

Introduction

The research into fungi on juniper in Belarus was carried out by us since 1997 and were summarized in an article "The fungi in the consortium of common juniper in Belarus" (2002) and a monograph "Mycobiota in the consortium of juniper in Belarus" (Belomesyatseva, 2004, *in Russian*). During the data collection we constantly adverted to the publications of other mycologists concerning juniper-associated fungi outside Belarus. First of all they are L. Holm and K. Holm, O. Petrini, F.D. Kern, R.L. Gilbertson, and A. Bernicchia. In our country we recorded rather not great number of species in comparison with literature data on junipericolous fungi and myxomycetes in global scale. The data on these fungi are spread in many sources, and to simplify the task of subsequent researchers we have compiled a checklist of the taxa mentioned in basic publications, which has included 820 species.

Foretelling the chapters on fungi on juniper we should to write in brief about the host genus. According to R. Pigler (1931) the genus *Juniperus* L. is the single in the subfamilia Juniperoideae Pgl. of the family Cupressaceae F.W. Neger., ordo Pinales (Coniferales). About 70 species of the genus were described. They are ever-green small trees up to 10–18 m height, bushes, or repent bushes. The genus has wide geographical distribution in Northern Hemisphere from Arctic to Subtropics, and over the all Temperate Zone. Some species occur even in mountain areas of Tropic Zone (Central America, West Indies, East Africa). The distribution patterns together with wide ecological amplitude of the species cause the development of different life forms from tall big trees of savanna type in subtropical climate, small many-trunk bush-like trees in temperate climate to low and repent bushes in high mountains, Arctic, and arid areas. The most of species have small natural distribution areas, restricted to certain mountainous countries and mountain systems and replaced outside them by close, but good morphologically delimited species. Only several species, as *J. communis*, have wide distribution area.

The fungi on different *Juniperus* species are studied in very different degree. In the available sources we see the next host species, subspecies, and varieties: *J. ashei* Buchholz, *J. bermudiana* L., *J. californica* Carr., *J. chinensis* L., *J. communis* L., *J. communis* subsp. *nana* Willd., *J. communis* var. *depressa* Pursh, *J. communis* var. *siberica* Burgsd., *J. conferta* Parl., *J. depeana* Steud, *J. depeana* Steud var. *pachyphloea* (Torr.) Martinez (= *J. pachyphloea* Torr.), *J. excelsa* M. Bieb., *J. flaccida* Schlecht., *J. foetidissima* Willd., *J. horizontalis* Moench (= *J. prostrata* Pers.), *J. indica* Bertoloni, *J. macrocarpa* Sibth. & Sm., *J. macropoda* Boisa (= *J. polycarpus* C. Koch.), *J. mexicana* Schiede, *J. monosperma* (Engelm.) Sarg., *J. oblonga* M. Bieb. (= *J. wittmanniana* Stev.), *J. occidentalis* Hook, *J. osteosperma* (Torr.) Little (= *J. utahensis* (Engelm.) Lemmon), *J. oxycedrus* L. (= *J. glauca* Salisb.), *J. phoenicea* L., *J. pinchotii* Sudw., *J. procera* Hochst., *J. rigida* Sieb. & Zucc., *J. sabina* L., *J. sargentii* (Henry) Takedo, *J. scopulorum* Sarg., *J. seravschanica* Kom., *J. silicicola* (Sm.) Bailey, *J. thurifera* L., *J. turcomanica* B. Fedtsch., *J. turkestanica* Kom., *J. virginiana* L.

Thus, only 32 species of *ca* 70 are involved in mycological studies. Three species, *J. communis*, *J. sabina*, and *J. virginiana* are of the biggest value for us since the greatest numbers of fungi were recorded on them.

A history of the research into fungi on juniper

The fungi on juniper attracted special scientists attention since the 18th century. At first the researchers' interest concentrated on telio stages of the genus *Gymnosporangium* Hedw., especially *Gymnosporangium tremelloides* (A. Braun) R. Hartig and similar to it, which are widespread practically over the all *Juniperus communis* distribution area and cause striking hypertrophy with spindle-shaped swellings on skeletal branches and trunks. Thus, C. Linnaeus described in 1755 *Gymnosporangium* telio stage on juniper under the name *Tremella juniperina*, J.J. Dickson published in 1785 the description of *Tremella sabinae*, and C.H. Persoon described in 1797 the species *Puccinia juniperi*. Of course, now these names are referred to basionyms of currently used names.

A lichen-forming ascomycete *Lichen juniperinus* published by C. Linnaeus in 1753 belongs to the first descriptions of lichens from juniper. Later on the basis of this taxon present-day lichenologists have delimited several species, including *Cetraria juniperina* (*Vulpicida juniperinus*),¹ reported on juniper in Belarus (Abramov et al., 1971).

In 1783 A.J.G. Batsch described *Peziza cupressi* (on *Thuja* sp. and *Juniperus* sp.), a discomycete with rather prominent fruit bodies, which is known now under the name *Pithya cupressi*.

The beginning and the first half of the 19th century was the time when mycology become an independent scientific discipline. The scientists layed fungal taxonomy foundations, as E.M. Fries, F.F. Chevallier, J.B. Desmazieres, R.K. Greville, N. Jacquin, A.P. de Candolle, and G. de Notaris, described and systematized new and new species of fungi, including the species developing on juniper. For example, E.M. Fries is the author (or the sanctioning author) of 47 basidiomycetous, 32 ascomycetous, and 9 anamorphic fungi species inhabiting juniper.

This period in juniper mycobiota studying can be conditionally called phytopathological — the mycologists payed attention mostly to the fungi causing evident lesion symptoms, various plant diseases, e.g. *Lophodermium* — the agent of juniper needlecast (Schütte). A historical sketch of the taxonomic position concept development for almost any phytopathogenic species can be compared with a detective investigation. For example, E.M. Fries described needlecast agent in 1818 as *Hysterium juniperinum*, R.K. Greville in 1823 described the same species under the name *Hysterium juniperi*; further, C.E. Kuntze in 1898 transferred the species (described by Fries) in the genus *Hypoderma*, and L.R. Tehon in 1935 to the genus *Lophodermina*. Based on R.K. Greville diagnosis American mycologist G.D. Darker in 1967 published the species *Lophodermium juniperi* (Grev.) Darker, while G. de Notaris as early

¹ Currently used names are given in brackets.

as in 1847 gave to this ascomycete its currently used name — *Lophodermium juniperinum* (Fr.) De Not.

At the first half of the 19th century the research on taxonomy of rust fungi continued, especially it is worthy to note the species *Gymnosporangium clavariiforme* (Jacq.) DC. — one of the most widespread pathogens, including Belarus. Its quite modern diagnosis was given by A.P. de Candolle in "Flore Francaise" (Lamarck, de Candolle, 1805).

In the 19th century both in Europe (especially in Scandinavian countries) and in North America mycologists found a number of juniper-inhabiting ascomycetes. For example, *Dothidea juniperi* Desm. 1841 (*Seynesiella juniperi*), *Sphaeria juniperi* Duby 1854 (*Herpotrichia juniperi*), *Tryblidium sabinum* De Not. 1867 (*Holmiella sabinana*), *Sphaerella juniperina* Ellis 1883 (*Mycosphaerella juniperina*).

In the second half of 19th century there was also research of juniper-inhabiting deuteromycetes. Examples of the species described are *Diplodia juniperi* Westend. 1857, *Fusicoccum juniperi* P. Karst. 1870 (*Ceuthospora juniperi*), *Cercospora sequoiae* var. *juniperi* Ellis & Everh. 1887 (*Pseudocercospora juniperi*), *Sphaeropsis juniperi* Peck 1889 (*Aplosporella juniperi*), *Rhabdospora sabiniae* Sacc. & Fautrey 1898 (*Septoria sabiniae*).

