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Mycocoenological methods based on investigations in the Estonian forests

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Mycocoenology deals with fungal groups and their connections with other structural elements of a biocoenosis. For explanation of the role and importance of fungal groups in the system of structural elements of a biocoenosis, investigation of phytocoenological connections between lower and vascular plants, our present knowledge of them being rather scanty, is the main theoretical problem in mycocoenology. By mycocoenological research methods it is most useful to study the fungal resources of site types and so finally establish foundations for a scientific utilization of fungi in a given region. Mycocoenology is a young, but highly promising field of science. Beginning with the latest decade, intensive activity was noted in mycocoenological research, especially in Hungary, Poland, Czechoslovakia and Germany. Consequently theoretical problems and field research methods have been unsatisfactorily applied in mycocoenology.

Setting aside theoretical problems of mycocoenology, we present certain standpoints on mycocoenological field methods and draw a number of conclusions as to the composition of the fungal cover and ecology of different forest site types. These conclusions are drawn as a result of mycocoenological research in Estonian forests in the period 1954—1964.

In spite of the in creasing number of mycocoenological researches during recent years, satisfactory research methods have as yet not been elaborated. H u e c k (1953) sums up the more important methods used so far, but does not propose his own methods. The reason lies in the peculiarity of fungal life due to which different methods must be elaborated and tested. Therefore, phytocoenological research methods cannot be fully applied in mycocoenology.

Route and stationary researches may be distinguished in phytocoe-

nology. Both these research lines can be applied in mycocoenology as well. But all investigators agree that stationary investigation is the main method in mycocoenology, because only perennial sampling areas give us a complete survey of the whole fungal cover in a given plant community. Separate analyses from route research work give us only a survey of the character of the fungal cover at the given moment. If we have sufficient route analyses, we can draw certain preliminary conlusions from separate analyses made at different times and places on the ecology and composition of the fungal cover in various plant communities. Route research is inevitable in regard to the fungal cover during phytocoenological field work, this factor having been neglected up till now (Vasilkov 1938).

When analysing the fungal cover, it is necessary to register the vegetation of vascular plants according to phytocoenological methods in the case of either of the research lines. The description of site conditions must include the soil variety, soil pH, humidity regime, animal and human influences of the area under observation. The soil relief character should be described and the site of analysis indicated.

Stationary investigations and route analyses were made on 15 site types in Estonia (beginning with the driest-lichen and *Calluna* type — and ending with the wettest — bog and mesotrophic marsh type) to evaluate mycocoenological field methods and connections between various fungal groupings and various forest site types. The following five types were under detailed observation: *Vaccinium, Myrtillus,* swampy *Myrtillus, Oxalis* and *Aegopodium-Mercurialis* types.

Stationary investigations were carried out on 900 and 1.000 sq. metre square sample areas. All the plant cover layers and the character of relief were described on each sample area. Soil variety and humidity regime were determined. All the fungal species were registered, and their fruit bodies were counted. The substrata and sociability were noted for each species. Observations were made only in autumn at 8—10-day intervals.

Each sample area was treated as a whole. Only in one case it was divided into observation belts 30 to 2 m each. A passage of 0.5 m was left between each belt not included in the area under investigation and fungal fruit bodies growing there were not taken into account. This method was based on our experience, because in the case of absence of such passages many young fruits bodies were crushed in the moss, thus changing the results.

Route analyses were made on 100—5.000 sq. m sample areas of various shape, depending on the fungal cover and the character of site. In each case all similar indicators as in stationary observations were registered, except the abundance of fruit bodies which was established

by the Haas six-stage scale (Haas 1958) somewhat simplified (see below, p. 5). Sociability was indicated in both route and stationary analyses after the Haas 5-stage scale (Haas 1958). The following conclusions were drawn as regards research methods:

Connections between fungal groupings and forest site types and their role in the structure of plant communities can be exhaustively explained only in different plant communities as a result of stationary observations during the whole vegetation period over at least 2 years. The average period for observations is ten days.

The above-mentioned problems cannot be solved by route investigations. Preliminary data on the composition of the fungal cover on a site type can be collected in this way.

