocoenological studies, from September 1977 to October 1979, a total of 181 species were found. Six of them, which also occur in the evergreen oak woods of the coastal region, must be considered as characteristic of the *Quercion ilicis*, namely *Cortinarius calochrous* Fr., *C. sodagnitus* Rob. Henry, *Hygrophorus dichrous* var. *fuscovinosus* Bon, *H. russula* (Schaeff. : Fr.) Quél., *Krombholziella lepida* (Bouchet) Alessio, and *Phellinus torulosus* (Pers.) Bourdot & Galzin (Perini & al. 1989).

The fructification of fungal species (Fig. 5A) concentrates on the last four months of the year, peaking in November with 94 species. From January to June the number of species found is rather small, apart from a low secondary peak in March, with 13 species. The histogram of the approximate number of fruit bodies (Fig. 5B) comes close to that for species numbers.

Chestnut coppices

A comparison was made of macrofungal fructification rhythms in mediterranean and submontane types of vegetation, in terms of species numbers only, using data of a mycocoenological survey performed in chestnut coppices (Barluzzi & al. 1992). The nine plots (18,000 m^2) studied lie between the "Colline Metallifere" (provinces of Siena and Grosseto) and the foot of the Apennines (province of Arezzo), at altitudes ranging from 470 m to 870 m a.s.l. (Fig. 2). Below 525 m, these coppices can be assigned to the *Quercion robori-petraeae* Br.-Bl. 1932, and above that altitude, to the *Carpinion betuli* Oberdorfer 1953. The Cotorniano diagram (Fig. 1) is illustrative of the climate.