Aphyllorphoroid fungi on juniper were being studied by E.M. Fries and some time later by P.A. Karsten. Meanwhile most of the species were not only transferred later into other genera but appeared not to be specialized to juniper. Sometimes the species host range turned out to be rather wide, and so the specific epithet "juniperi" eventually lost — it occurred with *Thelephora juniperina* Weinm. ex Fr. : Fr. 1828 (*Stereum rugosum*).

Finnish mycologist P.A. Karsten worked sufficiently with basidiomycetes inhabiting juniper and described not less than 22 species. Besides, the first description of 13 new ascomycete species on juniper in "Mycologia Fennica" also belongs to him.

We can find information on our subject in works of L. Rabenhorst and his followers A. Allescher, G. Lindau, H. Rehm, and G. Winter — each of them described new species on juniper. The works were published mainly in "Kryptogamen-Flora" series (e.g. Rabenhorst, 1844).

The boundary of 19th and 20th centuries was marked by a big number of prominent mycology works, among them "Sylloge fungorum omnium hucusque cognitorum" (1882–1931) by P.A. Saccardo and his progeny (D. Saccardo, etc.). Till now the series "Sylloge fungorum" has not lost its importance and remains a necessary guide, including juniper fungi studies. According to our calculations there are the diagnoses of 217 species of juniper-associated fungi in "Sylloge fungorum". They are distributed as follows: in the initial species diagnoses there are references to juniper as a substratum for 41 basidiomycetes, 45 ascomycetes, and 27 fungi in an anamorphic stage. Besides, there are mentions of juniper among other hosts for 26 basidiomycetes, 58 ascomycetes, and 20 anamorphic fungi. More than 30 junipericolous species were described immediately by P.A. Saccardo and co-authors. Of course, the majority of specific names is now used as basionyms, e.g. a widespread fungus *Sporidesmium glomerulosum* Sacc. 1878 (*Stigmina glomerulosa*).

The author of several deuteromycetes inhabiting juniper was also C.L. Spegazzini, who cooperated with P.A. Saccardo.

The contribution to the juniper mycobiota study, mainly *J. virginiana* (but also *J. communis*) was made by J.B. Ellis, M.C. Cooke, B.M. Everhart, and C.H. Peck. For instance, M.C. Cooke personally and in co-authorship with J.B. Ellis and C.H. Peck described 12 new ascomycetes on leaves and bark.

The fundamental work of C.A.J. Oudemans "Enumeratio systematica fungorum" is an important digest for the mycologist studying host range for the fungi. The first volume published in 1919 contains lists of the fungi recorded on juniper. Totally C.A.J. Oudemans considers 5 *Juniperus* species: *J. communis*, including *J. communis* subsp. *nana*, *J. exelsa*, *J. oxycedrus*, *J. phoenicea*, *J. sabina*. He lists for them 88 species of sac fungi, 28 basidial fungi, 7 hyphomycetes and 26 coelomycetes. The data on these fungi were collected from more than 180 original sources analyzed by the author. The species were grouped according to both systematical position and preferable substratum (juniper leaves, bark, wood, roots, and galbuli).

The significant works are H. Diedicke's "Kryptogamenflora der Mark Brandenburg" (1915) and W.B. Grove's "British stem-and leaf-fungi. 1. Coelomycetes" (1935). They contain some supplementing to P.A. Saccardo data, for example, concerning *Diplodia juniperi* occurrence, and also some new combinations, as *Phomopsis inconstans* (Sacc.) Died. 1912.

Several species on juniper were indicated by A.A. Jaczewski in the fundamental "Fungi identification book" (1913, 1917).

Especially big progress was observed in this period in the field of studying rust fungi of the genus *Gymnosporangium*. Many species concepts based on diagnoses published in works by J.C. Arthur, P. Dietel, F.S. Earle, R.C. Fragoso, R. Hartig, S. Ito, K. Miyabe, H. Sydow, P. Sydow, F.D. Kern, C.B. Plowright, and V.G. Tranzschel still remain unchanged. They described the majority of juniper rust agents known now, as widespread *Gymnosporangium confusum* (described by Ch.B. Plowright in "A monograph of the British Uredineae and Ustilagineae", 1889), *Gymnosporangium tremelloides* (A. Braun) R. Hartig, *Gymnosporangium cornutum* Arthur, *Gymnosporangium bethelii* F.D. Kern, *Gymnosporangium orientale* H. Syd. and P. Syd., *Gymnosporangium turkestanicum* Tranzschel.

The genus *Gymnosporangium* is a rather interesting exception among other Uredinales in the respect that coniferous plants, as a rule, serve as reservoir of its teliostage. At the same time the majority of other rust fungi attacking conifers, as *Cronartium*, *Coleosporium*, *Calyptospora*, *Hyalopsora*, *Melampsora*, *Melampsorella*, *Pucciniastrum*, *Uredinopsis* on hosts from Coniferales develop aecia and spermogonia, only one species from the genus *Chrysomyxa* can form telia on *Picea*. Famous expert in rust fungi F.D. Kern was engaged in the genus study over all his life, devoted to it two main work: "A biologic and taxonomic study of the genus *Gymnosporangium*" (1911), and "A revised taxonomic account of *Gymnosporangium*" (1973).

French scientists H. Bourdot and A. Galzin productively worked in the first half of 20th century, describing aphyllorphoroid fungi, including juniper-inhabiting ones (Bourdot, Galzin, 1928). He published for the first time the taxa *Corticium serum* var. *juniperi* Bourdot and Galzin 1911 and *Peniophora juniperina* (Bourdot and Galzin) Bourdot and Galzin 1928.

The book by J. Velenovsky "Monographia Discomycetum Bohemiae" issued in

1934 in Prague is an important point in juniper fungi research. Velenovsky's herbarium of it is one of the richest collections of discomycetes ever collected on this plant. Seven new species were described by him on juniper bark and wood. The work retains its significance in spite of the fact that later M. Svrček (1954) carried out a considerable revision and transferred the majority of taxa to other genera.

The first known to us research on juniper mycorrhiza is the monograph by D. Lihnell "Untersuchungen über die Mykorrhizen von *Juniperus communis*" (1939). The author identified mycorrhiza-forming species as *Cenococcum* sp.

Meanwhile, as far back as 1936 O.E. Ulbrich published the data on interaction of juniper with *Lactarius* species, but it was rather an assumption of such connections. Japanese mycologist T. Asai was also engaged in this problem but he came to negative results, and in his article "Über das Vorkommen und die Bedeutung der Wurzelpilze" (1934) he proved the absence of juniper mycorrhiza.

The modern stage in juniper fungi studying began from the middle of 20th century. In this period the new finds on juniper were described less often, but huge work on old genera revision and species new taxonomic position establishment was made. Besides, in the 60s there was an intense break in the field of mycocoenology, in ecological studying fungal species and fungal communities.

Such mycologists as M.E. Barr, C. Booth, E.S. Luttrell, K. Sawada, and H. Zogg studied ascomycetes on juniper and described many new species, e.g. *Glonium pusillum* H. Zogg 1962, *Halbania juniperi* Sawada 1950, *Pododimeria juniperi* (Bat. & Peres) Luttr. & M.E. Barr 1978, *Rhynchosphaeria cupressi* Natrass, C. Booth & B. Sutton 1963, *Sthughesia juniperi* (Dearn.) M.E. Barr 1987.

