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Title	Rust fungi (Pucciniales) in Changbaishan and the surrounding area, Jilin, China
Author(s)	WENG, Yue-Tai; XUE, Yu; ONO, Yoshitaka
Citation	茨城大学教育学部紀要. 自然科学 = Bulletin of the Faculty of Education, Ibaraki University. Natural science, 66: 19-35
Issue Date	2017-03-30
URL	http://hdl.handle.net/10109/13315
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Rust fungi (Pucciniales) in Changbaishan and the surrounding area, Jilin, China

Yue-Tai WENG * Yu XUE*, Yoshitaka ONO **

(Accepted November 1, 2016)

Abstract

Changbaishan is the highest mountain complex in northeast China and the Korean Peninsula located at 41°41' to 42°51'N and 127°43' to 128°16'E on the border between P. R. China and D. P. R. Korea. Despite well-acknowledged geological and biological diversity in Changbaishan and the surrounding area, fungal diversity was poorly explored. We studied rust fungi collected in the area in 2015 and those listed in literature. This paper reports 120 species in 18 genera of the rust fungi distributed in the area.

Keywords – Geographic distribution • Northeast Asia • Rust fungus diversity • Taxonomy

Introduction

Changbaishan (in Chinese; Paektu-san in North Korean and Baekdu-san in South Korean) is located at 41°41'49"N – 42°51'18"N and 127°42'55"E – 128°16'48"E (<http://www.unesco.org/new/en/natural-sciences/environment/ecological-sciences/biosphere-reserves/asia-and-the-pacific/china/changbaishan/>, accessed 5 October 2016) on the border between P. R. China and D. P. R. Korea, and in Antu County, Jilin Province, P. R. China (Fig. 1). Because it is of volcanic origin with repeated eruptions in the past and the most recent major eruption in 1903, it is composed of several peaks, each exceeding 2500 m above sea level (Fig. 2A), surrounding the crater lake, Heaven Lake. The highest peak is 2744 m above sea level. Changbaishan is the highest mountain complex in northeast China and the Korean Peninsula. Changbaishan exhibits unique geological formation and is covered with characteristic vegetation (Fig. 2B–D). It has been designated as one of the MBA Biosphere Reserves by UNESCO (<http://www.unesco.org/new/en/natural-sciences/environment/sciences/biosphere-reserves/asia-and-the-pacific/china/changbaishan/>, accessed 5 October 2016).

Climatically, the Changbaishan area is classified in the Xiaoshan Da Hinggan Ling, Changbai Shan

*Department of Forestry, School of Forestry, Northeast Forestry University, Harbin, Heilongjian, 150040, P. R. China

**Department of Science Education, College of Education, Mito, 310-8215, Japan

mid-temperate, humid zone (mean January temperature -22.5°C , mean July temperature 21.0°C , annual precipitation 625 mm: Zheng et al. 2010, Zhang and Zheng 2015). In the phytogeographical classification, this area is central to the Northeast China Region of the Sino-Japanese Subkingdom, the Eastern Asiatic Kingdom (Takhtajan 1986, Sun and Wu 2015), where *Pinus koraiensis* Siebold & Zucc. is a representative tree, and *Astilboides* and *Mundenia* (both Saxifragaceae) and *Plagiorhegma* (Berberidaceae), *Brachybotrys* (Boraginaceae), *Diplandrorchis* (Orchidaceae) and *Symphyllocarpus* (Asteraceae) are characteristic components among others. The flora of this region is composed of species of temperate characteristics, containing 1776 species of seed plants in 575 genera, 116 families. The flora of this region has a close affinity to that of northern Japan.



Fig. 1. Location of Changbaishan and the study area in Changbaishan National Nature Reserve and Ardao Baihe in Antu County, Jilin Province, China. The area surveyed in 2015 is encircled by solid line.

The vegetation of the Changbaishan area falls in the category of the temperate mixed coniferous and deciduous broad-leaved forest zones (Fig. 2D; Li et al. 2001, Chen 2015). *Pinus koraiensis* dominates together with *Acer pictum* Thunb. subsp. *mono* (Maxim.) H. Ohashi, *Fraxinus mandshurica* Rupr., *Phellodendron amurense* Rupr., *Populus maximowiczii* A. Henry var. *barbinervis* Nakai (= *P. ussuriensis* Kom.), and *Tilia amurensis* Rupr. var. *amurensis* in this vegetation zone. *Betula platyphylla* Skaczew, *Quercus mongolica* Fisch., *Populus* spp., *Pinus sylvestris* L. var. *sylostensis* and *Larix olgensis* A. Henry occur in the secondary forest where *P. koraiensis* has been removed. Due to the high elevation of Changbaishan, five vegetation types are recognized according to the difference in the elevation: *Betula costata*–*Pinus koraiensis*–*Abies holophylla*–*Ulmus* forests at 700–1100 m; *Pinus koraiensis*–*Abies nephrolepis* forests at 1100–1400 m;

Picea jezoensis–*Abies nephrolepis* forests at 1400-1800 m (Fig. 2C); *Betula ermani* elfin forest at 1800-2100 m; and small shrub-moss and herbaceous alpine meadow/tundra above 2100 m (Fig. 2B).

Despite well-acknowledged geological and biological diversity in Changbaishan and the surrounding area, fungal diversity was poorly explored. We studied rust fungi collected in the area in 2015 and those listed in literature. This paper reports 120 species in 18 genera distributed in the Changbaishan area.

