

Orchids in the Carpathian Basin and their Mycorrhizal Associations

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Summary

Protection of temperate terrestrial orchids is insufficient by saving only the orchid species. Preservation of their habitats, identification and study of their mycorrhizal fungal partners and collective protection of orchids and fungi are also obviously important. Several works studying isolation and identification of mycorrhizal fungi of temperate terrestrial orchids have been published. In the present work, we summarize the mycorrhizal and endophytic fungi identified from orchid roots so far. Beside the well-known mycorrhizal species of the *Rhizoctonia* form genus, more and more basidiomycota and ascomycota are recently identified as orchid mycorrhizal partners and some zygomycota are also reported from orchid roots.

Content

64 orchid species being found in Hungary and 43 of them have been proved to contain fungal structures in their roots, based on mycorrhizal studies. The following table shows the all known fungal taxa isolated from roots and pelotons of these 43 orchid species, based on our data and the relevant literature. Beside the mycorrhizal partners, endophytic and parasitic fungi can also live in orchid roots. Species of families Ceratobasidiaceae, Tulasnellaceae and Sebacinaceae are the traditionally acknowledged mycorrhizal partner species, formerly classified into the *Rhizoctonia* form genus. However, more and more basidiomycota (e.g. species of genera *Russula*, *Inocybe*, and the family Thelephoraceae) and ascomycota (e.g. *Tuber* and *Wilcoxina* species) are recently identified as orchid mycorrhizal partners. Many other species are known as endophytic in orchid roots, for example species of genera *Helotiales*, *Tetracladium*, *Davidiella*, *Leptodontidium* and the family Nectriaceae, while others have been recognized as ectomycorrhizal fungi, e.g. *Tuber* sp., *Wilcoxina* sp. and some species of Cortinariaceae. At last, there are some species which status has not been cleared so far. Ambiguity is increased by the fact that several anamorph taxa have not been matched with the teleomorph stage, for example in the case of *Epulorhiza* anamorph genus, which is divided by molecular analyses to two distant clades: *Epulorhiza* I and *Epulorhiza* II. The teleomorph stage is identified for only *Epulorhiza* I: the genus *Tulasnella*. *Rhizoctonia* form genus is also divided to several anamorph genera and numerous of them have been matched with their teleomorph pair (*Rhizoctonia repens* = *Epulorhiza repens* = *Tulasnella calospora*; *R. solani* = *Moniliopsis solani* = *Thanatephorus cucumeris*; *R. goodyerae-repentis* = *Ceratohiza goodyerae-repentis* = *Ceratobasidium cornigerum*...).

Table I.

The table shows 43 orchid species currently living in Hungary and the dominant fungal taxa isolated from their roots or protocorms. Fungi are grouped by the country of isolation and the referred literature. AT, Austria; BE, Belgium; CA, Canada; CZ, Czech Republic; DK, Denmark; EE, Estonia; FI, Finland; FR, France; DE, Germany; HU, Hungary; IT, Italy; JP, Japan; MM, Myanmar; NL, The Netherlands; NO, Norway; RU, Russian Federation; TR, Turkey; GB, United Kingdom; US, United States; IZ, Zoltan Illyes personal communication; ON, Noémi Ouanphanivanh personal communication; A, Ascomycota; B, Basidiomycota; Ch, Chytridiomycota; Z, Zygomycota.