The author of the well-known identification book "British Ascomycetes" (1978) R.W.G. Dennis reconsidered the taxonomic position of at least 10 species of fungi developing on juniper. Among them there were both upspecialized species, like *Nipterella duplex* (Starbäck) Starbäck & Dennis 1962, *Lachnellula arida* (W. Phillips) Dennis 1962 and strictly specialized for juniper and frequently occurring on it — *Chloroscypha sabinae* (Fuckel) Dennis 1954, *Colpoma juniperi* (P. Karst.) Dennis 1958, and *Stomiopeltis juniperi* Dennis & Spooner 1977.

The article "The species of *Didymascella* on *Juniperus*" by M.E. Pantidou and G.D. Darker (1963) is a detailed account on the ascomycete genus strictly confined to juniper.

The development of the Dothideales on coniferous species, including juniper, was considered in dissertation of F. Casagrande "Ricerche biologiche e sistematiche su particolari ascomiceti pseudoseriali" (1969).

The significant contribution to studying junipericolous ascomycetes was made by E. von Müller. He is the author of not less than 12 species, among them *Pododimeria gallica* E. Müll. 1959, *Xenomeres juniperi* M.E. Barr & E. Müll. 1962, *Hyaloscypha juniperi* E. Müll. 1968, *Psilachnum juniperinum* E. Müll. 1968, *Holmiella sabina* (De Not.) Petrini, Samuels & E. Müll. 1979. In addition to the questions of ascomycetes taxonomy, E. von Müller together with O. Petrini paid big attention to ecological questions of juniper endophytes development.

The biggest expert in sooty moulds taxonomy and ecology S. Hughes selected juniper-inhabiting species as a favourite group. He concentrated the research atten-

tion mainly on anamorphic sooty moulds and some ascomycetous ones (Euantennariaceae and Metacapnodiaceae; Hughes, 1970, 1972, 1981). Besides he considered plenty of unspecialized saprotrophs occurring also on juniper, e.g. *Brachysporium nigrum* (Link) S. Hughes 1958, *Chalara cylindrosperma* (Corda) S. Hughes 1958, *Constantinella micheneri* (Berk. & M.A. Curtis) S. Hughes 1953, *Monodictys levis* (Wiltshire) S. Hughes 1958. On the other hand, he described some strictly junipericolous fungi, e.g. *Conoplea juniperi* S. Hughes 1958 and *Stigmina glomerulosa* (Sacc.) S. Hughes 1958.

An interesting species *Septonema harknessii* was reported by C.V. Subramanian in his monograph "Hyphomycetes" (1971). It was originally described by S. Hughes from *Juniperus virginiana* in Canada, but subsequently found on *Phoenix canariensis* in Madras, India. Another remarkable species, proposed as new combination by C.V. Subramanian, *Matsushimaea fasciculata* (Matsush.) Subram. 1978 was collected on dead *Cinnamomum japonicum* leaves in Japan, on *Coccoloba uvifera* in Cuba, and also isolated from forest soil in Africa, i.e. its finds were confined to warm climatic zones. Later it was found by V.A. Melnik on decaying *Juniperus communis* leaves, collected in Belarus and Leningrad region of Russia (Melnik, Belomesyatseva, 2001b).

The great contribution to hyphomycete taxonomy are fundamental works by M.B. Ellis, first of all "Dematiaceous Hyphomycetes" and "More dematiaceous Hyphomycetes". The descriptions of 7 species from juniper (e.g. *Stigmina deflectens* (P. Karst.) M.B. Ellis 1959 and *Tropospora monospora* (W.B. Kendr.) M.B. Ellis 1976) are given in these two monographs. Besides, M.B. Ellis studies plenty of non-specialized species which were recorded later on juniper by other scientists: e.g. *Monodictys lepraria* (Berk.) M.B. Ellis 1976 and *Trimmatostroma scutellare* (Berk. & Broome) M.B. Ellis 1976.

The other large work by M.B. Ellis written in co-authorship with J.P. Ellis, "Microfungi on land plants" (1987), is a very convenient and frequently used host-based micromycetes handbook. Four *Gymnosporangium* species, 16 ascomycetes, 2 hyphomycetes, and 2 coelomycetes are indicated for the genus *Juniperus* here.

A certain contribution to studying fungi associated with *Juniperus virginiana* was made by American researcher C.S. Hodges in big article "Comparison of four similar fungi from *Juniperus* and related conifers" (1962).

Dutch mycologist G.S. de Hoog who defined taxonomic position of many saprobic hyphomycetes, is the author of some species directly related to our theme, e.g. *Exophiala mansonii* (Castell.) de Hoog 1977, *Ramichloridium anceps* (Sacc. & Ellis) de Hoog 1977, *Leptodontidium camptobactrum* (de Hoog) de Hoog 1979.

Here it is necessary to note the article series "Lignicolous hyphomycetes" by V. Holubová-Jechová (e.g. 1972, 1984). These papers are rather meaningful when study the micromycetes decaying dead part of juniper, in particular the issues including the genera *Brachysporium*, *Chloridium*, and *Chalara*. A significant contribution to this area was brought by W. Gams too (Gams, Holubová-Jechová, 1976).

Not less than 6 *Chalara* species develop on juniper, though they are not strictly specialized to it. The genus was elucidated in "A monograph of *Chalara* and allied genera" by T.R. Nag Raj and W.B. Kendrick (1975).

The author of mitosporic fungi conidiogenesis theory W.B. Kendrick carried out many generic revisions. Three species recorded on juniper were for the first time described by him and co-authors.

In the fundamental work "Coelomycetous anamorphs with appendage-bearing conidia" (1993) T.R. Nag Raj critically reconsiders some important for us taxa, e.g. *Discosia strobilina* Libert, *Pestalotia juniperi* Allesch., and *Pestalotia juniperi* Rostr. A new combination *Pestalotiopsis stevensonii* (Peck) Nag Raj has the particular value for history of Belarus mycology, since there is a reference to collection of V.I. Korzenok from Belarus on pine seedling dead needles. Earlier the species was considered to be only with North American distribution. Later it was found on juniper and in different geographical areas.

The greatest modern authorship in anamorphic fungi taxonomy B.C. Sutton repeatedly adverted to junipericolous fungi. First of all in his basic work "The Coelomycetes. Fungi imperfecti with pycnidia, acervuli and stromata" (1980), B.C. Sutton lists 8 species on juniper. Ten years later, in co-authorship with C.S. Hodges he wrote a large article "Revision of *Cercospora*-like fungi on *Juniperus* and related conifers" (Sutton, Hodges, 1990). Besides, he published a number of new diagnoses in "Hyphomycetes from Manitoba and Saskatchewan" (1973) and "Mitosporic fungi from Malawi" (1993) where he described a new genus of fungi on juniper – *Ojibwaya*. Nine species occurring on juniper was discovered or revised by him solely or with co-authors. Examples are *Ojibwaya perpulchra* B. Sutton 1973, *Seiridium juniperi* (Allesch.) B. Sutton 1975, and *Asperisporium juniperinum* (Georgescu & Badea) B. Sutton & Hodges 1990.

The modern descriptions of *Phomopsis juniperivora* and *Phomopsis inconstans* are given in F.A. Uecker's monograph "A world list of *Phomopsis* names with notes on nomenclature, morphology and biology" (1988).

Interesting data about coelomycetes on juniper in Japan were presented by Y. Suto and T. Kobayashi in the work "Taxonomic studies on the species of *Pestalotiopsis*, parasitic on conifers" (1993).

Almost 40 species of ascomycetes, deuteromycetes, and rust fungi on 3 *Juniperus* species and 4 subspecies are listed in the first volume of V. Bontea's book "Ciuperici parasite și saprofite din România" (1985).