The abundance of fruit bodies and sociability are essential mycocoenological indicators while analysing the fungal cover. Sociability is even much more important as compared with abundance. It is the only indicator demonstrating but partly (with the present methods) the connection of fruit bodies with the respective mycelia thus giving a certain idea on the distribution of mycelia in soil. Let us repeat here the idea emphasized by numerous scientists — the whole of mycocoenology up to the present day is the coenology of fruit bodies, but the existing methods give us but very little information about mycelia, the true fungal body. For estimation of sociability the Haas 5-stage scale is most suitable. The aim of the work would suggest the use of methods indicating abundance. If the aim is the discussion of the specific composition, specific dominance, characteristic and differential of species of the fungal cover in certain forest communities, then it is adequate to estimate abundance subjectively according to the corresponding scale. If quantitative factors, such as the dynamics of occurrence of fruit bodies, yield, etc. are investigated, then objective methods must be applied, i.e. fruit bodies have to be counted. In stationary researches objective methods have, consequently, to be preferred, but subjective estimation of abundance is sufficient in route investigations. The way of estimating abundance also depends on the time limits and other opportunities at the researcher's disposal. There is never time to count fruit bodies in route researches. A six-stage scale where abundance is combined with sociability estimation is advisable in subjective estimation:

\+ — there is one fruit body or they group together,
1 — fruit bodies occur in a few specimens or groups,
2 — fruit bodies or their groups occur in small numbers,
3 — fruit bodies or their groups occur in large numbers,
4 — fruit bodies or their groups occur in abundance,
5 — fruit bodies or their groups occur in great abundance.

It is inevitable to apply such a combined scale, because sociability must be borne in mind while estimating abundance. The largest number of fruit bodies does not always coincide with largest abundance. Two species with the same number of fruit bodies, one of them occurring in single specimens all over the sample area and the other for instance only in two clustered groups, cannot be taken as species of similar abundance. Fruit bodies growing in a cluster belong to one and the same mycelium and must be counted as a single fruit body as compared with the species growing singly also belonging to one mycelium. This principle is essential in the differentiation of fungal dominants. Of course, mistakes may occur with such estimation, because it is difficult to find out to which mycelium belong the species growing singly. However, we must stand for this method of abundance estimation, because more mistakes may occur when other methods are applied.

In the method of large sample areas squares, for fungal cover analyses, at least under Estonian conditions, must exceed 900 sq. m, of course, if the site is larger than this area. Even such a large sample area cannot give quite satisfactory results, because it comprises a considerably small part of the actual body of the forest community and numerous fungal species remain out of consideration. The sample area may be larger, aven up to 0.5 ha. Many investigators up to the present day have made the mistake of choosing a too small sample area, so that even most characteristic fungal species have been left out. Sample areas in different site types must not be of the same size and they cannot be so, because site conditions differ a great deal. The areas need not be always square either. It is impossible to fit the size and shape of sample areas into a cliché. This question has to be solved in a different way under different conditions.

Research in concrete forest sites on whole by the method of small sample areas or transection seems to be most successful giving a survey of the actual fungal cover of the given forest community. Several researchers (Moser 1959; Höfler, Cernohorsky 1954; Feher, Besenyei 1933) successfully applied this method. It should be regarded as more practicable as compared with the previous one, because it gives us the special composition and abundance and the regularities of fungal distribution in addition (Moser 1959). Moser is right in pointing out that it is not all the same whether we find a species with 50 specimens on 100 sq. m concentrated on one spot or distributed evenly all over the sample area. The application of mathematical statistics in the studies on vascular plant vegetation have shown that investigation of a large sample area is not satisfactory, but the application of numerous small sample areas gives us good

results (Bykov 1957). It is impossible to apply so small sample areas with fungi as with vascular plants (1 sq. m, for instance), except in detailed investigations where it may be necessary, larger ones even up to 100 sq. m have to be investigated depending on the character and time of analysis of the plant communities. Such small sample areas are chosen in great numbers on a larger observation area. Thus a 100 sq. m sample area may be used as one of numerous such areas within the boundaries of a larger territory. Many researchers (such as Höfler 1937; Friedrich 1940, Leischner-Siska 1939 et al.) have applied sample areas of this size erroneously as the only sample area in the method of large sample areas. The method of small sample areas has not yet been introduced in Estonia by mycocoenologists.

