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Rust Fungi (Pucciniales) Collected at Imperial Palace Garden from 2021 to 2023

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Abstract. Thirty-three species of rust fungi (Pucciniales) were collected in the Imperial Palace Garden during the survey conducted from 2021 to 2023. Of these, 12 species are newly recorded compared with the previous surveys conducted in 1997–1999 and 2012–2013, which recorded 35 and 29 species, respectively. Seventeen species were confirmed to colonize and survive in the garden, whereas nine species are presumed to have disappeared. The species composition has also changed compared with the earlier surveys. This floristic change in rust fungi is suspected to be a result of continuous changes in environmental conditions and plant growth in the garden.

Keywords: host plant, plant parasite, rust flora.

Introduction

Rust fungi (Pucciniales, formerly Uredinales) are one of the largest groups in fungi, with over 8,400 described species (Hiratsuka *et al.*, 1992; Cummins and Hiratsuka, 2003; Aime *et al.,* 2018; Aime and McTaggart, 2021; Kakishima *et al.*, 2023; He *et al.*, 2024). They are obligate parasites of vascular plants and have been reported worldwide. Each species is known to be parasitic on taxonomically narrow groups of plants (host specificity), which is suspected as the result of the co-evolution between rust fungi and their host plants. Many species cause serious plant diseases in agriculture and forestry. Rust fungi have unique characteristics and produce five types of morphologically and functionally different spores (spermatium, aeciospore, urediniospore, teliospore, basidiospore). Thick-walled urediniospores, called amphispores, are also produced in many species for overwintering. Depending on the types of spores produced, six different life cycles have been recognized. Some species need two taxonomically different host plants to complete their life cycles (heteroecious), whereas others complete their life cycles on a single host plant (autoecious).

Two families (Melampsoraceae and Pucciniaceae) mainly based on the morphological characteristics of the telial stage were traditionally accepted, and widely used in the world (Arthur, 1934; Hiratsuka *et al.,* 1992; Cummins and Hiratsuka, 2003). More than 300 genera have been assigned into these families. Cummins and Hiratsuka (2003) revised the families of rust fungi, emphasizing spermogonial structures, and proposed 13 families and 133 genera (including anamorphic genera). After applying the molecular phylogenetic approach to systematics of rust fungi, many new genera and changes to the existing genera have been proposed. Based on phylogeny, morphology, host range and life cycle, Aime and McTaggart (2021) proposed 7 suborders and 18 families, which differed considerably from the earlier classifications. Additionally, 7 new families were proposed by Zhao *et al.* (2021, 2023) and Yadav *et al.* (2023). Recent classifications of the Pucciniales have been compiled by He *et al.* (2024) and Hyde *et al.* (2024).

The Imperial Palace Garden is attached to Imperial Palace and located in the center of Tokyo. This garden has been maintained since the Edo period as a natural forested area and preserves rich greenery, including trees several centuries old, and provides a tranquil natural environment in the center of Tokyo (Koyama *et al.*, 2000). Thirty-five and twenty-nine species of rust fungi were reported from the garden in previous surveys conducted in 1997-1999 and 2012-2013, respectively (Table 1) (Kakishima *et al.*, 2000; Kakishima and Okane, 2014). Since those surveys, plant growth conditions and plant species composition have changed considerably due to environmental changes and garden management. Therefore, we conducted a survey of rust fungi from May 2021 to November 2023 to clarify current flora of rust fungi in the garden. This paper lists the rust fungi identified from approximately 150 specimens collected during this period and discusses changes in the rust flora compared with the previous surveys.

Materials and Methods

From May 2021 to November 2023, rust fungi were surveyed in the garden and specimens were collected. In addition, one specimen (TNS F-110023), collected in September 2025 and provided by Dr. Y. Hirooka, was examined. The specimens were dried and used for morphological observations. Species were identified mainly based on their host plants and morphological features observed with light microscopy. All specimens are deposited in the Herbarium of the Department of Botany, National Museum of Nature and Science, Tsukuba, Japan (TNS). The taxonomy of rust fungi follows the recent classifications by Aime and McTaggart (2021), He *et al*. (2024), and Hyde *et al.* (2024), and species names are in accordance with the International Code of Nomenclature for algae, fungi, and plants (ICNafp, Shenzhen Code; Turland *et al*., 2018).

Results

Thirty-three species of rust fungi, belonging to 11 families and 13 genera, were identified (Table 1) from approximately 150 specimens. Among them 12 species are newly recorded in the garden. In the following list, host plants, spore stages (0: spermogonial stage; I: aecial stage; II: uredinial stage; III: telial stage), and specimen numbers are provided after each species name.