Eighth species of coelomycetes on juniper are discussed in a series of articles published by Lithuanian mycologists A. Treigienė and S. Stanevičienė in 1997–2000. The work by A. Treigienė devoted to the genera *Diplodia*, *Microdiplodia*, and *Sphaeropsis* (2000) is of special value for our subject. The article by S. Stanevičienė, A. Treigienė, M. Igantavičiūtė, and S. Markovskaja "Mycological and lichenological research in Eastern Lithuania. Micromycetes" (1998) touches upon the problem to which everyone working with the genus *Gymnosporangium* teliospore in Eastern Europe repeatedly returns — about the rarity of the stage collections on the background of vigorous aecia development.

Turning to the modern state of the research into *Gymnosporangium*, it is necessary to note the contribution of I.H. Crowell. He summarized the results in the work "The local distribution of the genus *Gymnosporangium*" (1940).

The species of *Gymnosporangium* occurring everywhere in East Europe, including Belarus, are discussed in the large 2-volume work of Romanian mycologist T. Săvulescu "Monografia Uredinalelor" (1953).

Questions of the the genus origin and taxonomy were studied in big article by E. Leppik "Some viewpoints on the phylogeny of rust fungi. 2. *Gymnosporangium*" (1956). The correlation between gradual evolution of hosts groups and the genus *Gymnosporangium* sections is considered in the paper, and the process is studied both in temporal and ecogeographical aspects.

The works of J.A. Parmelee were devoted to the study of juniper rusts in North America, most significant of them are "The genus *Gymnosporangium* in Eastern Canada" (1965) and "The genus *Gymnosporangium* in Western Canada" (1971). The total number of species considered by him is 18. Each species is accompanied by a very detailed description of biology, phenology, distribution sites in Canada, and general distribution.

The questions of juniper pathology were considered in an interesting article by R.S. Peterson "Studies of juniper rusts in the West" (1967).

The scientist whose name takes a special place in juniper mycobiota study history is L. Holm, known mostly by the works on ascomycetes taxonomy and ecology (about them we will tell further). In the discussed period he took a great interest in the genus *Gymnosporangium* and wrote "Études urédinologiques". In three articles of this series (1968, 1969, 1971) he considered biological features of the genus *Gymnosporangium* and *Uredo* representatives, paying special attention to the species producing uredospores on juniper.

From the chronological point of view it is necessary to remember F.D. Kern's last monograph mentioned above "A revised taxonomic account of *Gymnosporangium*" (1973).

In 1983 C. Borno and B.J. Kamo published a short article "Timing of infection and development of *Gymnosporangium* on *Juniperus*" in which they considered the germination peculiarities for aeciospores falling on juniper sprout.

It is remarkably that juniper rust, especially *G. tremelloides*, generates not only pure scientific interest. Now there is rather vast popular scientific literature and a many Internet sites with *Gymnosporangium* color photos. We can give as an example well illustrated article by T.F. Preece from the journal *Mycologist* (1995) "Orange tongues of fire on *Juniperus communis*", and the photos on websites {<http://www.forestpests.org/>} and {<http://fungi.umn.edu/gallery/rusts.html>}.

A famous Dutch mycologist M.A. Donk considered some of juniper-inhabiting fungi belonged to Aphyllophorales in article series "Notes on resupinate Hymenomyces". About 30 species (together with synonyms) having particular interest to us are mentioned or subjected to taxonomic combinations in his works. *Tubulicrinis juniperinus* (Bourdot & Galzin) Donk is a species strictly confined to juniper (Donk, 1956).

The pathogenic polypores are discussed in the work of American scientist H. von Schrenk "Two diseases of red cedar, caused by *Polyporus juniperinus* n.sp. and *Polyporus carneus* Nees" (1950).

Czech mycologist A. Pilát, being no specifically involved in this theme, processed *ca* 10 species of basidiomycetes occurring on this plant or its remnants.

Dutch mycologists W. Jülich and J.A. Stalpers, making nomenclature combinations and rearrangements, in co-authorship and solely considered over 20 aphylloroid fungi species which are able to develop on juniper (Jülich, Stalpers, 1980; Jülich, 1984). The majority of them are unspecialized ones. It should to note two fungal names proposed by these authors: *Kneiffiella juniperi* (Bourdot & Galzin) Jülich and Stalpers 1980 and *Grandinia juniperi* (Bourdot & Galzin) Jülich 1982 (both belong to *Hyphodontia juniperi* now).

Three new species of corticioid fungi on juniper in Netherlands and Germany were described by B.W.L. de Vries (1987), incl. *Hyphoderma cryptocallimon* and *Trechispora kavinioides*.

Scandinavian aphyllorologists traditionally frequently advert to juniper. Thus, in "The Corticiaceae of North Europe" and in his earlier papers J. Eriksson, solely and in co-authorship with K. Hjortstam and L. Ryvarden (Eriksson, Ryvarden, 1973–1976; Eriksson et al., 1978–1984), reconsidered the position of some resupinate species inhabiting juniper remnants, e.g. *Hyphodontia juniperi* (Bourdot & Galzin) J. Erikss. & Hjortstam. Besides, J. Eriksson described for the first time a species *Peniophora junipericola* J. Erikss. 1950.

Norwegian mycologist L. Ryvarden since 1972 and till now regularly regarded fungi from juniper. Some new taxa were described by him and co-authors, e.g. *Antrodia juniperina* (Murrill) Niemelä and Ryvarden 1975, *Trametes junipericola* Manjon, G. Moreno and Ryvarden 1984, and *Lenzitetella malençonii* Ryvarden 1991. Totally he took part in documenting of approximately 35 species occurring on *Juniperus*, including the works in cooperation with R.L. Gilbertson and A. Bernicchia.

The largest expert in juniper-inhabiting aphylloroid fungi of North America is R.L. Gilbertson, the co-author of L. Ryvarden in the monographs "North American Polypores" and "European Polypores". He began to study this subject together with J.P. Lindsey at the beginning of the 70s, working with wood-decay fungi of Arizona, USA (Gilbertson, Lindsey, 1975, 1978). Later the work was continued in cooperation with M. Blackwell on the extensive territory from Texas up to Missouri. The paper "Notes on wood-rotting fungi on junipers" (Gilbertson, Blackwell, 1987) is the most valuable for our theme, listing 51 species of fungi on 4 juniper species. This article and in previous one, "Notes on wood-rotting fungi on junipers in the Gulf Coast region" (Gilbertson, Blackwell, 1985), are provided by species determination keys. In general 83 basidiomycetes are mentioned for juniper in R.L. Gilbertson's works. Besides, he with colleagues proposed as new combinations or described for the first time more than 15 species, e.g. *Hyphoderma deserticola* Gilb. & Lindsey 1975, *Leptosporomyces juniperinus* Gilb. & Lindsey 1978, and *Schizopora apacheriensis* (Gilb.) Gilb. & Ryvarden 1987.

Juniper fungi were a favorite research object for Italian mycologist A. Bernicchia. Her big article "Wood-inhabiting aphylloraceous fungi on *Juniperus* spp. in Italy" (2000), done in cooperation with L. Ryvarden, summarizes more than 20-year work in this direction. The author collected about 300 specimens on 7 juniper species in Continental Italy, Sardinia, and Corsica. The list of fungi includes 105 species

belonging mainly to Corticiaceae s.l. and Polyporaceae s.l. The following species new to science were found on juniper by A. Bernicchia: *Echinodontium rywardenii* Bernicchia & Piga 1998, *Hyphoderma etruriae* Bernicchia 1993, *Neolentiporus squamosellus* Bernicchia & Rywarden 1998, *Phellinus juniperinus* Bernicchia & S. Curreli (1990), *Vararia maremmana* Bernicchia 1992.