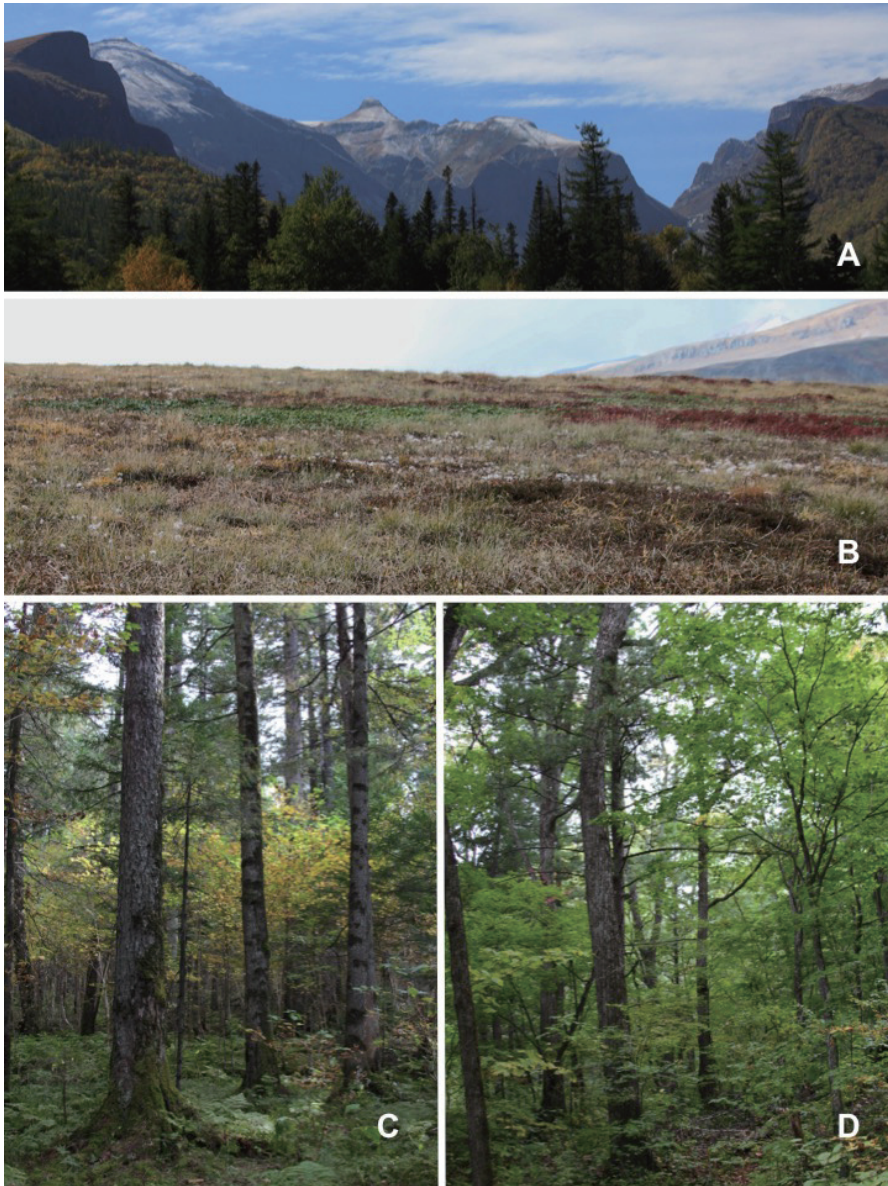


Fig. 2. Vegetation of Changbaishan. A. Peaks constituting the summit of Changbaishan above *Picea jezoensis*–*Abies nephrolepis* forests. B. Alpine meadow at ca. 2400 m. C. *Picea jezoensis*–*Abies nephrolepis* forests at ca. 1600 m. D. Mixed coniferous and deciduous broad-leaved forest at ca. 1000 m.

Materials and Methods

Field survey and specimen collection were undertaken in Changbaishan National Nature Reserve and the Ardao Baihe area (surrounded by solid line in Fig. 1) in September 8–12, 2015. The rust fungus specimens collected in the field survey were deposited in Department of Forestry, Northeast Forestry University and the Herbarium of Systematic Mycology, College of Education, Ibaraki University (IBAR). The specimens are listed under each rust fungus taxon in the Result and Discussion section. The fungus names accepted in Index Fungorum (<http://www.indexfungorum.org>, accessed 26 September 2016) were adopted wherever appropriate in this study. Similarly, scientific names listed in Yonekura and Kajita (2003–. BG plants vernacular name–scientific name index (YList). <http://ylist.info/index.html>, accessed 26 September 2016) were used wherever applicable. Names of collectors were abbreviated in initials: YX (Yue-Tai Wen), YW (Yu Xue) and YO (Yoshitaka Ono).

Microscopic slides were prepared using the methods described by Ono et al. (2012) and Pota et al. (2013). Sorus structure and spore morphology were observed with an Olympus BX51 microscope (Olympus, Tokyo, Japan) and bright-field and differential interference contrast (DIC) optics. Morphological characteristics observed by microscopy and host identity were compared to those described for individual species in the flora fungorum sinicorum (Zhuang et al. 1998, 2003, 2005, 2012), the rust flora of Japan (Hiratsuka et al. 1992) and original descriptions, wherever necessary, for the fungus identification. Published records of the Changbaishan rust fungi were compiled from Xue (1993) and Zhuang et al. (1998, 2003, 2005, 2012). In the Results and Discussion section, rust genera were arranged according to a taxonomic system proposed by Cummins and Hiratsuka (2003). Rust species were listed in alphabetical order under each genus. Map in Fig. 1 were prepared with free blank maps downloaded from “d-maps.com” at http://d-maps.com/pays.php?num_pay=517&lang=en (accessed 26 September 2016).

Results and Discussion

Pucciniastraceae

Hyalopsora aspidiotus (Peck) Magnus on *Gymnocarpium dryopteris* (L.) Newman (Cystopteridaceae): Changbaishan, North Trail, Underground Forest, 12 Sep 2015. YX, YW & YO (IBAR11097); on *Thelypteris phegopteris* (L.) Sloss. ex Rydb. (Thelypteridaceae): Changbaishan, Xue 1993: 36 (the host listed as *Phegopteris polypodioides*).

Hyalopsora hakodatensis Hirats. f. on *Cornopteris* sp. (Athyriaceae), Changbaishan, Xue 1993: 36.

Hyalopsora polypodii (Dietel) Magnus on *Athyrium yokoscense* (Franch. & Sav.) Christ (Athyriaceae): Changbaishan, North Trail, Underground Forest, 12 Sep 2015. YX, YW & YO (IBAR11092).

Melampsoridium alni (Thüm.) Dietel on *Alnus manschurica* (Callier) Hand.-Mazz. (Betulaceae): Changbaishan, Xue 1993: 27, 30 & 36; Changbaishan, North Trail, on a trail to waterfall, 8 Sep 2015. YX, YW & YO (IBAR11023); on S208 to the South Gate, ca. 73 km from Ardao Baihe, 11 Sep 2015. YX, YW & YO (IBAR11057).

Melampsorium betulinum (Pers.) Kleb. on *Betula ermanii* Cham. (Betulaceae): Changbaishan, Xue 1993: 36 & 38 (listed as *Melampsorium betulae*): on *Betula platyphylla* Sukaczew: Changbaishan, Xue 1993: 27, 30 & 33 (listed as *Melampsorium betulae*).

Naohidemycetes vaccinii (Jørst.) S. Sato, Katsuya & Y. Hirats. ex Vanderweyen & Fraiture on *Vaccinium uliginosum* L. (Ericaceae): Changbaishan, Xue 1993: 38 (listed as *Thekopsora vaccinii*); on *Vaccinium vitis-idaea* L.: Changbaishan, Xue 1993: 38 (listed as *Thekopsora vaccinii*).

Pucciniastrum agrimoniae (Dietel) Tranzschel on *Agrimonia pilosa* Ledeb. (Rosaceae): Changbaishan Xue 1993: 28, 31 & 33; East side of Ardao Baihe, 10 Sep 2015. YX, YW & YO (IBAR11051).

Pucciniastrum areolatum (Fr.) G.H. Oth on *Padus racemosa* Lam. (Rosaceae): Changbaishan, on S208 to the South Gate, ca. 73 km from Ardao Baihe, 11 Sep 2015. YX, YW & YO (IBAR11062); on *Picea jezoensis* (Siebold & Zucc.) Carriere (Pinaceae): Changbaishan, Xue 1993: 36 (listed as *Thekopsora areolata*).

Pucciniastrum asterum (Tranzschel) Jørst. on *Aster pekinensis* (Hance) F.H. Chen (Asteraceae): Changbaishan, Xue 1993: 31 (listed as *Thekopsora asterum* on *Kalimeris integrifolia*).

Pucciniastrum brachybotrydis (Tranzschel) Jørst. on *Brachybotryis paridiformis* Maxim. ex Oliv. (Boraginaceae): Changbaishan, on S208 to the South Gate, ca. 60 km from Ardao Baihe, 11 Sep 2015. YX, YW & YO (IBAR11081); Changbaishan, Xue 1993: 28 & 31 (listed as *Thekopsora brachybotrydis*).

Pucciniastrum epilobii (Pers.) G.H. Oth. on *Chamerion angustifolium* (L.) Holub. (Onagraceae): Changbaishan, Xue 1993: 36.; Changbaishan, North Trail, 8 Sep 2015. YX, YW & YO (IBAR11020); North Trail, on a trail to waterfall, 8 Sep 2015. YX, YW & YO (IBAR11025); North Trail, Underground Forest, 12 Sep 2015. YX, YW & YO (IBAR11089); on S208 to the South Gate, ca. 73 km from Ardao Baihe, 11 Sep 2015. YX, YW & YO (IBAR11063 & 11066).

Pucciniastrum goeppertianum (J.G. Kühn.) Kleb. on *Vaccinium vitis-idaea* L. (Ericaceae): Changbaishan, Xue 1993: 35 (listed as *Calyptospora goeppertiana*).