Orchid species	Dominant mycobiont taxa present	Country	reference
<i>Cypripedium calceolus</i>	<i>Epulorhiza</i> , <i>Epulorhiza</i> II, Tulasnellaceae (B)	EE,HU,CA	17,51,52,58
<i>Cephalanthera rubra</i>	<i>Inocybe erubescens</i> (B)	HU	IZ
	<i>Tomentella</i> (B), <i>Leptodontidium</i> (A), <i>Phialophora</i> (A)	DE	5
<i>C. longifolia</i>	<i>Amphynema</i> (B), <i>Ceratobasidium</i> (B), Cortinariaceae (B), Thelephoraceae (B), Helotiales (A), <i>Leptodontidium</i> (A), Nectriaceae (A), <i>Tetracladium</i> (A), <i>Wilcoxina</i> (A)	EE	1
	<i>Russula</i> , Russulaceae (B)	IT,MM	25,41
	<i>Hebeloma</i> , <i>Tomentella</i> (B)	IT	25
	<i>Meliniomyces</i> (A)	MM	41
<i>C. damasonium</i>	<i>Cortinarius</i> , <i>Inocybe</i> , <i>Tomentella</i> (B)	DE	5
	<i>Thelephora</i> , Thelephoraceae (B)	DE,FR,CZ	5,23,27
	<i>Hymenogaster</i> (B)	DE,CZ	5, 27
	Dipodascaceae (A), <i>Fusarium</i> (A), Helotiales (A), <i>Mortierella</i> (Z),	CZ	27
	Cortinariaceae (B)	FR	23
	<i>Tetracladium</i> (A)	CZ	27,46
	<i>Tuber maculatum</i> (A)	HU	35
<i>Neottia ovata</i>	<i>Rhizoctonia</i> , <i>R. repens</i> (B)	GB,DK	4,11
	<i>Ceratobasidium</i> (B)	GB	60
	<i>Epulorhiza</i> (B)	DK	4
<i>N. nidus-avis</i>	Sebacinaceae, <i>Sebacina</i> , <i>S. dimitica</i> (B)	GB,DE,FR, IT	5,25,30,47
	<i>Trichoderma</i> ? (B)	GB	30
	Agaricales (B), Bolbitiaceae (B), Cantharellales (B), Corticiaceae (B), <i>Laccaria</i> (B), <i>Russula</i> (B), <i>Thelephora</i> (B), <i>Tomentella</i> (B), Terfeziaceae (A), Sarcoscyphaceae (A)	FR	47
<i>Epipactis palustris</i>	Ceratobasidiaceae, <i>Ceratobasidium</i> (B)	DE,HU	5,18,19,34
	<i>Leptodontidium</i> (A)	DE	5
	<i>Epulorhiza</i> II, Tulasnellaceae, <i>Tulasnella</i> (B)	DE,HU	5,18,19,34
	Sebacinaceae, sebacinoid (B)	DE,HU	5,18,19,34
<i>E. microphylla</i>	Tuberaceae, <i>Tuber excavatum</i> , <i>T. aestivum</i> (A)	FR,HU	34,45
	<i>Russula foetens</i> (B)	FR	45
	<i>Cortinarius</i> (B), <i>Hymenogaster bulliardii</i> , <i>H. olivaceus</i> (B), <i>Sebacina</i> (B), <i>Tomentella</i> (B), <i>Wilcoxina mikolae</i> (A)	FR	45
<i>E. atrorubens</i>	<i>Inocybe</i> (B), <i>Leptodontidium</i> (A), <i>Phialophora</i> (A)	DE	5
	<i>Sebacina</i> (B), <i>Tuber</i> (A), <i>Wilcoxina</i> (A)	DE,CZ	5,27
	Agaricomycetes(B), Entolomataceae(B), <i>Iterosonilia</i> (B), <i>Malassezia</i> (B), <i>Tricholoma</i> (B), Arthopyreniaceae(A), <i>Ascochyta</i> (A), <i>Aspergillus</i> (A), <i>Cladosporium</i> (A), Dipodasceaceae(A), <i>Eudarluka</i> (A), <i>Genea</i> (A), Nectriaceae (A), Pyronemataceae (A), <i>Tetracladium</i> (A),	CZ	27