Aphylophoroid fungi on juniper were recorded also by Polish scientists, e.g. in "Mała flora grzybów" by S. Domański, H. Orlos, and A. Skirgiełło (1967).

In brief we will point out the recent works from the sphere of phytopathology. American phytopathologist N.A. Tisserat (Kansas State University) published in 1990 a brief manual "Juniper diseases" in which he describes the symptoms of needlecasts, cancer, and rust caused by 6 pathogenic micromycete species. The table of their occurrence and harmfulness on various species of juniper is given.

In the work by L. Swan "Western juniper technical report" (1997) and by J.J. Morrell and S.L. Connie "Comparative durability of western juniper shavings" (1999) the diseases are discussed from the point of view of fungal influence on the juniper wood quality.

Juniper needlecast caused by *Phomopsis juniperovora*, *Kabatina juniperi*, and *Sclerophoma pythiophila* was described by M.A. Hansen in the work "Juniper tip blights" (2000) and later by R.K. Jones with D.M. Benson in the article "Juniper diseases and their control in the landscape" (2001).

From the works devoted to mycorrhiza-forming species should be marked "Studies in the hypogean fungi of Norway" by F.E. Eckblad (1962) publishing the data on connection between common juniper and *Elaphomyces muricatus*.

The data of D. Lihnell and some additional information on the presence of *Cenococcum* in living juniper tissue are reported by J.M. Trappe in the article "Mycorrhizal hosts and distribution of *Cenococcum graniforme*" (1964).

French researcher B. Boullard published in 1986 a large article "Les mycorrhizes des *Juniperus*", considering the question about endomycorrhizal infections of this plant and its connection with the family Endogonaceae Paol. representatives. Illustrations of root cuts with mycorrhiza structures are provided. It is interesting that the researcher compared four various juniper species and came to the conclusion about mycorrhiza structure differentiation.

Arizona State University researchers, C.C. Klopatek and J.M. Klopatek in their article "Nitrifiers and mycorrhizae in pristine and grazed pinyon-juniper ecosystems" (1997) analyzed the impact of anthropogeneous influence on VA-mycorrhiza and ecto-mycorrhiza formation in pine forests with juniper underbrush, but they did not identify species belonging to mycorrhizal fungi.

Polish scientists J. Blazkowski, T. Madej, M. Tadych in the article "*Entrophospora baltica* sp. nov. and *Glomus fuegianum*, two species in the Glomales from Poland" (1998) inform about the extraction of mycorrhizal fungus *Glomus fuegianum* from rhizosphere of *Juniperus communis* growing on sandy dunes.

Americans C. Roberts and J.J. Allen studied microbiology of wormwood and juniper rhizospheres, but in the article "Soil patchiness in juniper-sagebrush-grass communities of central Oregon" (2000) they only briefly touch upon the presence of endomycorrhiza in these plants, but do not provide the data on its species structure.

Probably, nobody else worked on juniper fungi so much as Swedish scientists K. Holm and L. Holm who purposefully studied this subject over more than 25 years. In 1977 they published the monograph "Nordic junipericolous Ascomycetes" in which 64 species of 48 genera and 24 families were described. The data are based on herbarium material treatments from Sweden, Norway, Finland, Germany, and Iceland. The authors consider the micromycetes only on *Juniperus communis* and *J. communis* subsp. *nana*. They described new taxa or reconsidered taxonomic position of 15 ascomycete species, as well as large work on juniper ascomycetes synonymy arrangement was carried out. Examples are *Dasyscyphus borealis* K. Holm & L. Holm 1977, *D. juniperinus* K. Holm & L. Holm 1977, *Gremmeniella juniperina* K. Holm & L. Holm 1977, and *Mollisia juniperina* K. Holm & L. Holm 1977. Besides, problems of the fungi geographical distribution and ecology take a big place in the book.

The other biggest expert in juniper-associated fungi is a Swiss mycologist O. Petrini, being engaged in this subject since 1970.

Should be to note that F.E. Carroll and G.C. Carroll worked at the same time in similar direction. Thus, the significant article "Preliminary studies on the incidence of needle endophytes in some European conifers" by F.E. Carroll, E. Müller, and B.C. Sutton appeared in 1977. The article of G.C. Carroll and F.E. Carroll "Studies on the incidence of coniferous needle endophytes in the Pacific Northwest" (1978) introduces the bases of endophytes extraction modern technique from coniferous breeds tissue. The proposed methods were considerably improved by O. Petrini in his doctoral thesis "Untersuchungen über endophytische Pilze von *Juniperus communis* L." (1978) written under the supervision of E. Müller. He isolated from living tissues of juniper 24 species of ascomycetes, 2 species of basidiomycetes, 44 hyphomycetes, and 39 coelomycetes. Two works on the same problem were published by him in co-authorship with E. Müller — "Pilzliche Endophyten am Beispiel von *Juniperus communis* L.", and E. Müller and G.J. Samuels — "*Holmiella sabina* (de Not.) comb. nov. (syn. *Eutrybliidiella sabina*) and its *Cornicularia*-like anamorph, an endophyte of *Juniperus* species", both in 1979. Then O. Petrini in co-authorship with G.C. Carroll considered junipers endophytes of North America in the paper "Endophytic fungi in foliage of some Cupressaceae in Oregon" (1981).

The wider theme of O. Petrini the second thesis "Zur Verbreitung und Oekologie endophytischer Pilze" (1984) did not prevent him to advert to juniper but he also listed the plenty of new facts concerning juniper endophytes species structure and ecology.

Great volume of information, including data on fungi developing on various juniper species, is shown in the American Phytopathologists Society digest "Fungi on plant and plant products in the United States" (1989). Authors collective including D.F. Farr, G.F. Bills, G.P. Chamuris, and A.Y. Rossman indicates 294 species of fungi for 19 juniper species occurring in the USA. From them 10 species belong to Oomycetes (6 species of *Phytophthora* and 4 — *Phythium*), 63 species to Ascomycetes, 149 to Basidiomycetes (including 27 *Gymnosporangium* species), 61 to Deuteromycetes (including 28 – Hyphomycetes, 31 – Coelomycetes, and 2 species of *Rhizoctonia*).

Now we go to Soviet researchers of this theme, many of which continue to work already as Russian, Ukrainian, Georgian, etc. mycologists.

Juniper was considered in a number of Soviet monographs, dissertations, and large articles. The most of them belong to the field of botany, but a section devoted to juniper diseases, including fungal ones, present in many works, though sometimes it is very brief. Botanical works are interesting for us since they include the additional data about host. Especially it should to mark the work by K.D. Mухamedshin and N.K. Talantsev "Juniper forests" (1982).

The data about junipericolous fungi are available almost in all large reports on regional mycobiotas, in many identification books and monographs devoted to various fungal groups.

Several common ascomycete species developing on juniper are reported in works of N.A. Naumov, S.A. Gucevič, B.A. Tomilin, M.F. Smitskaja, A.G. Raitviir, and L.N. Vasilyeva.

Lophodermium juniperinum is the species described by all the authors. The species *Mytilinidion tortile* on juniper bark is reported by N.A. Naumov in his handbook (1964). Two operculate species, *Pithya cupressi* and *P. vulgaris* are described in Ukrainian handbooks (Morochkovs'kyi et al., 1969; Smitskaja, 1980).

During many years the fungi of Crimea were studied by a mycologist from Leningrad S.A. Gucevič. To her survey of rust fungi we will refer later. Several sac fungi species new to science were described by S.A. Gucevič on Cupressaceae representatives, including *Lophiotrema juniperinum* on *Juniperus sabina* bare wood and bark (Gucevič, 1970). It is worth to note that before her find the fungi from the genus *Lophiotrema* were not considered to develop on gymnosperms.