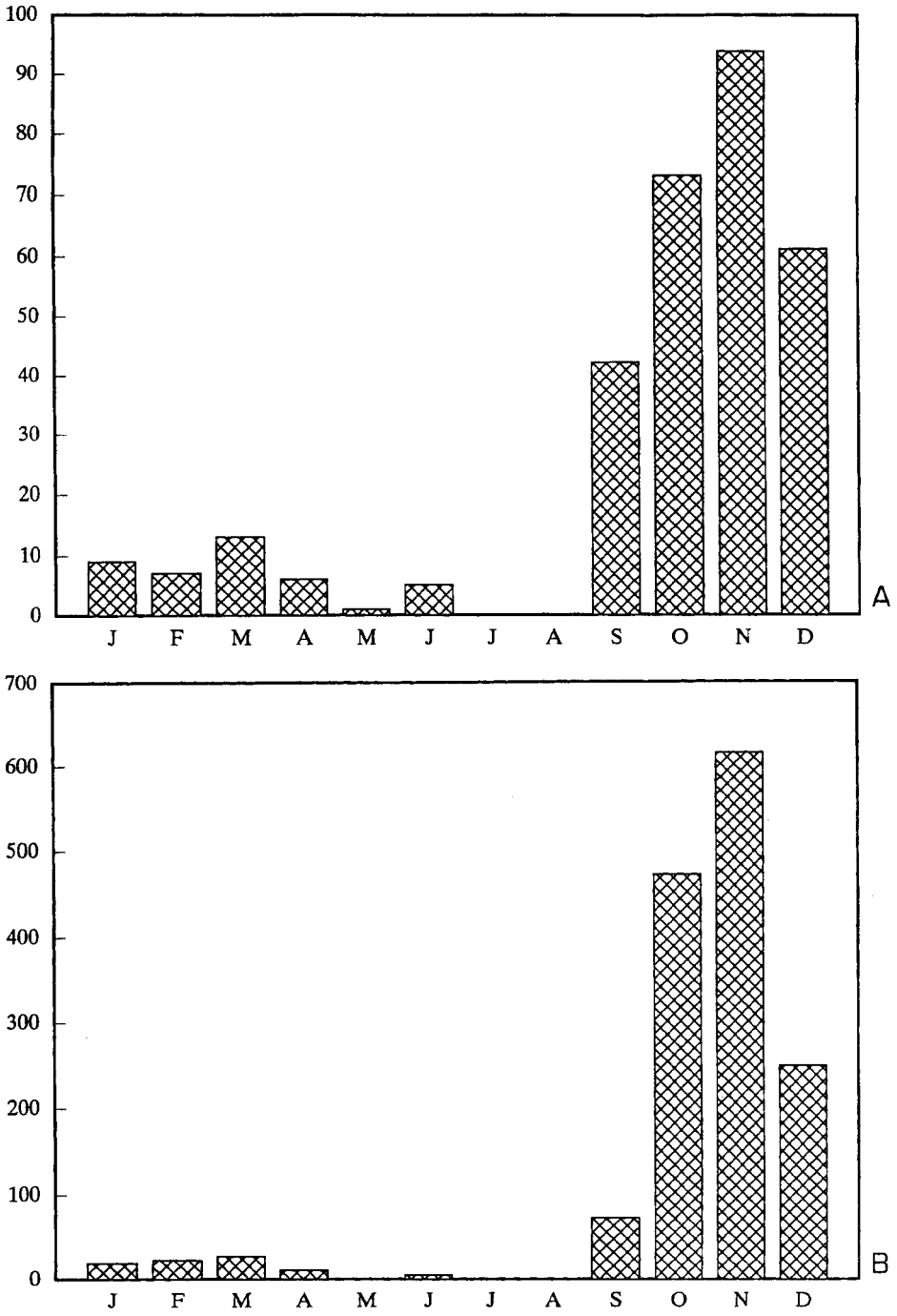

Fig. 5. *Quercus ilex* woods on the Siena hills: total number of species (**A**) and approximate number of fruit bodies, by the thousand (**B**), collected on average in a given month, during the observation period.

254 fungal species were noted from October 1979 to January 1982. Most of them have a broad ecological range or are by preference associated with montane broad-leaved deciduous forests *(Fagetalia sylvaticae)* and/or acid oak woods *(Quercetalia robori-petraeae)*. Only *Fistulina hepatica* Schaeff. : Fr., *Rutstroemia echinophila* (Bull. : Fr.) Quél., and *Mycena inclinata* (Fr.) Quél. seem to be linked to chestnut groves. The fungal production (Fig. 6) is virtually restricted to three months, starting in September (78 species), peaking in October (211 species), and dropping again in November (128 species).

General conclusions

Seasonal variation of the mycoflora

The monthly percentage of species, calculated on the basis of the total number of macrofungi noted in each vegetation community during the observation period, is shown in Fig. 7. In general terms, it is low in winter and spring. In the strictly mediterranean coenoses a gradual decrease from January to June is evident: from 27 % to 2 % of species in juniper scrub and from 21 % to 6 % in evergreen oak woods of the coastal region.