Pucciniastrum guttatum (J. Schröt.) Hyl., Jørst. & Nannf. on *Galium manshuricum* Kitag. (Rubiaceae): Changbaishan, Xue 1993: 30 (listed as *Thekopsora guttata*).

Pucciniastrum rubiae (Kom.) Jørst. on *Rubia argyi* (H. Lév. & Vaniot) H. Hara ex Lauener (Rubiaceae): East side of Ardao Baihe, 10 Sep 2015. YX, YW & YO (IBAR11050); Changbaishan, on S208 to the South Gate, ca. 73 km from Ardao Baihe, 11 Sep 2015. YX, YW & YO (IBAR11056); Changbaishan, Xue 1993: 31 (listed as *Thekopsora rubiae*).

Pucciniastrum tiliae Miyabe on *Tilia amurensis* Rupr. var *amurensis* (Malvaceae): Ardao Baihe, the Northeast Botanical Garden, 12 Sep 2015. YX, YW & YO (IBAR11094); Changbaishan, on S208 to the South Gate, ca. 60 km from Ardao Baihe, 11 Sep 2015. YX, YW & YO (IBAR11082); Changbaishan, Xue 1993: 31 & 34.

Uredinopsis filicina (Niessl) Magnus on *Thelypteris phegopteris* (L.) Sloss. ex Rydb. (Thelypteridaceae): Changbaishan, North Trail, on a trail to Emerald Lake, 8 Sep 2015. YX, YW & YO (IBAR11026); North Trail, Underground Forest, 12 Sep 2015. YX, YW & YO (IBAR11086); Changbaishan, on S208 to the South Gate, ca. 60 km from Ardao Baihe, 11 Sep 2015. YX, YW & YO (IBAR11076); on *Thelypteris* sp.: Changbaishan, North Trail, on a trail to waterfall, 8 Sep 2015. YX, YW & YO (IBAR11022).

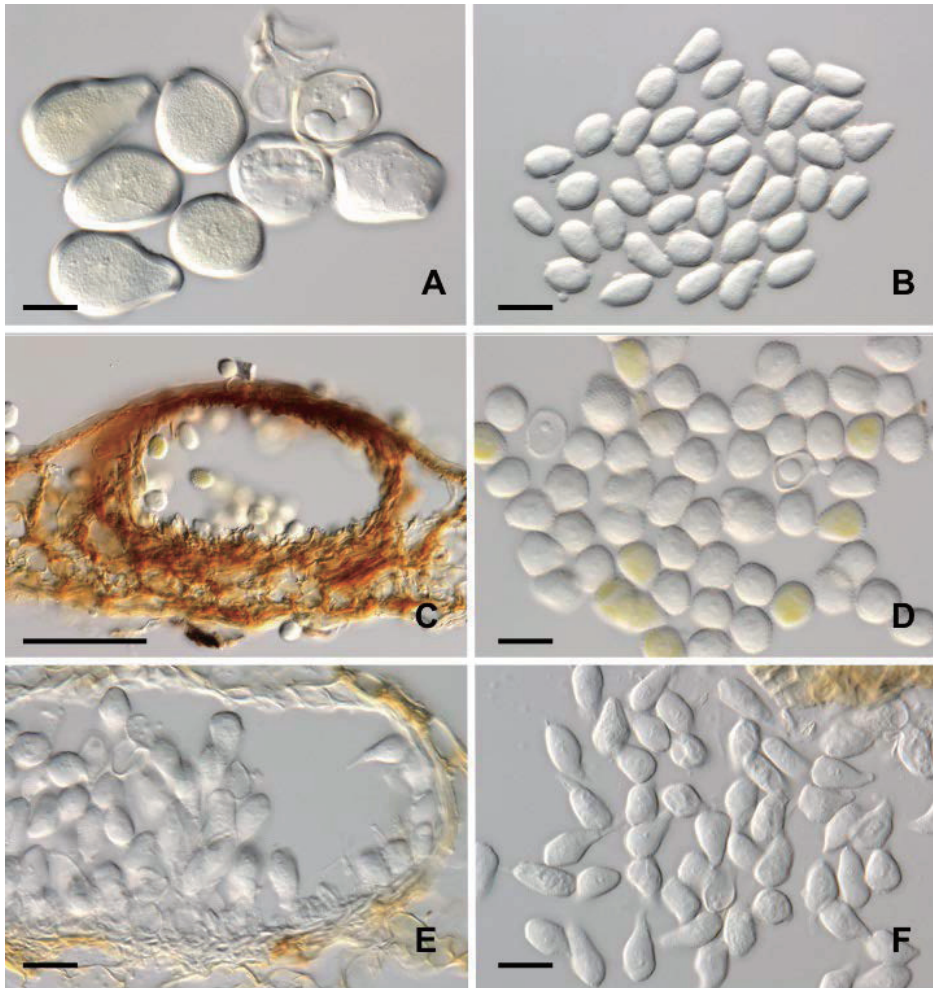


Fig. 2. Uredinium and spores of Changbaishan rust fungi. A. Amphispores of *Hyalopsora aspidiotus* (IBAR11097). B. Urediniospores of *Pucciniastrum areolatum* (IBAR11062). C. Peridiate uredinium of *Pucciniastrum brachybotrydis* (IBAR11081). D. Urediniospores of *Pucciniastrum brachybotrydis* (IBAR11081). E. Uredinium of *Uredinopsis filicina* (IBAR11022). F. Amphispores of *Uredinopsis filicina* (IBAR11022). Bars: 20 μm in A, B, D–F; 100 μm in C.

Uredinopsis ossiformis Kamei on *Dryopteris expansa* (C. Presl.) Fraser-Jenk. & Jermy (Dryopteridaceae): Changbaishan, Xue 1993: 37.

Uredinopsis pteridis Dietel & Holw. on *Pteridium aquilinum* (L.) Kuhn (Dennstaedtiaceae): Changbaishan, Xue 1993: 28 & 33.

Uredinopsis struthiopteridis F.C.M. Störmer on *Matteuccia struthiopteris* (L.) Tod. (Onocleaceae): Changbaishan, Xue 1993: 37.