Three interesting for us ascomycetes from the genus *Mycosphaerella* Johans were treated by B.A. Tomilin: *M. juniperi* (Fautrey & Roum.) Tomilin 1966, *M. juniperina* (Ellis) Tomilin 1969, and *M. silvatica* (Sacc.) Petr. & Syd. 1882. Later the first species was referred to synonyms by the author, and in the monograph "The fungi of the genus *Mycosphaerella* Johans. identification book" (1979) he gives only two last species growing on juniper. In the same time L. Holm considers *M. silvatica* as a synonym of *M. juniperina*. In a large-scale work on Russian Far East fungi "Pyrenomycetidae et Loculoascomycetidae" (1998) L.N. Vasilyeva considers *M. juniperina* and *M. silvatica* to be two different species, the first is referred to synonyms of *M. maculiformis*. She also considered the species *Anthostomella formosa* and *Valsa friesii*. It should to point out her article "Neuere Aufsammlungen stromatischer Pyrenomyceten aus Österreich, insbesondere der Steiermark" published in 1996 in co-authorship with Austrian mycologist Ch. Scheuer in which, in particular, *Valsa juniperina* is reported.

Returning to the genus *Mycosphaerella* we can note one more species reported by Russian mycologists — *M. punctiformis* in the article by B.A. Grishkan and B.A. Tomilin "Micromycetes in tundris systematis fl. Taimyra Superior (paeninsula Taimyr) inventi".

We can find data on sac fungi on juniper in various "floras": the volumes of "Kazakhstan fungus flora" devoted to ascomycetes (Shvartsman, Kazhieva, 1976; Vasyagina et al., 1987) contain data on 7 species, "Uzbekistan fungus flora" (Guly-

amova et al., 1990) — 4 species, “Ukraine fungi identification book” (Morochkovs’kyi et al., 1969) — 4 species, “Identification book of the Ukrainian SSR pyrenomycetes” (Smitskaja et al., 1986) — 3 species.

According to the well-known handbook “The Polyporaceae of the European USSR and the Caucasus” by A.S. Bondartsev juniper is indicated as a substratum for 6 species, and as the preferable host for 2 species — *Xylodon millavensis* (Bourdot & Galzin) Bondartsev 1953 and *Coriolellus heteromorphus* (Fr.) Bondartsev & Singer 1941 (*Antrodia heteromorpha*). Besides, there are some new combinations proposed by him individually or in co-authorship with R. Singer for the fungi found later by other mycologists on juniper: *Bondarzewia berkeleyi* (Fr.) Bondartsev & Singer 1941, *Phellinus pini* (Brot.) Bondartsev & Singer 1941, and *Byssocorticium atrovirens* (Fr.) Bondartsev & Singer 1944.

Twelve aphyllorphoroid species on juniper bark and wood are indicated by M.A. Bondartseva and E. Parmasto in issues from the series “Clavis diagnostica fungorum USSR / Definitorium fungorum Rossiae” (Bondartseva, Parmasto, 1986; Bondartseva, 1998).

A contribution to the study of aphyllorphoroid fungi on juniper, especially resupinate forms, was done by Estonian mycologist E. Parmasto. In his works, first of all in “Conspectus systematis Corticiacearum” (1968) he discussed several species regarded in our checklist. The holotype of a new species *Atheloderma mirabile* Parmasto 1968 (*Hyphoderma mirabile*) describing in the monograph was collected on juniper.

Perhaps deuteromycetes remain still the least studied component of juniper mycobiota. Telling about the research in this field, first of all it should to note monographs and articles written by V.A. Melnik and co-authors. In the atlas “Imperfect fungi on tree and bush species” (Melnik, Popushoi, 1992), in books from the series “Definitorium fungorum Rossiae” (Melnik, 1997, 2000), and in articles devoted to some finds of imperfect fungi on juniper rare species (e.g. Melnik, Belomesyatseva, 2001a) there are the data on *Asperisporium juniperinum*, *Conoplea juniperi*, *Dicyma pulvinata*, *Dendryphiopsis atra*, *Troposporella monospora*, *Matsushimaea fasciculata*, and *Ojibwaya perpulchra*.

Ukrainian mycologist T.V. Andrianova proposed a new combination for a frequently occurring on juniper bark coelomycete species — *Septoria sabinae* (Sacc. & Fautrey) Andrian. (1999; basionym *Rhabdospora sabinae*).

The monograph “Fungi of the genus *Cytospora* Fr. in the USSR” by M.N. Gvritshvili contains the data on 5 species recorded on 3 *Juniperus* species: *C. kunzei*, *C. leucosperma*, *C. leucostoma* f. *ferruginea*, *C. pinastri*, and *C. sacculus*.

Returning again to regional “floras”, it should to note first of all the book series of S.R. Shvartsman with co-authors “Kazakhstan spore plants flora. Imperfect fungi” (Byzova et al., 1968; Shvartsman et al., 1971, 1973, 1975). It includes morphological descriptions of 9 species found on juniper, and the protologue of a new coelomycete, *Coniothyrium juniperi* Shvartsman 1968 collected on *Juniperus seravschanica* branches in Tien Shan.

A single fungus species on *Juniperus zeravschanica* is described in “Uzbekistan fungus flora. Hyphomycetes” (Sagdullaeva et al., 1990).

In brief we can review main books containing data on the genus *Gymnosporangium*.

The fundamental V.G. Tranzschel's work "Rust fungi of the USSR survey" (1939) includes complete data on teliostage collections on 8 juniper species, and the key to 14 *Gymnosporangium* species known for the USSR; more 5 Japanese species are reported without detailed diagnoses. Besides, V.G. Tranzschel published a new species *Gymnosporangium turkestanicum* on *J. turkestanica* from Central Asia.

Famous Soviet uredinologist V.F. Kuprevich in the co-authorship with V.I. Uljanishchev in "Rust fungi of the USSR identification book", published already after V.F. Kuprevich death (Kuprevich, Uljanishchev, 1975a, 1975b), give the description of 17 *Gymnosporangium* species, but also with a note on possible finds of Japanese species in the Soviet Far East.

In V.I. Uljanishchev's multivolume work "Azerbaijan mycoflora", the genus *Gymnosporangium* (Vol. 2, 1967) for Central Asia and Caucasus includes 6 species. The work is of special value for us because the author carried out an areology analysis of these fungi, and the geographical elements proposed by him are widely applied in the former Soviet fungal geography.

In "Survey of Crimean rust fungi" S.A. Gucevič (1952) discusses 3 *Gymnosporangium* species developing on *J. excelsa*, *J. foetidissima*, *J. oxycedrus*, and *J. sabina*.

It is impossible to miss one of the best Soviet handbook on this group "Far East rust fungi" by Z.M. Azbukina (1974). In addition to the description of 6 species collected in this region, the author gives much data on *Gymnosporangium* geography and ecology, and also discusses a number of nomenclature and taxonomical problems (for example, position of *G. juniperinum*, *G. juniperi*, etc).

The books by Ya.I. Korbonskaja "Central Asia and Southern Kazakhstan rust fungi identification book" (1969) and later "Fungi of Tadjikistan: an ecology-systematical list" (1990) contain rather rich list of species on *Juniperus*, including 7 *Gymnosporangium* species recorded on *J. turkestanica* and *J. seravschanica*. In co-authorship with Z.M. Azbukina she described a new species on *J. turkestanica* leaves from Tadjikistan: *G. gjaerumii* Korbonsk. & Azbukina 1997.