RESULTS

The distribution of fungal species (fungi on wood incl.) largely depends on the site type peculiarities. These peculiarities are more pronounced in coniferous stands than in deciduous ones. Fungal species common for all the 15 site types were not found. *Amanita vaginata* var. *badia* and *Cortinarius cinnamomeus* were the least fastidious species as regards differences in site types. There were two common species in five site types studied in detail: *Lactarius vietus* and *Paxillus involutus*. Most species were characteristic of one site type only. It is interesting to point out that fungal species occurring on wood and other similar substrata can be regarded as species distributed in all the site types. Only *Galerina marginata* (in 10 site types), *Gymnopilus penetrans* and *Micromphale perforans* (in 7 site types) are an exception. Even such widely-spread species as *Kuehneromyces mutabilis, Naematoloma capnoides, Tricholomopsis platyphylla, T. rutilans, Pluteus atricapillus, Armillariella mellea, Asterophora lycoperdoides, Tylopilus felleus* and *Lycoperdon pyriforme* occurred only in a few site types. This shows that fungal groups growing on stumps and other similar substrata are far from being independant of the communities of vascular plants.

Most species occur in site types with optimal or slightly excessive humidity conditions, whereas relatively few species grow under extreme humidity conditions i.e. extremely dry and wet site types (such as lichen, *Calluna*, bog and mesotropic marsh site types). These types lack or exhibit a very rare occurrence of a number of species frequent under optimal conditions: *Lactarius deliciosus, L. scrobiculatus, L. glyciosmus, L. vietus, Russula queletii, Paxillus involutus, Inocybe geophylla* var. *geophylla, Hebeloma crustuliniforme*. The differences in humidity con-

Table 1

Site types, stand composition, commonest fungal species (number in brackest denoting the frequency in per cent) and the most important characteristic species (denoted with asterisks +)	Total number of fungal species	Number of common specis (in brackets % of the total number of species)	Number of characteristic species
1	2	3	4
1. *Vaccinium type* *Cystoderma amianthinum* (62), + *Tricholoma portentosum*	76	16(21)	11
2. *Myrtillus type* *Cantharellus cibarius* (53)	131	14(11)	4
a. coniferous forests *Cantharellus cibarius* (53), + *Rozites ceperata*	57	8(14)	7
b. mixed forests + *Lactarius subdulcis* (56), + *L. torminosus*, + *L. trivialis*, + *L. vietus*, + *Russula fragilis*, + *Leccinum scabrum*, + *Cortinarius armillatus*	131	14(11)	10
3. Swamp *Myrtillus* type *Cortinarius armillatus* (60), + *Russula vinosa*	85	15(17)	10
4. *Oxalis* type *Paxillus involutus* (44), + *Inocybe geophylla* var. *geophylla*	175	18(10)	10
a. coniferous forests + *Lactarius deliciosus* (88)	57	17(29)	10
b. mixed forests *Paxillus involutus* (52), + *Cortinarius armillatus*, + *Amanita muscaria* var. *muscaria*, + *Hebeloma crustuliniforme*, + *Lactarius camphoratus*, + *L. glyciosmus*, + *L. spinosulus*, + *L. torminosus*, + *L. vietus*, + *Leccinum scabrum*, + *Mycena epipterygia*, + *Tricholoma album*	157	19(12)	17
5. *Aegopodium-Mercurialis* type *Lactarius torminosus* (50), *Mycena pura* f. *pura* (50), + *Inocybe geophylla* var. *lateritia*, + *Lactarius hepaticus*	142	30(21)	21
a. coniferous forests *Lactarius scrobiculatus* (60), + *Galerina marginata* (60)	66	7(11)	4
b. mixed forests + *Lactarius torminosus* (60), + *Hebeloma crustuliniforme*, + *Paxillus involutus*, + *Tricholoma album*, + *T. flavobrunneum*	126	27(21)	26

ditions and soil, on the one hand, and the stand composition, on the other, are the main causes for the above-described regularities. The differences in stand composition are most evident in lichen, *Calluna*, bog and mesotrophic marsh site types, where pine forests prevail almost without exception. For instance, *Amanita rubescens* forming mycorrhizes with the pine is lacking in the above-mentioned four site types obviously due to unfavourable humidity and soil conditions, but *Lactarius scrobiculatus*, a spruce forest species is lacking due to the unfavourable composition of the stand. Owing to the predominance of pine forests in the four site types under discussion there is a number of common species in them, in spite of widely different humidity and soil conditions between the lichen and *Calluna* site types, on the one hand, and the bog and mesotrophic marsh site types, on the other. Such species are, for instance, *Lactarius rufus, Russula decolorans, Amanita vaginata* var. *badia* and *Cortinarius cinnamomeus*.