	<i>Volutella</i> (A), <i>Mortierella</i> (Z)		
	<i>Tulasnella</i> , Tulasnellaceae (B)	DE,EE	5,50
	<i>Geopora cooperi</i> , <i>Trichophaea woolhopeia</i> (A)	EE,CZ	27,50
<i>E. helleborine</i>	<i>Ceratobasidium</i> (B)	GB,DE	5
	Tuberaceae, <i>Tuber</i> , <i>Tuber maculatum</i> (A)	CA,CZ,DE, HU,IT,US	5,25,27,34
	<i>Leptodontidium</i> (A)	GB,US,IT, CZ	5,25,27
	Pyronemataceae, <i>Wilcoxina</i> (A)	DE,US,IT	5,25
	<i>Phialophora</i> (A)	US	5
	Agaricostilbomycetidae(B), <i>Clitocybe</i> (B), <i>Hymenogaster</i> (B), <i>Inocybe</i> (B), <i>Malassezia</i> (B), <i>Peniophora</i> (B), <i>Russula</i> (B), Thelephoraceae (B), <i>Trichoderma</i> (B), <i>Trichosporon</i> (B), Tre- mellales(B), <i>Candida</i> (A), Chaetosphaeriaceae (A), <i>Cladosporium</i> (A), <i>Coniosporium</i> (A), Dipodascaceae(A), <i>Exophiala</i> (A), <i>Fusarium</i> (A), <i>Geopora</i> (A), <i>Geopyxis</i> (A), Helotiales(A), <i>Leptosphaeria</i> (A), <i>Nectriaceae</i> (A), <i>Penicillium</i> (A), <i>Plectosphaerella</i> (A), Pleosporaceae(A), <i>Truncatella</i> (A), <i>Volutella</i> (A), <i>Tetracladium</i> (A), <i>Mortierella</i> (Z), Chytridiomycete(Ch)	CZ	27
	<i>Genea</i> , <i>Helvella</i> (A)	CZ,JP	27,32
	<i>Tuber</i> , <i>T. maculatum</i> (A)	HU,JP	32,35
	<i>Hydnotria</i> , <i>Trichophaea</i> (A)	JP	32
	<i>Piloderma</i> (B)	US	5
	<i>Sebacina</i> , Sebacinaceae, sebacinoid (B)	DE,FR	5,61
<i>E. purpurata</i>	<i>Filobasidium</i> (B), <i>Malassezia</i> (B), <i>Russula</i> (B), <i>Alternaria</i> (A), <i>Debaryomyces</i> (A), Dipodascaceae (A), Helotiales (A), <i>Hydnotria</i> (A), <i>Trichocladium</i> (A), <i>Wilcoxina</i> (A)	CZ	27
<i>E. albensis</i>	<i>Ceratobasidium</i> (B), <i>Cryptococcus</i> (B), <i>Malas-</i> <i>sezia</i> (B), Thelephoraceae(B), <i>Alternaria</i> (A), <i>Bionectria</i> (A), <i>Candida</i> (A), Capnodiales(A), <i>Debaryomyces</i> (A), Dipodascaceae(A), <i>Geopy-</i> <i>xis</i> (A), <i>Penicillium</i> (A), <i>Tuber</i> (A), <i>Wilcoxina</i> (A)	CZ	27
<i>Limodorum abortivum</i>	<i>Russula</i> , <i>R. delica</i> , <i>R.chloroides</i> , <i>R.brevipes</i> (B)	IT,FR	15,25
	<i>Gymnomyces</i> (B), <i>Macowanites</i> (B), <i>Tuber melanosporum</i> , <i>T. maculatum</i> (A)	IT,FR	15
	<i>Ceratobasidium</i> (B)	IT	15,36
	<i>Epicoccum nigrum</i> , <i>Fusarium oxysporum</i> (A)	IT	15
<i>Epipogium aphyllum</i>	<i>Inocybe fuscidula</i> , <i>I. subnudipes</i> , <i>I. glabripes</i> , <i>I. dulcamara</i> , <i>I. terrigena</i> (B)	FR, RU, JP	42
	<i>Hebeloma velutipes</i> (B)	JP	42
	<i>Lactarius scrobiculatus</i> (B), <i>Thelephora</i> (B), <i>Xerocomus</i> (B), <i>Metarhizium</i> (A), <i>Neonectria</i> (A), <i>Paecilomyces</i> (A), <i>Protoventuria</i> (A), <i>Olpidium</i> (Ch)	FR	42
<i>Liparis loeselii</i>	<i>Epulorhiza</i> I., <i>E. repens</i> , <i>Tulasnella</i> (B)	HU,CZ,US	8,18,19,20
	<i>Ceratobasidium</i> (B)	HU	18,19,20