Six species of *Gymnosporangium* occurring on 6 juniper species are described in "Ukraine fungi identification book" in the volume devoted to the subclassis Phragmobasidiomycetidae (Zerova et al., 1971). The appropriate section was written by S.F. Morochkovs'kyi and M.F. Smitskaja.

The composition of an identification book on Lithuanian rust fungi by A.J. Minkevičius (1984) is based on host preferences. The author considers 5 fungal species on 4 juniper species.

Judging from the sources discussed above the most frequent species in the former Soviet Union area are *Gymnosporangium clavariiforme*, *G. juniperi*, *G. confusum*, and *G. cornutum*.

Now let us go to consideration of monographs collecting the data on fungi belonging to various systematic groups. As a rule, in such works concerning junipericolous fungi the biggest emphasis is placed on *Gymnosporangium* species and some the most common pathogens, e.g. *Lophodermium* and *Colpoma*.

First of all it would be worth to look at S.A. Simonian's monographs "Fungal parasites of Armenian SSR botanical gardens plants" (1965) and "Armenian SSR botanical gardens and dendroparks mycoflora" (1981), though she noticed only a small amount of typical juniper fungi species. However, a great interest is excited by the comparative analysis of the pathogens affect degree for 24 gymnosper species, including 6 species of juniper. The juniper belongs to the steadiest to fungal attack. The second important element giving special value to S.A. Simonian monographs is discussed by the author system of coenological analysis of connections between autotroph and its mycobiota, and also inside fungal community. Should to not also the work by Simonian and Barsegyan (1985) concerning juniper phylloplane fungi.

The authors of "Kirgiz SSR fungus flora" (Pospelov et al., 1957) among junipericolous fungi consider exclusively rust ones. The same can be said about the surveys "Mycoflora of Northeast Armenia" by D.G. Melik-Khachatryan (1964), "Southwest Central Tien Shan micromycetes" by N.A. Gamalitskaya (1964), and "Nakhichevan' ASSR mycoflora" by T.M. Ahundov (1979).

Agents of rust and needlecast are reported in the monograph by K. Brundza "Lithuanian SSR cultivated plants parasitic fungi" (1961), where juniper is considered as a cultivated official plant.

Two *Gymnosporangium* species, and one species from each ascomycetes, imperfect, and aphyllorphoroid fungi are considered in the book by T.S. Panfilova and N.I. Gaponenko "The Angren River Basin mycoflora" (1963).

In "Terskey Ala-Too Mountain Ridge of Kirgiz SSR mycoflora" (1966) A.A. Domashova considers in details and illustrates the species *Caldesia sabina* (*Holmiella Sabina*).

Rather many species (12) are listed in "Zailiiskii Alatau mycological flora" by B.K. Kalymbetov (1969). The species *Amphisphaeria umbrina*, *Trematosphaeria buelioides*, and *Alternaria rudis* (*Peyronelia rudis*) can be classified as rare finds for juniper.

Juniper needlecast agent only is reported by P. Pöldmaa and A.G. Raitviir in "Materials to Yenisei-Khatanga Watershed forest tundra fungi flora" (1972).

In the first volume of "Southern Turkmenistan micromycetes" by Ye.N. Koshkelova (1977) 4 species of ascomycetes and 4 coelomycetes are reported besides the ordinary rust species.

A series of junipericolous species is given by Ya.I. Korbonskaja in the ecology-systematical survey "Fungi of Tadjikistan" (1990): besides *Gymnosporangium* 5 other Basidiomycota species, 2 ascomycetes, and 4 deuteromycetes.

A preliminary checklist of Ukrainian fungi edited by D.W. Minter and I.O. Dudka (1996) includes 11 species on junipers — rusts, needlecast agent, and 4 lichenized ascomycetes.

Three myxomycetes, 2 ascomycetes and 1 *Gymnosporangium* species are reported in "Fungi of Russian Arctic" (Karatygin et al., 1999).

In the collection of systematic checklists "Biodiversity of Leningrad region" (1999) M.A. Bondartseva, I.V. Zmitrovich, and V.M. Lositskaja reported 6 basidiomycetes on juniper and also provide data about the development of an interesting species *Tremella juniperina* P. Karst. on *Colpoma juniperi* fruitbody. In the same book

I.N. Tikhomirova and A.V. Tobias listed 3 species of rust fungi and Yu.K. Novozhilov 5 species of myxomycetes on juniper.

The ability of juniper to form mycorrhiza was a subject of consideration of a number of authors. Should to mention N.V. Lobanov's monograph "Woody plants mycotrophy" (1953) and "Woody species mycotrophy" by N.K. Shemakhanova (1962). Both authors studied juniper ectomycorrhiza, but come to negative results about such symbiosis.

In the work "Mycosymbiotrophism as a form of consortive connections in the Soviet Union plant cover", published by I.A. Selivanov in 1981, juniper zygomycete endomycorrhiza is mainly considered. He underlines that mycelium and vesicules develop not only in the intercellular space, but also inside many cells of juniper roots that testifies about "balanced" interactions between the fungus and the host.

Another work devoted to this question is the article "Mycosymbiotrophism development in Tien Shan juniper in different ecological conditions" (Shkaraba, Mukhamedshin, 1981). The authors came to the conclusions about VA-endomycorrhiza development mainly in intercellular space, and mycorrhizal roots were found by them in all selected samples. Depending on the altitude and slope exposition mycorrhiza-formation intensity changed to a small degree only. The seasonal fluctuations were observed: some increase of mycorrhiza-formation intensity by the end of a vegetative season was registered.

A question about *Cenococum* sp. infection of juniper was briefly considered by V.I. Shubin in the monograph "Northwest European part of the USSR mycorrhizal fungi" (1988), and in monograph by Katenin (1972).

To complete the picture of juniper relations with agaricoid basidiomycetes, it is necessary to consider the usage of it remnants by litter saprotrophs. In this connection the greatest interest is excited by the species described in alvars and juniper stands. Thus, Estonian mycologist K. Kalamees in 1987 published the diagnoses of 4 new species and 1 new form growing on *Juniperus* remains in Uzbekistan juniper stands: *Hydropus flocculinus*, *Lepista juniperi*, *Melanoleuca brunnea*, *Mycena pura* f. *roseobrunnescens*, and *Omphalina fuliginea*. The agaricoid fungi growing in alvars were regarded by J.J. Barkman (1985).

Many experts were engaged in the study of juniper diseases and the working out of the appropriate protective actions.

Ukrainian phytopathologist S.F. Negrutsky adverted to juniper over the all his scientific activity. Since the end of 1950th and in subsequent decades he studied ecology and biology of *Heterobasidion annosum* root rot of juniper, the root damage agent attacking many other conifers (e.g. Negrutskii, 1960)

Junipers diseases in Caucasus were studied by T.D. Garshina and the appropriate article was published in 1968. She studied trunk and branches decay of different genesis and needlecast. The greatest interest attracts her data about high attack degree of trees by *Gymnosporangium* sp. and its high harmfulness (dying back up to 96%), which is considered to be rather rare event.

Fifteen fungi species, mainly aphyllorphoid ones, causing juniper wood decay of different types are discussed in a handbook "Fungi and fungal diseases of trees and shrubs" by N.A. Cheremisinov, S.F. Negrutskii, and I.I. Leshkovtseva (1970).

This book in general repeats the data from Vanin's manual on forest pathology (1938).

According to the article of Crimean mycologist V.P. Isikov "Diseases of *Juniperus excelsa* in the Crimea" (1986) the most widespread fungus on it was *Gymnosporangium dobrozrakovae* Mitrofanova. The amount of the trees attacked by the pathogen reached 75%. The author reports also several wood-decay polyporoid fungi.

