Geographical Analysis of Higher Basidiomycetes Flora of the Steppe Zone of the Ukraine [1])

S. P. Wasser and I. M. Soldatova

N. G. Kholodny Institute of Botany, Academy of Sciences, Ukrainian SSR, Kiev, USSR

Little attention to study the geographical distribution of higher Basidiomycetes in the whole world is explained by insignificant investigations of mycoflora of many regions, zones and whole continents (South America, Australia, Africa) of the terrestrial globe. Even with the presence of a great deal of data on distribution of one or another group of fungi or certain genera (*Agaricus*, *Lepiota*, *Entoloma*, *Stereum*, *Polyporus*) there is no geographical analysis in the papers. Though the first studies in the field of geographical distribution of fungi permitted to draw conclusions which at present are a starting point of studies on mycogeography. The most important of them are as follows:

1. The extensive areas which include different climatic zones are peculiar to higher Basidiomycetes contrary to the angiospermous plants.

2. Distribution of fungi is controlled by distribution of substrates.

3. The climate has a less effect on distribution of fungi though some fungi have definite geographical boundaries limited by climatic factors.

4. The smaller the territory under study, the greater the number of fungi dominates in composition of its flora.

5. The areas not of species but genera of the seed plants usually correspond to the areas of higher Basidiomycetes similar to the areas of mosses and lichens (Herzog, 1926; Lazarenko, 1939; Vasiljeva, 1973; Oxner, 1974). According to Vasiljeva's (1973) opinion such a wide dispersion of higher Basidiomycetes is due to the peculiarities of structure and life of the fungus vegetative body.

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[1]) With great satisfaction we dedicate this paper to the 70th anniversary of Prof. Rolf Singer's birthday, who is a world known scientist, a patriarch of world agaricology, stationary or extramural teacher of a new generation of agaricologists in all countries of the whole world. His papers, especially "The Agaricales in Modern Taxonomy" (1975), are the encyclopaedia of world agaricology (Wasser, Ukrainian Botanical Journal, 32, 6, 1975: 802—804) and a base for any research on Agaricales be it taxonomy, phylogeny, geography, ecology, etc.

In our opinion it is necessary to pay attention to the fact that a great number of mycorrhizal higher Basidiomycetes is connected not with one species of woody and shrubby plants but with many ones (TRAPPE, 1962), their wide dispersion is explained by this phenomenon as well. For example, in the Primorye Territory (Far East, USSR) there are almost no species of woody plants common with North America or Europe, at the same time over 50% species of agarics, found in the Primorye Territory, grow both in Europe and North America (VASILJEVA, 1973).

The first attempt to give some evidence on geographical distribution of fungi including higher Basidiomycetes goes back to FRIES (1861) who divides all fungi of the terrestrial globe into two mycological belts: moderate, including the Arctic, and tropical, including subtropics. He indicated that the latter is poor in fungi.

JACHEVSKIJ (1933) considering subdivisions of FRIES to be elementary and taking into account the relation of fungi with plant communities distributes all fungi of the terrestrial globe in six botanical and geographical kingdoms: neotropical, paleotropical, Capsian, Australian, Holarctic and Antarctic which in their turn are divided into regions.

VASIL'KOV (1955) considers distribution of pileate fungi in the USSR in the vegetation zones and indicates that geographical relations in their distribution are closely connected with ecological ones. As the change in species composition of pileate fungi occurs more rapidly in the latitudinal direction than in the meridian one, Vasil'kov distinguishes the following zones: the Arctic deserts, tundra, forest (dividing into two subzones — taiga and broad-leaved forests), steppe, deserts and mountain zones.

VASILJEVA (1973) on the basis of arealogical analysis refers Agaricales of the Primorye Territory to ten types of areas: cosmopolitan, holarctic, palearctic, European—American—Far East, European—Far East, American—Far East, Far East—endemic, Siberian—Far East, American—Asian—Far East and tropical—Asian—Far East.

There are geographical analyses of macromycetes from different taxonomic groups in the papers by SOSIN (1952), BONDARTSEV (1953), PARMASTO (1955, 1970), FAVRE (1955), M. LANGE (1957), LJUBARSKIJ (1959), NIKOLAEVA (1961), KREISEL (1961), SHVARTSMAN (1962, 1968), SINGER (1962, 1975), CUNNINGHAM (1963), RAITVIIR (1964), MOSER (1968), RODRIGUES (1968—1969), STEPANOVA (1969), SKIRGIELLO (1970), NEZDOJMINOGO (1970), WASSER (1973, 1975), FILIMONOVA (1974), MOSER & HORAK (1974), KALAMEES (1974, 1975), BEGLJANOVA (1975) and others. However, the common single principle of the geographical analysis of flora is not given in these papers.