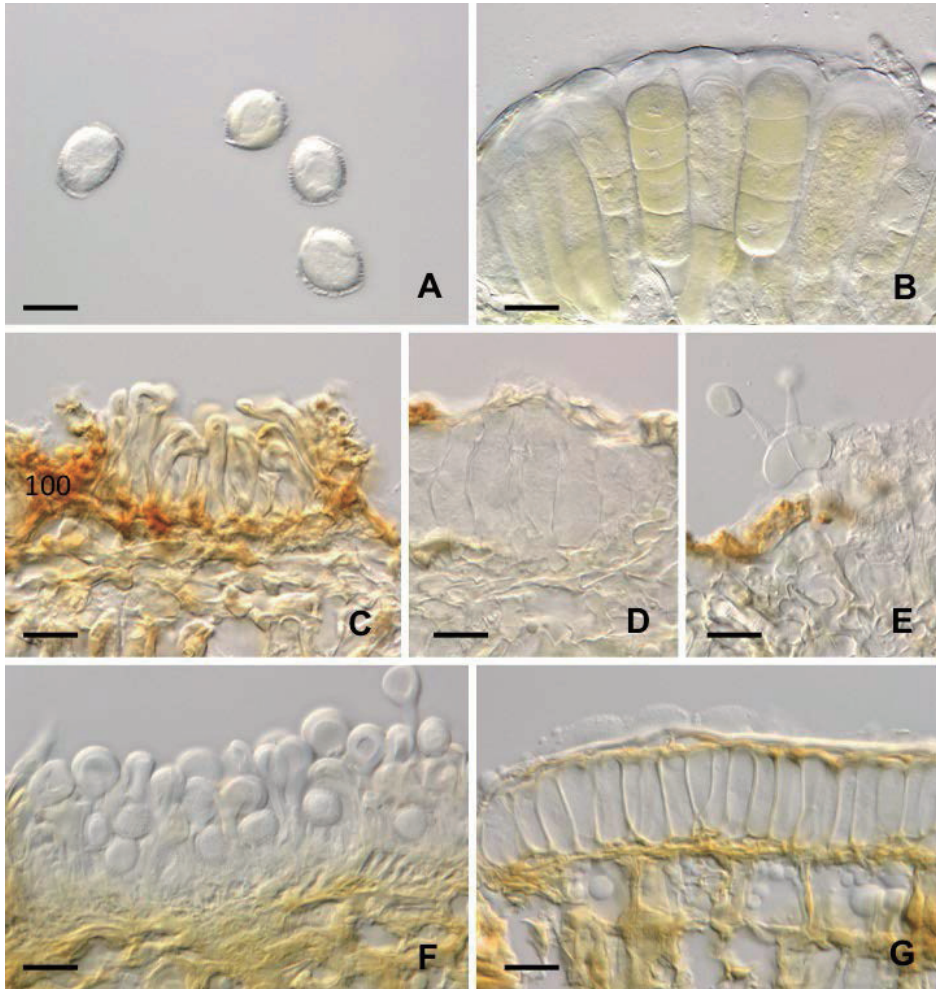


Fig. 3. Sori and spores of Changbaishan rust fungi.. A. Aeciospores of *Chrysomyxa succinea* (IBAR11030). B. One-celled teliospores and four-celled basidia of *Coleosporium tussilaginis* (IBAR11043). C. Uredinal paraphyses of *Aplopsora loniceræ* (IBAR11078). D. Teliospores of *Aplopsora loniceræ* (IBAR11078). E. Basidium and basidiospores of *Aplopsora loniceræ* (IBAR11078). F. Uredinium of *Melampsora epitea* (IBAR11041). Note thick-walled, capitate paraphyses and echinulate urediniospores. G. Telium of *Melampsora epitea* (IBAR11041). Note evenly thin-walled teliospores. Bars: 20 µm in A–G.

Coleosporiaceae

Chrysomyxa succinea (Sacc.) Tranzschel on *Picea jezoensis* Carr. (Pinaceae): Changbaishan, North Trail, on a trail to Underground Forest, 8 Sep 2015. YX, YW & YO (IBAR11030); on *Rhododendron aureum* Georgi (Ericaceae), Changbaishan, Xue 1993: 35 & 38 (listed as *Chrysomyxa ledi* var. *rhododendri*); Changbaishan, South Trail to Heaven Lake, alt. 2100–2200 m, 9 Sep 2015. YX, YW & YO (IBAR11035).

Coleosporium cimicifugatum Thüm. on *Actaea spicata* H. Hara (Ranunculaceae): Changbaishan, Xue

1993: 26, 29 & 35; on *Cimicifuga simplex* (DC.) Wormsk. ex Turcz. (Ranunculaceae): Changbaishan, Xue 1993: 26 & 29; Changbaishan, on S208 to the South Gate, ca. 73 km from Ardao Baihe, 11 Sep 2015. YX, YW & YO (IBAR11055).

Coleosporium clematidis Barclay on *Clematis terniflora* DC. var. *mandshurica* (Rupr.) Ohwi (Ranunculaceae): Changbaishan, Xue 1993: 26 & 32 (the host listed as *Clematis mandshurica*).

Coleosporium neocaliae Saho on *Parasenecio hastatus* (L.) H. Koyama (Asteraceae): Changbaishan, on S208 to the South Gate, ca. 60 km from Ardao Baihe, 11 Sep 2015. YX, YW & YO (IBAR11083); on *Parasenecio auriculatus* (DC.) J. R. Grant: Changbaishan, Xue 1993: 35 (listed as *Coleosporium cacaliae* on *Cacalia auriculata*); on *Parasenecio kamtschaticus* (Maxim.) Kadota: Changbaishan, Xue 1993: 38 (listed as *Coleosporium cacaliae* on *Cacalia kamtschatica*).

Coleosporium phellodendri Kom. on *Phellodendron amurense* Rupr. (Rutaceae), Changbaishan, Xue 1993: 26 & 29; Ardao Baihe, the Northeast Botanical Garden, 12 Sep 2015. YX, YW & YO (IBAR11093); Ardao Baihe, on S208 to the South Gate, ca. 60 km from Ardao Baihe, 11 Sep 2015. YX, YW & YO (IBAR11072).

Coleosporium pini-asteris Orish. on *Aster scaber* Thunb. (Asteraceae): Ardao Baihe, on S208 to the South Gate, ca. 60 km from Ardao Baihe, 11 Sep 2015. YX, YW & YO (IBAR1080); Ardao Baihe, on S208 to the South Gate, ca. 73 km from Ardao Baihe, 11 Sep 2015. YX, YW & YO (IBAR11069).

Coleosporium saussureae Thüm. on *Saussurea grandifolia* Maxim. (Asteraceae), Changbaishan, Xue 1993: 27 & 29.; on *Saussurea pulchella* (Fisch. ex. Hornem.) Fisch., Changbaishan, Xue 1993: 27, 29, 32 & 33; East side of Ardao Baihe, 10 Sep 2015. YX, YW & YO (IBAR11053); On S208 to the South Gate, ca. 73 km from Ardao Baihe, 11 Sep 2015. YX, YW & YO (IBAR11054).

Coleosporium tussilaginis (Per.) Lév. on *Adenophora pereskiiifolia* (Fisch. ex Roem. & Schult.) Fisch. ex G. Don (Campanulaceae): Changbaishan, Xue 1993: 32 (listed as *Coleosporium campanulae*); on *Campanula glomerata* L. subsp. *glomerata* (Campanulaceae): Changbaishan, Xue 1993: 32 (listed as *Coleosporium campanulae*); on *Sonchus oleraceus* L. (Asteraceae): East side of Ardao Baihe, 10 Sep 2015. YX, YW & YO (IBAR11043); Ardao Baihe, the Northeast Botanical Garden, 12 Sep 2015. YX, YW & YO (IBAR11103); on *Senecio cannabifolius* Less. var. *daurica* (Asteraceae): Changbaishan, Xue 1993: 27 & 29 (listed as *Coleosporium senecionis*).

Coleosporium yamabense Saho on *Petasites rubellus* (J.F. Gmel) Toman (Asteraceae): Changbaishan, Xue 1993: 38 (listed as *Coleosporium petasitis* on *Petasites saxatilis*).

Cronartiaceae

Cronartium flaccidum (Alb. & Schwein.) G. Winter on *Paeonia japonica* (Makino) Miyabe & Takeda (Paeoniaceae): Ardao Baihe, the Northeast Botanical Garden, 12 Sep 2015. YX, YW & YO (IBAR11104).

Cronartium ribicola J.C. Fisch. on *Ribes mandshuricum* (Maxim.) Kom. (Grossulariaceae): Changbaishan, Xue 1993: 27.

Melampsoraceae

Melampsora caprearum Thüm. on *Salix capraea* L. (Salicaceae), Changbaishan, North Trail,

Underground Forest, 12 Sep 2015. YX, YW & YO (IBAR11091); on *Salix integra* Thunb.: Changbaishan, Xue 1993: 30 (listed as *Melampsora laricis-caprearum*); on *Salix* sp. (*Salix* cf. *futura* Seemen): Changbaishan, North Trail, on a trail to waterfall, 8 Sep 2015. YX, YW & YO (IBAR11024).