<i>Hammarbya paludosa</i>	<i>Epulorhiza</i> I., <i>Tulasnella</i> (B)	HU	18,19
<i>Corallorhiza trifida</i>	Basidiomycetes, <i>Ceratorhiza</i> (B)	CA	58
	<i>Tomentella</i> (B)	GB,US,AT,DE	29,59
	Thelephoraceae (B)	GB, US	29
	<i>Leptodontidium orchidicola</i> (A)	CA	9
<i>Goodyera repens</i>	<i>Ceratobasidium</i> , <i>C. cornigerum</i> , Ceratobasidiaceae, <i>Rhizoctonia stahlii</i> , <i>R. cerealis</i> , (B)	AT, FI, GB, US, CA	2,3,6,8,9, 11,38,48, 49,60,IZ
	<i>Epulorhiza repens</i> , <i>Rhizoctonia borealis</i> (B)	US	8
<i>Spiranthes spiralis</i>	<i>Rhizoctonia repens</i> (B)	TR	44,55,56
	<i>Ceratobasidium</i> (B), <i>Malassezia</i> (B), <i>Rhizoctonia</i> (B), <i>Alternaria</i> (A), <i>Bionectria</i> (A), <i>Davidiella</i> (A), <i>Fusarium</i> (A), <i>Leptosphaeria</i> (A), <i>Monilia</i> (A)	IT	55,56
<i>Orchis militaris</i>	<i>Epulorhiza</i> I, <i>Epulorhiza</i> II, <i>Tulasnella</i> , Tulasnellaceae (B)	HU,EE,BE, IT,NL	18,19,22, 26,34,50,55
	<i>Tetracladium</i> , <i>Tuber</i> (A)	IT	55
	<i>Coprinopsis</i> (B), <i>Cadophora</i> (A), <i>Fusarium</i> (A)	HU	ON
	Ceratobasidiaceae (B)	HU,BE	18,19,22,34
	Sebacinaceae (B)	HU	19,34
<i>O. purpurea</i>	<i>Epulorhiza</i> , <i>Epulorhiza</i> II. (B)	HU,BE	19,22,26
	<i>Ceratobasidium</i> , Ceratobasidiaceae (B), <i>Tulasnella</i> , Tulasnellaceae (B)	IT,BE	14,22,25
	<i>Davidiella</i> (A)	IT	55
<i>O. mascula</i>	<i>Thanatephorus ochraceus</i> , <i>T. orchidicola</i> (B)	GB	40,60
	Tulasnellaceae (B)	BE	21
<i>O. simia</i>	Tulasnellaceae (B)	FR	43
<i>Platanthera bifolia</i>	<i>Epulorhiza</i> I. (B)	HU	17
	<i>Rhizoctonia</i> , <i>R. repens</i> (B)	GB	16
	<i>Thanatephorus</i> (B)	IT	28
<i>P. chlorantha</i>	<i>Ceratobasidium</i> , Ceratobasidiaceae (B), <i>Tulasnella</i> , Tulasnellaceae (B), <i>Leptodontidium</i> (A), <i>Phialophora</i> (A)	DE	5
	<i>Rhizoctonia stahlii</i> , <i>Rhizoctonia</i> (B)	GB	6,16
<i>Gymnadenia conopsea</i>	<i>Ceratobasidium</i> (B)	DE,HU	18,19,53
	<i>Epulorhiza</i> I., Tulasnellaceae, <i>Tulasnella calospora</i> (B)	DE,HU,GB	16,18,19, 53
	<i>Cryptococcus</i> (B), <i>Lactarius</i> (B), <i>Russula</i> (B), <i>Sebacina</i> (B), <i>Tomentella</i> (B), <i>Cadophora</i> (A), <i>Cenococcum</i> (A), <i>Exophiala</i> (A), <i>Fusarium</i> (A), <i>Geopyxis</i> (A), <i>Hypocreales</i> (A), <i>Lacnora</i> (A), <i>Leptodontidium</i> (A), <i>Morchella</i> (A), <i>Neonectria</i> (A), <i>Peziza</i> (A), <i>Phialophora</i> (A), <i>Terfezia</i> (A), <i>Tetracladium</i> (A), <i>Verpa</i> (A), <i>Wilcoxina</i> (A)	DE	53
<i>G. densiflora</i>	Ascomycetes	DK	39
<i>Dactylorhiza</i>	Sebacinaceae (B), Ceratobasidiaceae (B)	HU	18,19