Such authors as SOSIN, VASIL'KOV, FAVRE, M. LANGE, KREISEL divide flora into the geographical elements basing on the zonal principle, VASIL'EVA, STEPANOVA — on the regional one, others use simultaneously combination of the zonal and regional principles (RAITVIIR, NEZDOJMINOGO, NAKHUTSRISHVILI, KALAMEES). This principle is widely distributed among the botanists-geographers (MINJAEV, 1965; MEUSEL et al., 1965; TRASS, 1970; TOLMACHEV, 1974). RAITVIIR (1964) considers that during mycogeographical analysis it is necessary to proceed from a study of areas of fungi proper and then to classify them on this basis.

In KALAMEES' (1974, 1975) opinion it is expedient to use the comparative-geographical analysis of the areas by H. MEUSEL et al. (1965) which is based on the zonal and regional principle. According to this scheme the world distribution of fungi occurs by a formula (diagnosis) in which the frequency of species on the continents or their parts is given by the vegetation zones and degrees of continentality. By this formula distribution of certain species of the order Agaricales in the terrestrial globe is expressed as follows:

1. *Clitocybe clavipes*

   m—temp (pensalp)—arct. (suboz) EUR—VORDAS—MAS—WSIB—OAS—JAP+AM

2. *Entoloma clypeatum*

   boreostrop—m (penalp)—b. suboz AFR—EUR—VORDAS—MAS—OAS—JAP+NAM—GRONL—arct CIRCPOL

3. *Agaricus silvicola*

   austrostrop—trop AFR+boreostrop—b. (suboz) AFR—EUR—VORDAS—SIB—OAS—JAP+NAM TempCIRCPOL

4. *Tricholoma flavobrunneum*

   m—arct. (suboz) AFR—EUR—WSIB—OAS

The formulas are composed in precise accordance with the vegetation-climatic zones established by MEUSEL and with application of his terminology.

"—" in formulas means continuous distribution of species. On no account symbol "+" used in this paper should be interpreted as disjunction of the area as it is used by MEUSEL. Now is not the time to speak about disjunction of the area with distribution of fungi (KALAMEES, 1975).

Subsequently KALAMEES (1974, 1975) considers that for the more detailed characteristic of geographical distribution of the fungi species it is convenient to use the notion of geoelement according to KLEOPOV (1938). This notion is established on the purely geographical

ground and based on the regional subdivisions of the terrestrial globe plant cover. But the distinguishing of these geoelements requires exact mapping of the fungi species and is a problem of future. In the recently published papers by KREISEL (1971, 1973) which especially completely reflect bibliography of papers from 1930 till 1972 where the maps of higher Basidiomycetes are given, it is shown that only 1079 regional maps of distribution of 815 species of higher Basidiomycetes are published in different journals, whereas the total amount of higher Basidiomycetes species composes 10.000 species.

These two approaches (of both MEUSEL and KALAMEES) to the analysis of geographical distribution of different groups of fungi as DUDKA (1976) indicates are based on the zonal and regional principle and are equivalent, as a whole; the formalized approach of KALAMEES being of more private character. KALAMEES gives the scheme of species world distribution but there is no classification of the areas. However he considers that classification of areas is necessary, indeed, as without it there are no possibilities to compare the parts of territories between themselves taking into account mycogeographical aspect, though he indicates that "creation of the unanimous well — grounded classification of mycoareas is a cause of future".

Following DUDKA (1976) we consider that the creation of classifications or schemes of distributing certain groups of fungi is necessary now as only by means of geographical analysis it is possible to establish regularities of appearing one or another group of fungi, their confinement to the definite territory, ways of migrations, etc.

We consider the flora element which is characterized by a definite type of area to be the main unit with geographical analysis of higher Basidiomycetes flora of the steppe zone of the Ukraine. The type of area in such a way is the principal characteristic of the flora element. The scheme suggested by us will undergo changes according to a degree of studying the flora, nevertheless the flora elements and areas distinguished by us are useful, as contrary to the formula of world distribution of species it permits judging not only distribution of species by the continents but also the general character of the flora under consideration.

With geographical analysis of higher Basidiomycetes flora of the steppe zone of the Ukraine we came across the phenomena that there are many gaps in the data about fungi distribution along the terrestrial globe. The species composition of higher Basidiomycetes is found most completely in Europe and North America, less completely in Asia. The South American, Australian and African continents are studied quite insufficiently. Having such incomplete data it is dificult to come to final conclusions about geography of higher Basidiomycetes as the further more precise definition of areas may shake some of our notions on them or disprove them completely.