Melampsora epiphylla Dietel on *Salix nummularia* Andersson (Salicaceae): Changbaishan, Xue 1993: 38 (the host listed as *Salix rotundifolia*); on *Salix rorida* Lalsch.: Changbaishan, on S208 to the South Gate, ca. 73 km from Ardao Baihe, 11 Sep 2015. YX, YW & YO (IBAR1060 & 11068).

Melampsora epitaea Thüm. on *Salix* cf. *divaricata* Pall. var. *metaformosa* (Nakai) Kitagawa (Salicaceae): Changbaishan, North Trail, on a trail to Emerald Lake, 8 Sep 2015. YX, YW & YO (IBAR 11027); South Trail to Heaven Lake, alt. 2100-2200m, 9 Sep 2015. YX, YW & YO (IBAR1037, 11038 & 11039); on *Salix integra* Thunb.: Changbaishan, Xue 1993: 30; on *Salix nummularia* Andersson: Changbaishan, South Trail to Heaven Lake, alt. ca. 2400m, 9 Sep 2015. YX, YW & YO (IBAR11041); on *Salix viminalis* L.: Ardao Baihe, the Northeast Botanical Garden, 12 Sep 2015. YX, YW & YO (IBAR11098); on *Salix* sp., Changbaishan, North Trail, on a trail to Underground Forest, 8 Sep 2015. YX, YW & YO (IBAR11034); East side of Ardao Baihe, 10 Sep 2015. YX, YW & YO (IBAR11044); Changbaishan, on S208 to the South Gate, ca. 73 km from Ardao Baihe, 11 Sep 2015. YX, YW & YO (IBAR11061).

Melampsora itoana (Hirats. f.) S. Ito & Homma on *Oxalis acetosella* L. (Oxalidaceae): Changbaishan, on S208 to the South Gate, ca. 73 km from Ardao Baihe, 11 Sep 2015. YX, YW & YO (IBAR1077); on *Oxalis griffithii* Edgew. & Hook. f.: Changbaishan, Xue 1993: 35.

Melampsora laricis-populina Kleb. on *Populus maximowiczii* A. Henry var. *barbinervis* Nakai (Salicaceae), Changbaishan, Xue 1993: 29, 33 (the host as *Populus ussuriensis*); on *Populus nigra* L., East side of Ardao Baihe, 10 Sep 2015. YX, YW & YO (IBAR1046); *Populus simonii* Carriere, Changbaishan, Xue 1993: 29; on *Populus suaveolens* Fischer, Changbaishan, North Trail, on a trail to waterfall, 8 Sep 2015. YX, YW & YO (IBAR11021); East side of Ardao Baihe, 10 Sep 2015. YX, YW & YO (IBAR11049); Changbaishan, on S208 to the South Gate, ca. 73 km from Ardao Baihe, 11 Sep 2015. YX, YW & YO (IBAR11059).

Melampsora magnusiana G.H. Wagner on *Populus alba* L. (Salicaceae): East side of Ardao Baihe, 10 Sep 2015. YX, YW & YO (IBAR11042).

Melampsora populnea (Pers.) P. Karst. on *Populus tremula* L. var. *davidiana* (Dode) C.K. Schneid. (Salicaceae): Changbaishan, Xue 1993: 29 & 33 (listed as *Melampsora laricis* on *Populus davidiana*).

Melampsora rostrupii G.H. Wagner on *Populus* cf. *candicans* Aiton (Salicaceae): Changbaishan, North Trail, Underground Forest, 12 Sep 2015. YX, YW & YO (IBAR11087).

Melampsora salicis-albae Kleb. on *Salix rorida* Laksch. (Salicaceae): Changbaishan, Xue 1993: 33.

Phakopsoraceae

Pucciniostele mandshurica Dietel on *Astilbe chinensis* (Maxim.) Maxim. ex Franch. & Sav. (Saxifragaceae): Changbaishan, Xue 1993: 28 & 31.

Chaconiaceae

Aplopsora lonicerae Tranzschel on *Lonicera maximowiczii* (Rupr.) Regel (Caprifoliaceae): Changbaishan, on

S208 to the South Gate, ca. 73 km from Ardao Baihe, 11 Sep 2015. YX, YW & YO (IBAR11078).

Uropyxidaceae

Triphragmiopsis jeffersoniae Naumov on *Jeffersonia dubia* (Maxim.) Benth. & Hook. f. (Berberidaceae): Antu, Zhuang et al. 2012: 110.

Triphragmiopsis laricinum (W.F. Chou) F.L. Tai on *Larix gmelini* (Rupr.) Rupr. (Pinaceae): Antu, Zhuang et al. 2012: 111; on *Larix olgensis* A. Henry: East side of Ardao Baihe, 10 Sep 2015. YX, YW & YO (IBAR11045); Changbaishan, on S208 to the South Gate, ca. 73 km from Ardao Baihe, 11 Sep 2015. YX, YW & YO (IBAR11065); Changbaishan, Xue 1993: 37; Changbaishan, Zhuang et al. 2012: 111; Antu, Zhuang et al. 2012: 111.

Phragmidiaceae

Phragmidium fusiforme J. Schröt. on *Rosa acicularis* Lindl. (Rosaceae): Antu, Zhuang et al. 2012: 146.

Phragmidium griseum Dietel on *Rubus arcticus* L. (Rosaceae): Changbaishan, Xue 1993: 31 & 34; on *Rubus crataegifolius* Bunge: Antu, Zhuang et al. 2012: 174; East side of Ardao Baihe, 10 Sep 2015. YX, YW & YO (IBAR11047).

Phragmidium kamtschatkae (H.W. Anderson) Arthur & Cummins on *Rosa amblyotis* C.A. Mey. (Rosaceae): Changbaishan, Xue 1993: 32, 33 (the host listed as *Rosa davurica*).

Phragmidium miyakeanum Hirats. on *Rubus mesogaeus* Focke. (Rosaceae): Changbaishan, on S208 to the South Gate, ca. 60 km from Ardao Baihe, 11 Sep 2015. YX, YW & YO (IBAR11075).

Phragmidium montivagum Arthur on *Rosa acicularis* Lindl. (Rosaceae): Antu, Zhuang et al. 2012: 151.

Phragmidium papillatum Dietel on *Potentilla cryptotaeniae* Maxim. (Rosaceae): Antu, Zhuang et al. 2012: 138; on *Potentilla chinensis* Ser.: Changbaishan, Xue 1993: 32.

Phragmidium rosae-multiflorae Dietel on *Rosa acicularis* Lindl. (Rosaceae): Changbaishan, Xue 1993: 36; on *Rosa amblyotis* C.A. Mey.: Changbaishan, Xue 1993: 28 & 32 (the host listed as *Rosa daurica*).

Xenodochus carbonarius Schldtl. on *Sanguisorba stipulata* Raf. (Rosaceae): Changbaishan, South Trail to Heaven Lake, alt. 2100-2200m, 9 Sep 2015. YX, YW & YO (IBAR11040); on *Sanguisorba sitchensis* C.A. Mey.: Antu, Zhuang et al. 2012: 196; on *Sanguisorba tenuifolia* Fisch. ex Link: Antu, Zhuang et al. 2012: 196.

Pucciniaceae

Gymnosporangium clavariiforme Dietel on *Crataegus maximowiczii* C.K. Schneid. (Rosaceae): Antu, Zhuang et al. 2012: 8.

Gymnosporangium tremelloides R. Hartig on *Sorbus pohuashanensis* (Hance) Hedl. (Rosaceae): Changbaishan, Xue 1993: 35.