The carr-site type differs in fungal cover notably from other site types occurring on undrained peat soils on account of differences in stand composition and ecological medium. The tree layer in the carr-site type is extremely varied in its composition, but pine forests prevail in mesotrophic marsh and bog forests. Several fungal species which are lacking as a rule, occur very rarely in mesotrophic marsh and bog forests are frequent in the carr-forests: *Hydnum repandum, Inocybe fastigiata, Laccaria laccata, Lactarius deliciosus, L. scrobiculatus, L. uvidus, Russula queletii, Cortinarius delibutus, C. infractus, C. odorifer, Tricholoma album, T. inamoenum, T. flavobrunneum*.

Swampy *Myrtillus* and drained marsh forest site type fungal covers are closely similar to the the fungal cover of site types under optimal humidity conditions. This seems to be mainly caused by the similarity in the above-mentioned site type vegetation to certain site type vegetations with optimal humidity conditions. The *Myrtillus* site type is very similar to the swampy *Myrtillus* site type in its vegetation. The *Myrtillus, Dryopteris*, and *Oxalis* site types match with the corresponding site type varieties of the drained marsh forest site type. The swampy *Myrtillus* and drained marsh forest site types have sodden bog soils. Judging by soil, the fungal cover of the above-mentioned site types might be expected to be similar to fungal covers of other wet site types with bog soil, such as mesotrophic marsh and bog. This similarity does not exist. Only few species common on the swampy *Myrtillus* site type occur in the *Myrtillus* site type, such as *Amanita porphyria, Russula flava, R. emetica* and *R. fragilis*. Only one species *Cantharellus cibarius* which is common in the *Myrtillus* site type occurs very rarely in the swampy *Myrtillus* site type. All the other species are frequent in both site types. The drained marsh site type lackes or has

seldom only *Cantharellus cibarius, Cortinarius armillatus, Hebeloma crustuliniforme, Gomphidius glutinosus, Lactarius spinosulus, Rhodophyllus nidorosus, Rozites caperata, Russula foetens, R. vinosa* from among species common in the forests with optimal humidity conditions.

In studies of the fungal cover in forest site types, one can have satisfactory achievements only when the fungal cover is analysed by forest stand groups, not by forest types. A forest type is determined according to the prevailing tree species, the composition of a stand being essential in studying the fungal cover.

Fir mixed stands are the richest in fungal species of site types from forest stand groups. The vast majority of species occurring in fir stands proper and fir-coniferous stands can be found also in fir mixed stands.

Most fungal species growing in coniferous stands occur also in mixed stands, the species growing in the latter occurring in coniferous stands in minority. This is dependent on the considerably wider ecological range in mixed stands as compared with coniferous stands.

The richest in species of the five site types studied in detail are the *Oxalis* type with 175 species, then the *Aegopodium-Mercurialis* (142) and *Myrtillus* types (131). The swampy *Myrtillus* (85) and *Vaccinium* type (76) follow. As to its fungal cover the *Aegopodium-Mercurialis* site type (21 characteristic species) is the easiest to be characterized out of the 5 site types studied in detail, the *Myrtillus* type being the most difficult one (4 characteristic species).

The most common and characteristic fungal species for individual site types and stand groups are presented in the table below (The species occurring in more than 25 per cent of analyses were regarded as common, in the corresponding site types or stand groups. The species which occurred with the highest frequency in site types or stand groups were regarded as characteristic).

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Mikocenologiczne metody oparte na badaniach w lasach estońskich

Streszczenie

Autor prowadził w Estonii badania mikocenologiczne „umiejscowione" (na powierzchniach 900 i 1000 m²) oraz „marszrutowe" (na powierzchniach 100—5000 m²) w siedliskach leśnych 15-tu typów. W wyniku badań doszedł do wniosku, że związek ugrupowań grzybów z siedliskiem leśnym określonego typu, a także ich rolę w strukturze zbiorowiska leśnego można wyjaśnić dopiero po przeprowadzeniu badań pierwszego typu przez okres co najmniej 2 lat przy 10-dniowej częstotliwości obserwacji. Obserwacje marszrutowe dają tylko wyniki orientacyjne. Zaleca 6-ciostopniową skalę dla oceny towarzyskości; wielkość powierzchni powinna przekraczać 900 m².

Różnica w rozmieszczeniu grzybów, zależnym tak bardzo od właściwości siedliska, lepiej uwydatnia się w lasach iglastych niż w liściastych.