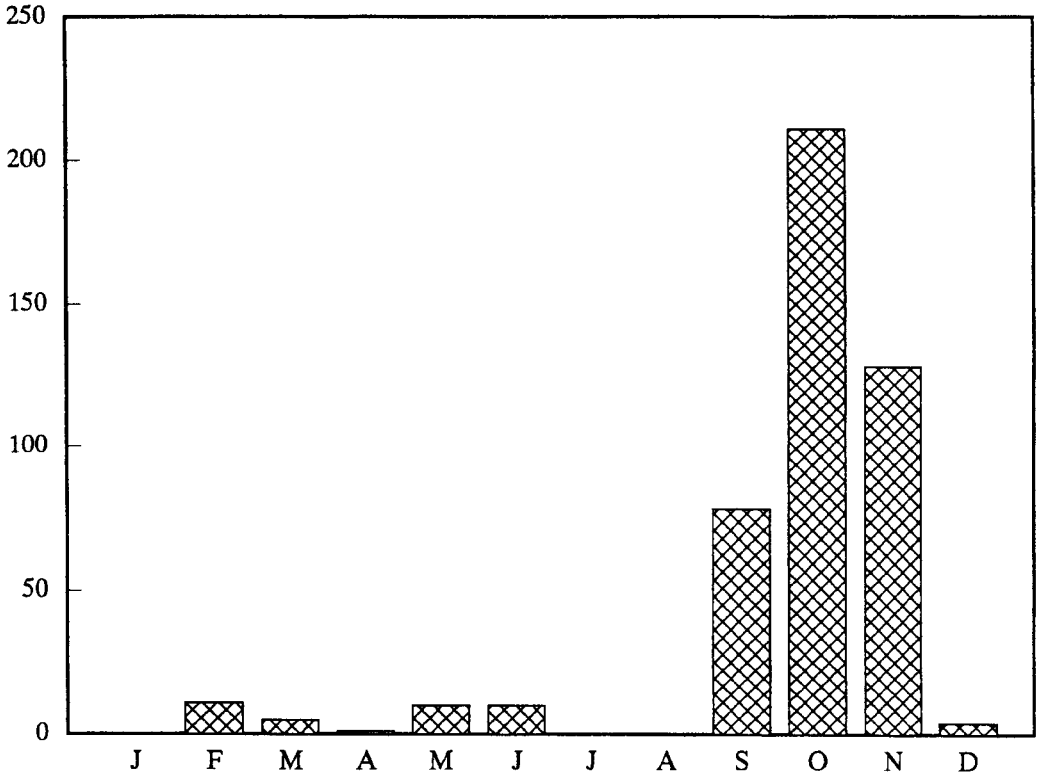

Fig. 6. Chestnut coppices: total number of species collected on average in a given month, during the observation period.

In the inland *Quercus ilex* L. woods, it remains below 5 %. In the submontane area of chestnut coppices, it is almost nil in winter and barely reaches 4 % in May and June.

Summer drought strongly influences the mycoflora in juniper scrub, completely obliterating fruit body production for three months, after which an outburst is observed in November, with 76 % of the total species fruiting. In the evergreen oak woods the first harvest is in September, with about 20 % of species. On the coast the maximum is in October (51 %), inland in November (53 %). Chestnut woods are less influenced by summer drought: already in September 31 % of the species are found, followed by 83 % in October and 50 % in November. Synchronous with the first frost, a strong decrease down to 2 % occurs in December.

The fruiting period therefore concentrates on the autumn months: out of the total species number, 84 % have been observed in that season in evergreen oak woods, 94 % in juniper scrub, and 98 % in chestnut coppices. The annual fructification rhythm shows a common critical summer low due to drought. but in the chestnut coppices there is a second critical low in winter, due to the harsh temperatures.

Seasonal variation in ecological groups

The seasonal variation of functional groups, expressed in percent of the macrofungal flora (Fig. 8A), and of substrate groups among the saprotrophic species (Fig. 8B), has also been assessed.

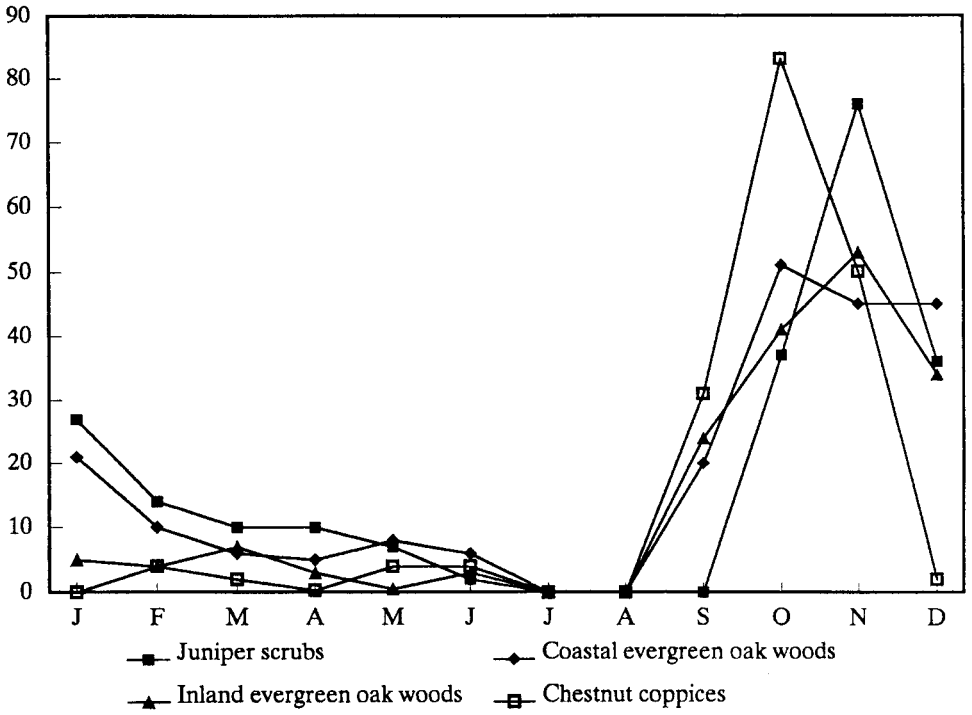

Fig. 7. Monthly percentage of species, calculated on the basis of the total number of species observed in the four types of vegetation studied.