Puccinia albulense (Magnus) Kuntze on *Veronicastrum sibiricum* (L.) Pennell var. *sibiricum* (Plantaginaceae): Changbaishan, Xue 1993: 31 (listed as *Puccinia veronicarum* on *Veronica sibirica*).

Puccinia alisovae Tranzschel on *Angelica* sp. (Apiaceae): Antu, Zhuang et al. 2003: 111.

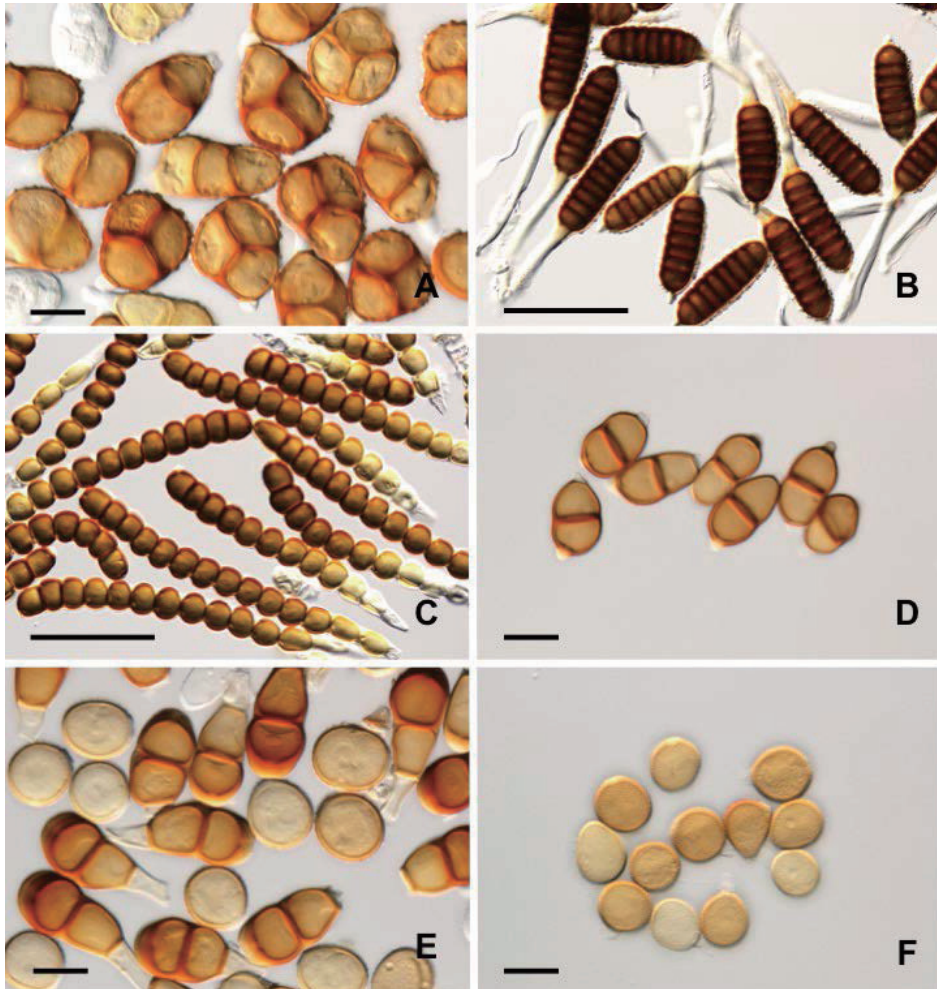


Fig. 4. Teliospores of Changbaishan rust fungi. A. *Triphragmiopsis laricinum* (IBAR11045). B. *Phragmidium miyakeanum* (IBAR11075). C. *Xenodochus carbonarius* (IBAR11040). D. *Puccinia argentata* (IBAR11032). E. *Puccinia hultenii* (IBAR11036). F. *Uromyces heimerlianus* (IBAR11105).

Bars: 20 μm in A, D–F; 100 μm in B & C.

Puccinia allii (DC.) F. Rudolphi on *Allium* sp. (Amaryllidaceae): Antu, Zhuang et al. 1998: 243.

Puccinia angelicae (Schumach.) Fuckel on *Anagelica anomala* Ave-Lall. (Apiaceae): Changbaishan, Xue 1993: 27, 30 & 32.

Puccinia angelicicola Henn. on *Angelica dahurica* (Fisch. ex Hoofm.) Benth. & Hook. f. ex Franch. & Sav. (Apiaceae): Antu, Zhuang et al. 2003: 113.

Puccinia aomoriensis Syd. & P. Syd. on *Atractylodes ovata* (Thunb.) DC. (Asteraceae): Antu, Zhuang et al. 1998: 179 (the host listed as *Atractylodes japonica*); Xue 1993: 31 (the host listed as *Atractylodes japonica*).

Puccinia argentata (Schultz) G. Winter on *Impatiens noli-tangere* L. (Balsaminaceae): Changbaishan,

North Trail, on a trail to Underground Forest, 8 Sep 2015. YX, YW & YO (IBAR11032).

Puccinia artemisiae-keiskeanae Miura on *Artemisia stolonifera* (Maxim.) Kom. (Asteraceae): Antu, Zhuang et al. 2003: 205.

Puccinia arundinellae-anomalae Dietel on *Arundinella hirta* (Thunb.) Tanaka (Poaceae): Changbaishan, Xue 1993: 27.

Puccinia asiatica (Kom.) P. Syd. & Syd. on *Mitella nuda* L. (Saxifragaceae): Changbaishan, Xue 1993: 36; Changbaishan, North Trail, Underground Forest, 12 Sep 2015. YX, YW & YO (IBAR11090).

Puccinia atrofusca (Dudley & C.H. Thomps.) Holw. on *Artemisia selengensis* Turcz. ex Besser (Asteraceae): Antu, Zhuang et al. 1998: 179.

Puccinia baicalensis Tranzschel on *Aegopodium alpestre* Ledeb. (Apiaceae): Antu, Zhuang et al. 2003: 114.

Puccinia behenis G.H. Otth on *Gypsophila oldhamiana* Miq. (Caryophyllaceae): Antu, Zhuang et al. 2003: 49.

Puccinia brachypodii Otth on *Agrostis alba* L. (Poaceae): Antu, Zhuang et al. 1998: 53; on *Anthoxanthum odoratum* L. subsp. *nipponicum* (Honda) Tzvelev (Poaceae): Changbaishan, Zhuang et al. 1998: 53 (the host listed as *Anthoxanthum nipponicum*).

Puccinia bupleuri (Opiz) F. Rudolphi on *Bupleurum longiradiatum* Turcz. (Apiaceae): Changbaishan, Xue 1993: 27 & 30.

Puccinia calcitrapae DC. on *Cirsium schantarense* Trautv. & C.A. Mey. (Asteraceae): Changbaishan, Xue 1993: 27, 30, 32, 36 & 38 (listed as *Puccinia cirsii*); on *Cirsium* sp.: Antu, Zhuang et al. 2003: 210; Changbaishan, North Trail, on a trail to Emerald Lake, 8 Sep 2015. YX, YW & YO (IBAR11028); North Trail, on a trail to Underground Forest, 8 Sep 2015. YX, YW & YO (IBAR11033); Changbaishan, on S208 to the South Gate, ca. 60 km from Ardao Baihe, 11 Sep 2015. YX, YW & YO (IBAR11079).

Puccinia caricis-rhizopodae Miura on *Carex* sp. (Cyperaceae): Antu, Zhuang et al. 1998: 198.

Puccinia circaeae Pers. on *Circaea alpina* L. (Onagraceae): Changbaishan, North Trail, on a trail to Underground Forest, 8 Sep 2015. YX, YW & YO (IBAR11029); North Trail, Underground Forest, 12 Sep 2015. YX, YW & YO (IBAR11084); North Trail, Underground Forest, 12 Sep 2015. YX, YW & YO (IBAR11085); on *Circaea caulescens* Nakai: Antu, Zhuang et al. 2003: 105; Changbaishan, Xue 1993: 36 (the host listed as *Circaea alpina* var. *caulescens*).