<i>incarnata</i>	<i>Epulorhiza I. Epulorhiza II</i> (B)	HU	18,19,34
	<i>Leptodontidium</i> (A)	HU	ON
<i>D. viridis</i>	<i>Epulorhiza anaticula</i> (B)	CA	57
	<i>Moniliopsis anomala</i> (B)	CA	9,10,58
	<i>Thanatephorus ochraceus, T. orchidicola</i> (B)	GB	40, 60
	<i>Ceratobasidium, Ceratobasidiaceae</i> (B)	CA,GB	33,58,60
	<i>Rhizoctonia</i> (B)	GB	16
	<i>Leptodontidium orchidicola</i> (A)	CA	9
<i>D. sambucina</i>	<i>Ceratobasidiaceae, Ceratobasidium</i> (B)	IT	28,37
	<i>Tulasnella or Sebacina</i> (B)	IT	28
	<i>Gyoerffyella</i> (A)	IT	37
<i>D. maculata</i>	<i>Ceratobasidium, Tulasnella or Sebacina</i> (B)	IT	28
<i>D. majalis</i>	<i>Tulasnella deliquescens, T. calospora</i> (B)	DK, DE	4,5,24,33
	<i>Laccaria</i> (B)	DK	24
	<i>Ceratobasidium</i> (B)	DE	5
	<i>Gyoerffyella</i> (A)	IT	37
<i>D. lapponica</i>	<i>Tulasnella</i> (B), <i>Sebacinaceae</i> (B)	NO	33
<i>Neotinea ustulata</i>	<i>Ceratobasidium</i> (B)	GB	54
<i>Himantoglossum adriaticum</i>	<i>Rhizoctonia versicolor</i> (B)	GB	7, 12
	Ascomycetes	GB	7
<i>Anacamptis palustris</i>	Cerato-ceae, <i>Epulorhiza I-II, Tulasnella</i> (B)	HU,IT	14,19,25, ON
	<i>Sebacina</i> (B)	IT	14
	<i>Coprinopsis</i> (B), <i>Fusarium</i> (A)	HU	ON
<i>A. pyramidalis</i>	<i>Papulospora</i> (A?)	TR	13
	Sebacinales (B)	IT	62
<i>A. morio</i>	<i>Tulasnella, T. calospora, Epulorhiza</i> (B)	HU,NO	19,33
	<i>Ceratobasidium cornigerum, Cerato-ceae</i> (B)	GB,BE	21,31
<i>A. coriophora</i>	Ascomycota	HU	ON
<i>Ophrys apifera</i>	<i>Tulasnella</i> (B)	IT	25
<i>O. sphegodes</i>	<i>Ceratobasidiaceae, Epulorhiza II.</i> (B)	HU	18,19
	<i>Tulasnella</i> (B)	IT	25
<i>O. fuciflora</i>	<i>Ceratobasidium</i> (B), <i>Tulasnella</i> (B)	IT	14,25
<i>O. oestrifera</i>	<i>Epulorhiza II., Tulasnella</i> (B)	HU	18,19
	<i>Ceratobasidiaceae</i> (B)	HU	18,19
	<i>Morchella</i> (A)	HU	18

Aknowledgements

This work was supported by a project under the Ányos Jedlik Programme entitled MIKOQUAL and by the project under the National Technology Programme entitled QUTAOMEL.

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