As a result of geographical analysis of higher Basidiomycetes flora (orders Boletales, Agaricales, Russulales, Aphyllophorales) of the steppe zone of the Ukraine which is presented by 630 species referring to 173 genera of 35 families five geographical elements are distinguished (we construct the classification scheme of the geographical elements on the zonal principle on the basis of the classification of the geographical elements according to the works of OXNER 1940—1942, LAZARENKO, 1956, MAKAREVICH, 1963): euriholarctic (214 species, 33.96%), multiregional (159 species, 25.23%), boreal (122 species, 19.37%), nemorose (103 species, 16.35%) and xeromeridional (32 species, 5.08%). These elements are characterized by seven types of areas: European (93 species, 14.77%), Eurasian (95 species, 15.08%), Eurasian—North American (236 species, 37.46%), out of them with irradiation to Africa 19 species (3.02%), Euramerican (36 species, 5.71%), cosmopolitan [1]) (146 species, 23.17%), endemic (7 species, 1.11%) and others [2]) (17 species, 2.70%) which are rather different by the number of species referring to them.

When comparing our data with those of geographical analysis of certain groups of higher Basidiomycetes in the Primorye territory (VASILJEVA, 1973), the north-eastern coast of the Baikal (NEZDIJMINOGO, 1970), Georgia (NAKHUTSRISHVILI, 1971) and the southern part of the Krasnojarsk territory (BEGLIANOV, 1975) it was found that in the Primorye territory, north eastern coast of the Baikal and in the southern part of the Krasnoyarsk territory the boreal species prevail, whereas in Georgia and in the steppe zone of the Ukraine the euriholarctic and multiregional ones. The species of the Eurasian — North American type of area prevail in both the mentioned regions and the steppe zone of the Ukraine. The presence of the xeromeridional, endemic stenotopic species evidences for considerable specificity of higher Basidiomycetes flora in the steppe zone of the Ukraine.

Speaking about specificity of flora we should like to dwell on the problem of its endemism. The generic endemism is presented by a monotypic genus *Lepiotopsis* ZER. A problem of species endemism in higher Basidiomycetes flora of the steppe zone of the Ukraine may be put forward and discussed only preliminarily. With insufficient studies in mycology of the adjacent to our zone of the Ukrainian SSR ter-

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[1]) The term "cosmopolitan" is taken conditionally for the species which are met in all continents of the terrestrial globe, except the Antarctic Continent. They are referred to the same group conditionally, because it is impossible to characterize their distribution more in detail as there are insufficient data on the pileate fungi of the Southern Hemisphere.

[2]) To "others" are those species referred whose nomenclature and taxonomy are insufficiently characterized; problems of their distribution remain open.

ritories and adjacent countries one may not be sure that the species taken today as endems of the steppe zone are endemic for it and are absent in the adjacent territories.

Endemism in higher Basidiomycetes flora similar to that in the moss flora (KOCH, 1954; ABRAMOV, 1969; VASILJEVA, 1973, BARDUNOV, 1974) is characterized by the following two features: a) the percentage of the endemic species in the flora of higher Basidiomycetes is always lower than the percentage of the endemic species for the same territory of higher plants, b) the areas of higher Basidiomycetes endemic species are wider than the areas of endemic species of higher plants. And the steppe zone of the Ukraine is not an exception of this rule. In the flora of higher Basidiomycetes of the zone under consideration at present seven species which may be endemic are known: *Paxillus zerovae* S. WASSER, *Suillus luteus* f. *albus* S. WASSER et SOLD., *Agaricus amanitaeformis* S. WASSER, *Lepiota moseri* S. WASSER, *Leucocoprinus bohusi* S. WASSER, *Leucoagaricus steppicolus* (ZER.) S. WASSER, *Lepiotopsis baumanni* ZER.

The five species mentioned before are extremely rare and each of them is known only from one locality. Both *Lepiota moseri* and *Suillus luteus* f. *albus* have two localities from points of the steppe zone which are situated comparatively close to each other.

Such a low percentage of higher Basidiomycetes endemism is typical of other regions of the USSR as well. According to VASILJEVA's (1973) data 4% in Agaricales flora of the Primorye territory are endemic species, whereas over 90% of the woody plants are endemic. In the flora of the north eastern coast of the Baikal out of 337 species of pileate fungi there is only one endem. The Caucasus is a land of endemism for flowering plants, and out of 569 Agaricales of Georgia only 11 are endems.

As "endem" is the broad notion and one may speak rightfully about both the European endemism and narrow endemism of steppe zones; all seven mentioned species are narrow located endems.