Puccinia clintoniae-udensis Bubak on *Clintonia udensis* Trautv. & Mey. (Liliaceae): Changbaishan, Zhuang et al. 1998: 246.

Puccinia cnici-oleracei Pers. on *Artemisia stolonifera* (Maxim.) Kom. (Asteraceae): Antu, Zhuang et al. 2003: 212.

Puccinia coronata Corda on *Poa pratensis* L. (Poaceae): Changbaishan, Xue 1993: 27; on *Rhamnus davurica* Pall. (Rhamnaceae): Changbaishan, Xue 1993: 30 (the host listed as *Rhamnus ussuriensis*); Antu, Zhuang et al. 1998: 62 (the host listed as *Rhamnus ussuriensis*); on *Rhamnus schneideri* Lév. & Vant. var. *manshurica* Nakai: Antu, Zhuang et al. 1998: 62; on *Roegneria turczaninovii* (Drobov) Nevski (Poaceae): Antu, Zhuang et al. 1998: 64; *Roegneria* sp.: Antu, Zhuang et al. 1998: 64.

Puccinia dioicae Magnus on *Carex* sp. (Cyperaceae): Antu, Zhuang et al. 1998: 204.

Puccinia dioscoreae Kom. on *Dioscorea nipponica* Makino (Dioscoreaceae): Changbaishan, Xue 1993: 30.

- Puccinia elymi* Westend. on *Elymus sibiricus* L. (Poaceae): Antu, Zhuang et al. 1998: 74.
- Puccinia glechomatis* DC. on *Meehania urticifolia* (Miq.) Makino (Laminaceae): Changbaishan, on S208 to the South Gate, ca. 73 km from Ardao Baihe, 11 Sep 2015. YX, YW & YO (IBAR11074).
- Puccinia graminis* Pers. subsp. *graminicola* Z. Urb. on *Triticum aestivum* L. (Poaceae): Changbaishan, Xue 1993: 30 (the host listed as *Triticum sativum*).
- Puccinia haleniae* Arthur & Holw. on *Halenia corniculata* (L.) Cornaz. (Gentianaceae): Antu, Zhuang et al. 2003: 149.
- Puccinia helianthi* Schwein. on *Helianthus annuus* L. (Asteraceae): Antu, Zhuang et al. 2003: 221.
- Puccinia hieracii* (Röhl.) H. Mart. on *Taraxacum* sp. (Asteraceae): Antu, Zhuang et al. 2003: 224.
- Puccinia hultenii* Tranzschel & Jørst. on *Rumex acetosa* L. (Polygonaceae): Changbaishan, South Trail to Heaven Lake, alt. 2000m, 9 Sep 2015. YX, YW & YO (IBAR11036).
- Puccinia lactucae-debilis* Dietel on *Ixeris chinensis* Nakai (Asteraceae): Antu, Zhuang et al. 2003: 228.
- Puccinia magnusiana* Körn. on *Phragmites communis* Trin. (Poaceae): Antu, Zhuang et al. 1998: 105.
- Puccinia menthae* Pers. on *Mentha arvensis* L. (Laminaceae): Antu, Zhuang et al. 2003: 168; on *Mentha davurica* Fisch., Changbaishan, Xue 1993: 31.
- Puccinia minussensis* Thüm. on *Lactuca indica* L. (Asteraceae): Antu, Zhuang et al. 2003: 232; Northeast Botanical Garden, 12 Sep 2015. YX, YW & YO (IBAR11100); on *Lactuca triangulata* Maxim.: Changbaishan, Xue 1993: 30; *Lactuca* sp.: Antu, Zhuang et al. 2003: 233.
- Puccinia miyoshiana* Dietel on *Spodiopogon sibiricus* Trin. (Poaceae): Changbaishan, Xue 1993: 30.
- Puccinia nanbuana* Henn. on *Angelica* cf. *anomala* Ave-Lall. (Apiaceae); Changbaishan, on S208 to the South Gate, ca. 73 km from Ardao Baihe, 11 Sep 2015. YX, YW & YO (IBAR11070).
- Puccinia okatamaensis* S. Ito on *Phragmites communis* Trin. (Poaceae): Antu, Zhuang et al. 1998: 120.
- Puccinia orbicula* Peck & Clinton on *Nabulus tatarinowii* (Maxim.) Nakai (Asteraceae): Changbaishan, on S208 to the South Gate, ca. 60 km from Ardao Baihe, 11 Sep 2015. YX, YW & YO (IBAR11071).
- Puccinia polygoni-amphibii* Pers. on *Persicaria thunbergii* (Siebold & Zucc.) H. Gross (Polygonaceae): Changbaishan, Xue 1993: 31 (the host listed as *Polygonum thunbergii*).
- Puccinia polygoni-sieboldii* (Hirats. f. & S. Kaneko) B. Li on *Persicaria sagittata* (L.) H. Gross (Polygonaceae): Antu, Zhuang et al. 2003: 36 (the host listed as *Polygonum sieboldii*).
- Puccinia punctata* Link on *Galium manshuricum* Kitag. (Rubiaceae): Changbaishan, Xue 1993: 27 & 31; Antu, Zhuang et al. 2003: 189.
- Puccinia pygmaea* Erikss. On *Deyeuxia langustifolia* (Kom.) Y.L. Chang ex S.L. Lu (Poaceae): Antu, Zhuang et al. 1998: 142.
- Puccinia recondita* Dietel & Holw. on *Aconitum ochranthum* C.A. Mey. (Ranunculaceae): Antu, Zhuang et al. 1998: 146; on *Clematis patens* Morr. & Decne. (Ranunculaceae): Antu, Zhuang et al. 1998: 146; on *Deyeuxia langsdorfii* (Link) Kunth (Poaceae): Antu, Zhuang et al. 1998: 148; on *Thalictrum aquilegifolium* L. var. *sibiricum* Regel. & Tiling (Ranunculaceae): Antu, Zhuang et al. 1998: 147.
- Puccinia ribis* DC. on *Ribes komarovii* Pojark (Grossulariaceae): Antu, Zhuang et al. 2003: 82; on *Ribes mandshuricum* (Maxim.) Kom.: Changbaishan, Xue 1993: 27.