The article by S.V. Kharlamova "The state of common juniper in natural stands of the Republic of Marii El" (1997) is also connected with this problem.

Small in volume, but important for this theme is T.V. Galas'eva and E.S. Sokolova's work "Juniper needlecast epiphytotic" (1991). It touches the question of drastic increase of needles shrinkage and dying back of this plant in the Eastern Europe.

Now let us advert to the state of juniper-associated fungi research in Belarus.

Belarus fungi begun studied since the end of 18th century. However, juniper-inhabiting ones were very poor documented until the beginning of our research. The earliest data belong to 1786 when Russian naturalist A. Meier carried out a description of Krichev County nature (the manuscript was published only in 1901), where he listed among different living organisms "Gubka yelovaya (spruce sponge) and on juniper stumps growing. *Tremella Juniperina* L.". This rather strange indication contains mixed data on presumably a polypore species (gubka yelovaya) and a species from the genus *Gymnosporangium* (*Tremella juniperina*).

Should to note an article by M.A. Shcherbakova, a collaborator of V.F. Kuprevich laboratory, about the culture of *Gymnosporangium juniperi-virginiana* *in vitro* (1960).

Belarusian aphyllorhizologist E.P. Komarova reported two species on juniper: *Athelia galzinii* (*Leptosporomyces galzinii*) and *Gloeocystidiellum radiosum* (*Vesiculomyces citrinus*; Komarova, 1966; Komarova et al., 1968). Besides she proposed new combinations for 3 species found on juniper by other authors: *Oxyporus subacidus* (Peck) Komarova 1961 (*Perenniporia subacida*), *Ceraporia purpurea* (Fr.) Komarova 1964 (*Ceriporia purpurea* (Fr.) Donk 1971), and *Coriolus serialis* (Fr.) Komarova 1964 (*AnTRODIA serialis*; Komarova, 1961, 1964).

The long-term research of Belarus Uredinales was carried out by I.S. Girilovich at the Department of Botany, Belarus State University. In 1990 he defended the dissertation "Powdery mildew and rust fungi of Belarus (species composition, distribution, harmfulness)". He recorded 4 *Gymnosporangium* species, but mainly in aecial stage on Rosaceae.

Six corticioid species on juniper are reported by E.O. Yurchenko in the article "Consortive bonds of corticioid fungi (Basidiomycetes) with vascular plants (*Plantae vasculares*) of Berezina Biospheric Reserve" (2000) and one in the article "Annotated list of non-poroid Aphyllorhizales of Belarus" (2003).

Studying agaricoid fungi in Belarus pine forests O.S. Gapienko came to the conclusion about the wholesome influence of juniper underbrush on mycorrhizal species diversity and the rise of mushroom production (Gapienko, Kobzar, 1998). It confirms the data of I.A. Selivanov about the positive influence of joint growth of some woody species on macromycetes fructification (Selivanov, 1981). Later

Ya.A. Shaparava mentions similar regularity for several species of the Russulales (Shaparava, 2000; Belomesyatseva, Shaparava, 2001).

The most significant works on forest pathology in Belarus belong to N.I. Fiodorov, especially his monograph "Conifers root rots" (1984) and the manual "Forest phytopathology" (1992, 2004), where he considers some juniper diseases — *Heterobasidion* root rot and needlecast, caused by *Herpotrichia juniperi* and *Lophodermium juniperinum*.

His follower V.B. Zvjagintsev thoroughly studied the development and distribution of honey agaric *Armillaria borealis* Merxm. & Korhonen in Belarus. The fungus attacks various woody species, including common juniper (Zvjagintsev, 2003).

In all 820 fungi and myxomycetes species are known on the genus *Juniperus* representatives according to the collected data. Basidiomycota (excluding rust fungi), Ascomycota, and anamorphic fungi take up approximately equal portions (260, 243, and 233 species respectively) in the structure of juniper-associated mycobiota known from published sources.

However this proportion changes a little if we consider fungi on different juniper species (Fig.).

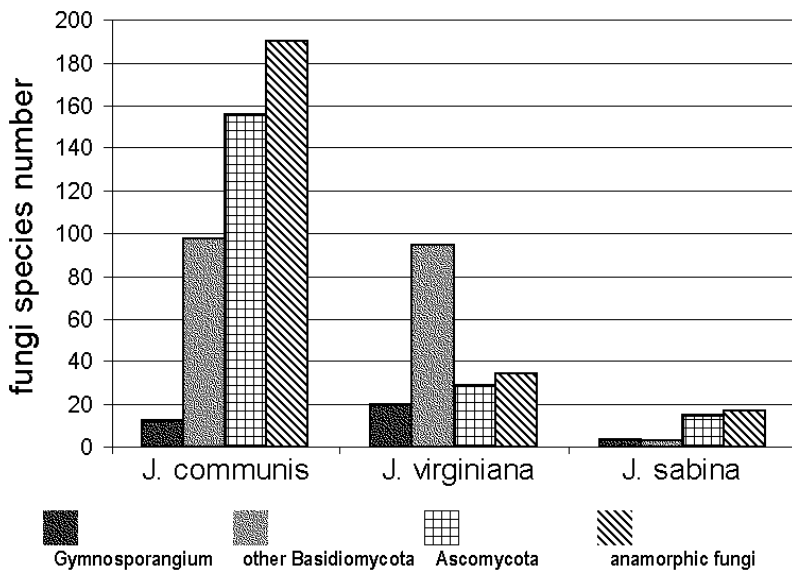


Fig. The main fungal groups ratio for three *Juniperus* species (according to generalized literature data).

From Fig. is seen that basidiomycetes on *J. communis* and *J. virginiana* are studied in approximately equal degree. At the same time ascomycetes and anamorphic fungi of *J. virginiana* take only 1/5 of the species number reported in literature for

J. communis. For such widespread species as *J. sabina* is seen that we have ten times less data, than for *J. communis*. Only several fungi species were recorded on junipers having small distribution areas, for example *J. ashei*, *J. flaccida*, and *J. thurifera*. The research level is also reflected in geographical aspect — most species are known from Scandinavia, North America, then – Germany, Switzerland, and France.

Concluding our historical review, we can say that the biggest addition to juniper-associated fungi species diversity data was made by works of L. Holm, K. Holm, and O. Petrini (concerning ascomycetes and deuteromycetes) and by R.L. Gilbertson and A. Bernicchia (concerning aphyllorphoroid fungi).

Comments to the list of species

Most of the currently used names and nomenclature information were derived from *Index Fungorum* (<http://www.indexfungorum.org/Names/Names.asp>).

Main synonyms are listed for the most of species, in general following *Index Fungorum* data. For the fungal taxa authors names and their abbreviations we used the standardized spelling according to Kirk and Ansell (1992). The sanctioning author (Fr.) is indicated separately in species entries, implying the using of “: Fr.” in authorship formulation for all the appropriate names.

The correct names and their authorship formulation for corticioid and some polyporoid and heterobasidiomycetous taxa were checked via CORTBASE vers. 2 (<http://andromeda.botany.gu.se/cortbase.html>, see Parmasto, 1997), and such names are marked by an asterisk, like “**Coniophora arida (Fr.) P. Karst.,***”.

The species are arranged according to the system of *Ainsworth & Bisby's dictionary of the fungi*, 9th edition (Kirk et al., 2001).

The data extracted from *Index of fungi* (1954–1996) are accompanied by simplified references to the appropriate *Index* volume number only. The same quotation principle is used for *Petrak's lists* (1956–1957).

The data on species distribution quoted as “Eastern Europe; Belomesyatseva (2004)” belong to Belarus area.