Ecology of our endems is original as well. *Paxillus zerovae* and *Suillus luteus* f. *albus* grow in pine forests in sandy soils, *Agaricus amanitaeformis* and *Lepiota moseri* in the mixed broad-leaved stands of parks (the latter in the field protecting shelterbelts), *Leucocoprinus bohusi*, *Leucoagaricus steppicolus* and *Lepiotopsis baumanni* in the reserve virgin herb-sheep fescue-stipa steppes.

A degree of isolation and character of relations of higher Basidiomycetes endems in the Ukrainian SSR steppe zone are different. Only one species *Lepitopsis baumanni* refers to the monotypic endemic genus. This genus is rather original, it refers to the family Agaricaceae but undoubtedly is quite remote from all growing in the Ukraine and USSR species of this family.

Suillus luteus f. *albus* has the rank of a hereditary form. The rest endems have the rank of a species.

Paxillus zerovae according to the author (WASSER, 1973) is close to *P. filamentosus* FR. It differs clearly from the other species of the genus *Paxillus* as the large fleshy carpophores and spores are of another type and size. *Agaricus amanitaeformis* according to the author (WASSER, 1974) is closely related to *A. fissuratus* (MOELL.) MOELL. but it differs distinctly from the latter by the colour of carpophores, size and form of spores, absence of cystidia, form and colour of stipe, as well as by the ecological peculiarities. *Lepiota moseri* (WASSER, 1975a) is most closely related to *L. leucothites* (VITT.) P. D. ORTON, from which it differs by the pileus and flesh colour, size and form of spores and by ecology. *Leucocoprinus bohusi* (WASSER, 1975a) is closely related to *L. badhamii* (BERK. et BR.) MOS., from which it differs clearly by the carpophore habitus, pileus and flesh coloration, size and form of spores and by ecology. *Leucoagaricus steppicolus* according to the author (ZEROVA, 1974 (*Limacella steppicola*) was referred to the genus *Limacella*. A detailed study of the species in nature and type and paratypes microscopic studies permitted WASSER (1976) to transfer this species to the genus *Leucoagaricus*.

The presence among our endems of *Lepiotopsis baumanni* species with a high degree of differences from the nearest relatives, having no contacts in space with them and belonging to a monotypic genus shows undoubtedly that this species is rather old and it may be considered as palaeoendem. The other species having the nearest relatives in the territory of the USSR are considered to be nonendems.

The index explaining the role and significance of fungi in the gross plant spectrum of one or another region is of great importance for both botanical and geographic and ecological and cenotic studies. For elucidating the significance and role of higher Basidiomycetes in flora of the definite zone or region similar to the lichen coefficient introduced by MATTICK (1953) we suggest to use the coefficient of higher Basidiomycetes (CHB) [1]). CHB is equal to a ratio of a number of higher Basidiomycetes species of the definite region to a number of the vascular plants known from there. If for the whole earth a number of known higher Basidiomycetes is equal approximately to 10.000 and a number of the vascular plants to 300.000, then CHB is 0.03. For the Ukrainian SSR CHB is 0.35, for the steppe zone of the Ukraine 0.40, for the Primorye territory 0.55, for the Byelorussian SSR 0.60, for the Soviet Baltic republics 0.93 (Table).

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[1]) For elucidating the significance and role of fungi in flora of the definite zone or region we suggest to use the fungal coefficient (FC) which is determined as well as CHB.

Coefficient of Higher Basidiomycetes of Different Republics and Zones of the USSR

Republic or zone	number of higher Basidiomycetes species	number of vascular plants species	coefficient of higher Basidiomycetes
Ukrainian SSR	1800	5000	0.35
Steppe Zone of the Ukrainian SSR	800	2000	0.40
Ukrainian Carpathians	1000	2200	0.45
Armenian SSR	650	2000	0.32
Primorye Territory	1100	2000	0.55
Soviet Baltic Republics (Estonia, Latvia, Lithuania)	1400	1500	0.93

The complex of factors (climate, soil and plant cover, human economic activity, etc.) affects the value of CHB. In North Europe CHB rises to over 1. In the Arctic regions the value of CHB increases and in the Antarctic Continent with the climate rather unfavourable for development of higher plants (for the Antarctic Continent only two species of the vascular plants are known) CHB reaches 10.

The absence of more or less complete data on the higher Basidiomycetes flora of the vast territories and whole continents (the tropics, subtropics, Australia, Africa, South America) does not permit the evidence on the value of CHB for the whole floristic zones and regions of the Earth to be presented.

Determination of CHB is useful not only for the floristic studies but also for the botanical and geographical, ecological and cenotic ones. CHB explains the role and importance of higher Basidiomycetes in the gross plant spectrum of one or another region or zone.

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