- Puccinia saniculae* Grev. on *Sanicula rubriflora* Fr. Schmidt (Apiaceae): Antu, Zhuang et al. 2003: 136.
- Puccinia stipae-sibiricae* S. Ito on *Phedimus aizoon* (L.) 't Hart (Crassulaceae): Antu, Zhuang et al. 1998: 161 (the host listed as *Sedum aizoon*).
- Puccinia tanacetii* DC. on *Artemisia mandshurica* Rupr. (Asteraceae): Changbaishan, Xue 1993: 31; on *Artemisia stolonifera* (Maxim.) Kom.: Changbaishan, Xue 1993: 34; on *Artemisia lavandulaefolia* DC.: Antu, Zhuang et al. 2003: 243.
- Puccinia tatarinowii* Kom. & Tranzschel on *Nabalus tatarinowii* (Maxim.) Nakai (Asteraceae): Changbaishan, Xue 1993: 31 (the host listed as *Prenathes tatarinowii*).
- Puccinia tosoensis* Tokun. & Kawai on *Synurus deltoides* (Aiton) Nakai (Asteraceae): Antu, Zhuang et al. 2003: 249.
- Puccinia violae* (Schumach.) DC. on *Viola albida* Palib. (Violaceae): Antu, Zhuang et al. 2003: 102; on *Viola sacchalinesis* Boiss., Changbaishan, North Trail, on a trail to Underground Forest, 8 Sep 2015. YX, YW & YO (IBAR11031); Ardao Baihe, the Northeast Botanical Garden, 12 Sep 2015. YX, YW & YO (IBAR11099); Northeast Botanical Garden, 12 Sep 2015. YX, YW & YO (IBAR11101); *Viola verecunda* A. Gray: Changbaishan, Xue 1993: 28 & 33.
- Puccinia yaramesuge* Homma on *Carex campylorhiza* (Cyperaceae), Changbaishan, Xue 1993: 30.
- Uromyces aconiti* Fuckel on *Aconitum macrorhynchum* Turcz. & Ledeb. (Ranunculaceae): Changbaishan, Xue 1993: 32.
- Uromyces amurensis* Kom. on *Maackia amurensis* Rupr. & Maxim. (Fabaceae): Antu, Zhuang et al. 2005: 27; Changbaishan, Xue 1993: 28, 32.
- Uromyces appendiculatus* F. Strauss on *Phaseolus vulgaris* L. (Fabaceae): Antu, Zhuang et al. 2005: 30.
- Uromyces dactylidis* G.H. Otth on *Alopecurus aequalis* Sobol. (Poaceae): Changbaishan, Zhuang et al. 2005: 117.
- Uromyces ervi* (Wallr.) Westend. on *Vicia pseudo-orobus* Fischer & C.A. Mey. (Fabaceae): Changbaishan, on S208 to the South Gate, ca. 73 km from Ardao Baihe, 11 Sep 2015. YX, YW & YO (IBAR11058); on *Vicia unijuga* A. Br.: East side of Ardao Baihe, 10 Sep 2015. YX, YW & YO (IBAR11052).
- Uromyces geranii* (DC.) G.H. Otth & Wartm. on *Geranium krameri* Franch. & Sav. (Geraniaceae): Changbaishan, Xue 1993: 34 (the host listed as *Geranium japonicum*).
- Uromyces hedysari-obscuri* (DC.) Carestia & Picc. on *Hedysarum vicioides* Turcz. subsp. *japonicum* (B. Fedtsch.) B.H. Choi & H. Ohashi var. *japonicum* (B. Fedtsch.) B.H. Choi & Ohashi (Fabaceae): Antu, Zhuang et al. 2005: 42 (the host listed as *Hedysarum vicioides*).
- Uromyces heimerlianus* Magnus on *Vicia pseudo-orobus* Fischer & C.A. Mey.: Changbaishan, on S208 to the South Gate, ca. 73 km from Ardao Baihe, 11 Sep 2015. YX, YW & YO (IBAR11105); on *Vicia unijuga* A. Braun: Antu, Zhuang et al. 2005: 43.
- Uromyces itoanus* Hirats. f. on *Kummerowia striata* (Thunb.) Schnidl. (Fabaceae): Antu, Zhuang et al. 2005: 53 (listed as *Uromyces lespedezae-procumbentis*).
- Uromyces lespedezae-procumbentis* (Schwein.) Lagerh. on *Lespedeza bicolor* Turcz. (Fabaceae): Antu, Zhuang et al. 2005: 53; Changbaishan, Xue 1993: 34.

Uromyces orobi (Schmach.) Lév. on *Vicia unijuga* A. Braun (Fabaceae): Changbaishan, Xue 1993: 33.

Uromyces sommerfeltii Hyl., Jørst. & Nannf. on *Solidago virgaurea* L. (Asteraceae): Antu, Zhuang et al. 2005: 106; Changbaishan, Zhuang et al. 2005: 106.

Uromyces striatus J. Schröt. on *Trifolium repens* L. (Fabaceae): Changbaishan, Xue 1993: 34.

Uromyces trifolii-repentis Liro on *Trifolium repens* L. (Fabaceae): Changbaishan, on S208 to the South Gate, ca. 73 km from Ardao Baihe, 11 Sep 2015. YX, YW & YO (IBAR11067).

Uromyces veratri (DC.) J. Schröt. on *Veratrum nigrum* L. (Melanthiaceae): Antu, Zhuang et al. 2005: 142; Changbaishan, Xue 1993: 32.

Uromyces viciae-fabae (Pers.) J. Schröt. on *Lathyrus komarovii* Ohwi (Fabaceae): Antu, Zhuang et al. 2005: 73; on *Vicia amoena* Fisch. ex DC.: Antu, Zhuang et al. 2005: 74; Changbaishan, East side of Ardao Baihe, 10 Sep 2015. YX, YW & YO (IBAR11048); on *Vicia amurensis* Oett.: Antu, Zhuang et al. 2005: 74; on *Vicia japonica* A. Gray: Antu, Zhuang et al. 2005: 74; *Vicia cracca* L.: Changbaishan, Xue 1993: 28 (listed as *Uromyces viciae-craccae*); on *Vicia unijuga* A. Braun: Antu, Zhuang et al. 2005: 74.

Anamorphic Genus

Aecidium viburni Henn. & Shirai on *Virburnum sargentii* Koehne (Adoxaceae): Changbaishan, Xue 1993: 29.

As to the regional mycodiversity, China is one of geographic regions where rust fungi have been relatively well studied. Compilation of rust species from the records published by Tai (1979), Teng (1996) and Zhuang et al. (1998, 2003, 2005, 2012) revealed that 999 species in 57 teleomorphic genera and 76 anamorphic species are distributed in China (Ono unpublished). However, in terms of rust biology, species distributed in China have been poorly studied. Complete life cycle of 477 species (ca. 47.7 %) has not been determined. Even in the most species for which the complete life cycle is known, the life cycle study was carried out with populations of those species outside of China. Seven hundred and sixty-three species are distributed in Japan; and 351 species (46.0 %) among them remain to be studied for their complete life cycle (Ono unpublished). However, many species for which the complete life cycle is known were studied with Japanese populations (Hiratsuka et al. 1984). By contrast, in British Isls, only 54 species (21.3 %) of a total of 253 species are unknown for their complete life cycle. Taxonomic identification of the species and elucidation of their biological nature are interactive; and, therefore, a view of rust diversity (in terms of species richness) will change as the biological study of the species is advanced. As seen in the above enumeration of species, majority (ca. 80 %) of species recorded in the Changbaishan area are known from one or two collections. Apparently, more intensive field survey and collection are needed for better understanding of the rust fungus diversity in this geologically and floristically interesting area. As mentioned previously, the Changbaishan area is central to the Northeast China Region of the Sino-Japanese Subkingdom, the Eastern Asiatic Kingdom (Takhtajan 1986, Sun and Wu 2015), where 1776 species of seed plants in 575 genera, 116 families are recorded. According to Rossman (1994), we know only 14 % of a total of 50000 rust species that exist on this globe. By

analyzing the number of rust species in Neotropics (some Central American countries and Brazil) and North America (Indiana, USA), Hennen and McCain (1993) assumed that the rate of rust fungi to host plants in a given area ranges between 1:20 and 1:4. The estimate of 1.5 million fungus species on the globe was based on an assumed fungus to plant ratio of 6:1 (Hawksworth 1991). If these assumptions are applicable in the Northeast China Region, 300 or more rust species are expected to be distributed there; and this figure would be reflected to the rust species diversity in the Changbaishan area.

Disclosure

The authors declare no conflict of interests. This study complies with the current laws of P. R. China and Japan.

Acknowledgments

This study was supported, in part, by Grant-in-Aid from Northeast Forestry University. The field survey and collecting study materials were carried out under the permission from the Changbaishan National Nature Protective and Administrative Bureau, Forest Department of Jilin Province, Forest Ministry of P. R. China.

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