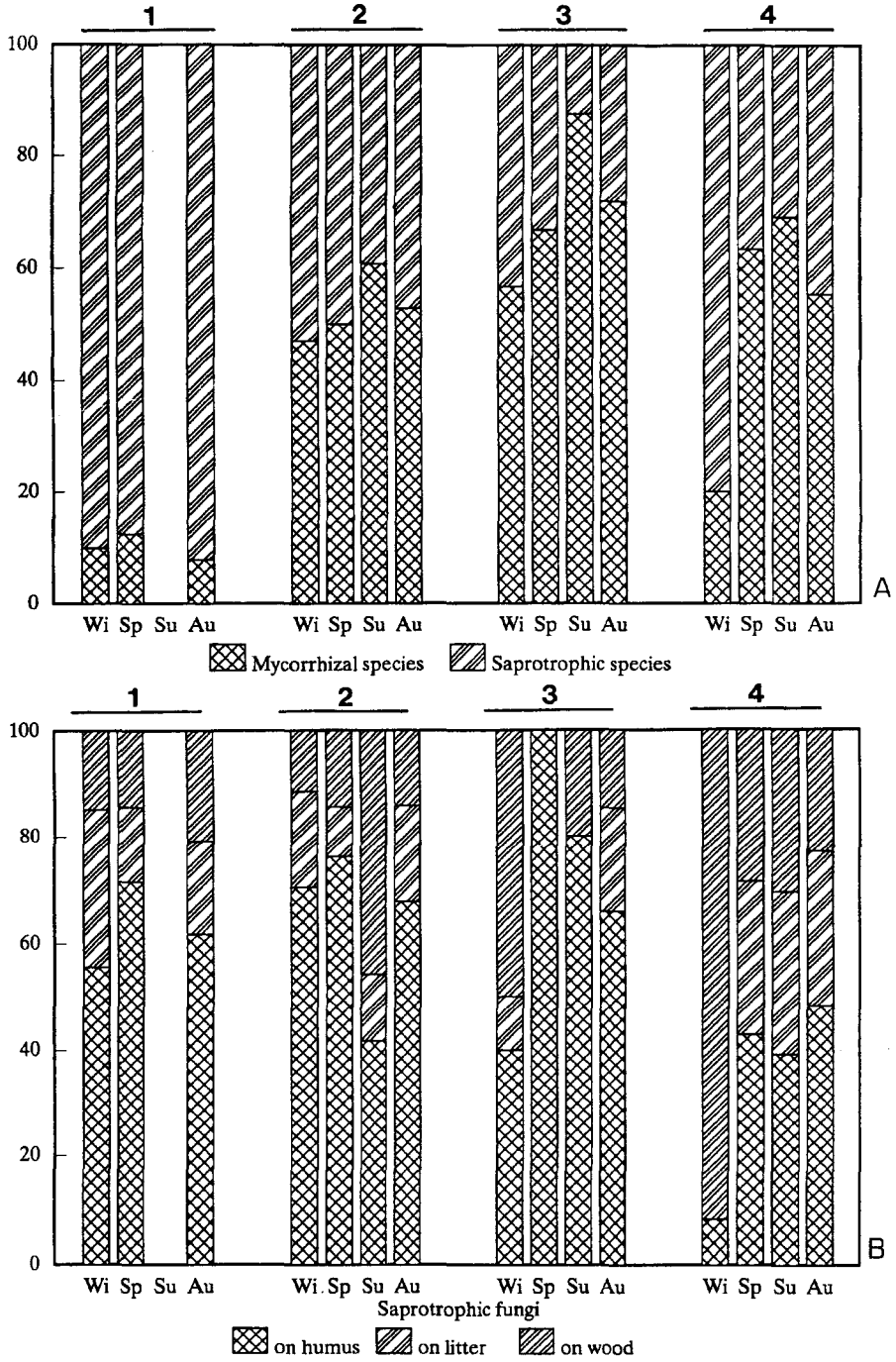

Fig. 8. Seasonal variation of functional groups, expressed in percent of the macrofungal flora (**A**), and of substrate groups among the saprotrophic species (**B**), in the four types of vegetation studied. – **1**, juniper scrub; **2**, evergreen oak woods of the coastal region: **3**, evergreen oak woods of the Siena hills; **4**, chestnut coppices; **wi** = winter (Jan-Mar), **sp** = spring (Apr-Jun), **su** = summer (Jul-Sep), **au** = autumn (Oct-Dec).

The few parasites collected in evergreen oak woods and chestnut coppices, *Armillariella mellea* (Vahl : Fr.) P. Kumm., *Fistulina hepatica* (Schaeff. : Fr.), *Ganoderma lucidum* (Curtis : Fr.) P. Karst., *Omphalotus olearius* (DC. : Fr.) Singer, and *Phellinus torulosus* (Pers.) Bourdot & Galzin, have not been taken into consideration.

The seasonal ratio of mycorrhizal to saprotrophic species is almost constant in all vegetation types studied. In the evergreen oak woods and in the chestnut coppices the highest percentage of mycorrhizal species is found in summer. The most representative genera are *Russula* (26 %) and *Boletus* (19 %) in the coastal *Quercus ilex* woods, *Tricholoma* (17 %), *Cortinarius* (12 %), and *Lactarius* (12 %) in the inland ones, and again *Russula* (17 %) and *Boletus* (10 %) in chestnut coppices. In juniper scrub the percentage of mycorrhizal fungi is low, allowing for a slight increase in spring. Only 8 species of mycorrhizal fungi are found (*Hebeloma hiemale* Bres., *Inocybe olida* Maire, *Ramaria myceliosa* (Peck) Corner, *Scleroderma meridionale* Demoulin & Malençon, *S. verrucosum* Bull. : Pers., *Xerocomus chrysenteron* (Bull.) Quél., *X. rubellus* (Krombh.) Quél., *X. subtomentosus* (L. : Fr.) Quél.), which is due to the fact that junipers, the dominant species, do not form ectomycorrhizas.

Of the three substrate groups among the saprophytes (Fig. 8B), the humus fungi generally prevail in all communities, having their highest percentage in spring in the mediterranean coenoses but in autumn in the submediterranean ones. The 100 % figure observed in spring in the inland evergreen oak woods corresponds to three species: *Agaricus xanthoderma* Genev., *Peziza violacea* Pers., and *Sarcosphaera crassa* (Santi) Pouzar.

The seasonal fluctuation of the other two substrate groups differs between mediterranean and submediterranean coenoses. Litter fungi, absent in the inland evergreen oak woods in spring and summer, in juniper scrub have their highest percentage in winter, with: *Arrhenia spathulata* (Fr.) Redhead, *Flammulaster carpophiloides* (Kühner) Watling, *Hemimycena delicatella* (Peck) Singer, *Marasmius androsaceus* (L. : Fr.) Fr., *M. corbariensis* (Roum.) Singer, *Pithya cupressina* (Fr.) Fuckel, *Psilocybe coprofila* (Bull. : Fr.) P. Kumm., *Ripartites tricholoma* (Alb. & Schwein. : Fr.) P. Karst. *M. androsaceus*, a saprotroph on fallen needles and leaves of numerous trees, in Scotland was found to form rhizomorphs specifically associated with dieback of heath (Macdonald 1977). No litter fungi are found in the chestnut coppices in winter, but in the other seasons they occur with a high percentage, with *Marasmius* and *Mycena* as predominant genera.

Fungi on wood reach their highest values in winter in inland evergreen oak woods, with over 50 %, and in chestnut coppices with over 90 %. They peak in autumn in juniper scrub, and in summer in coastal evergreen oak woods. Among the autumnal lignicolous fungi collected in juniper scrub are *Coprinus xanthotrix* Romagn., *Cyathus olla* Batsch : Pers., *C. striatus* (Huds.) Pers., *Mycena meliigena* (Berk. & Cooke) Sacc., *Perenniporia ochroleuca* (Berk.) Ryvarden, *Pleurotellus chioneus* (Pers. : Fr.) Kühner, and *Simocybe rubi* (Berk.) Singer. Among the vernal species of the coastal evergreen oak woods one may note *Collybia marasmioides* (Britzelm.) Bresinsky & Stangl, *Gymnopilus spectabilis* (Fr.) Singer, *Hohenbuehelia geogenia* (DC. : Fr.) Singer, *Lycoperdon pyriforme* Schaeff. : Pers., and *Psathyrella hydrophila* (Bull.) Maire.

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