List of rust fungi

Fam. Coleosporiaceae

Coleosporium asterum (Dietel) Syd. & P. Syd. (Fig. 1)

Host plant: *Aster ageratoides* Turcz. var. *ageratoides* [= *A. ageratoides* var. *harae* (Makino) Kitam., *A. ageratoides* Turcz. var. *harae* (Makino) Kitam. f. *leucanthus* Honda, *A. ageratoides* f. *leucanthus* Honda] (II, 27 Oct. 2021, TNS F-83143); *Aster* sp. (II, 1 July 2022, TNS F-110322).

Note: This species has hetero-macrocyclic life cycle, producing spermogonial and aecial stages on *Pinus densiflora* Sieb. & Zucc. and uredinial and telial stages on species of *Aster* and *Kalmeris* (Asteraceae) (Kaneko, 1981; Hiratsuka *et al.,* 1992). However, its spermogonial and aecial stages have not been found even though *P. densiflora* is commonly found in the garden.

Coleosporium clerodendri Dietel (Fig. 2)

Host plant: *Clerodendrum trichotomum* Thunb. (II, III, 27 Oct. 2021, TNS F-83142; II, III, 10 Nov. 2021, TNS F-83149; II, III, 22 Nov. 2022, TNS F-83154; II, III, 15 Nov. 2023, TNS F-83181; II, III, 15 Nov. 2023, TNS F-83184; II, III, 18 Nov. 2021, TNS F-110288; II, 1 July 2022, TNS F-110323).

Note: Life cycle of this species is unknown, and only uredinial and telial stages have been reported on some plant species of *Clerodendrum* (Kaneko, 1981; Hiratsuka *et al.*, 1992).

Coleosporium phellodendri Dietel (Fig. 3)

Homonym: *Coleosporium phellodendri* Kom. (nom. inval.)

Host plant: *Phellodendron amurense* Rupr. (II, III, 27 Oct. 2021, TNS F-83140; II, III, 10 Nov.

Table 1. Species of rust fungi (Pucciniales) collected at Imperial Palace Garden in three different periods.

Family	Species[1)]	Period of survey[2)] 1997-1999	2012-2013	2021-2023
Coleosporiaceae	***Coleosporium asterum***	+	+	+
	C. clerodendri	+	+	+
	C. phellodendri	+	+	+
	C. solidaginis	+	+	
	C. yamabense			+
	C. xanthoxyli	+	+	+
Gymnosporangiaceae	***Gymnosporangium koreense*** (**=** ***G. asiaticum***)	+	+	+
Melampsoraceae	*Melampsora coleosporioides*			+
	M. idesiae	+	+	+
Milesinaceae	*Uredinopsis struthiopteridis*			+
Neophysopellaceae	*Neophysopella kraunhiae* (= *Ochropsora kraunhiae*)			+
	N. ampelopsidis (= *Phakopsora ampelopsidis*)	+		
	N. meliosmae-myrianthae (= *Phakopsora meliosmae-myrianthae, P. euvitis, P. vitis*)	+	+	
Nothopucciniastraceae	***Nothopucciniastrum boehmeriae*** (**=** ***Pucciniastrum boehmeriae***)	+	+	+
	N. styracinum (= *Pucciniastrum styracium*)	+		
Nyssopsoraceae	*Nyssopsora cedrelae*			+
Phakopsoraceae	*Cerotelium fici*			+
	Phakopsora artemisiae-japonicae (= *P. artemisiae*)	+		
	P. fici-erectae	+	+	+
	P. malloti	+	+	
	P. sojae (= P. pachyrhizi)	+	+	+
Phragmidiaceae	*Kuehneola japonica*	+	+	
	Ggerwasia rubi			+
	Phragmidium duchesneae (= *Phragmidium mexicanum*)		+	+
	P. rubi-thunbergii	+		
Pileolariaceae	*Pileolaria klugkistiana*	+		
Pucciniaceae	*Puccinia caricis-gibbae*			+
	P. caricis-incisae (=*Uredo caricis-incisae*)	+		
	P. crepidis-japonicae			+
	P. deutziae (= *P. kusanoi*)		+	+
	P. fagopyricola	+	+	+
	P. glechomae (= *P. glechomatis*)			+
	P. hemelocallidis		+	+
	P. lantanae	+	+	+
	P. longicornis			+
	P. miscanthi	+	+	+
	P. nishidana	+	+	+
	P. oenanthes-stoloniferae			+
	P. oxalidis	+	+	+
	P. paederiae (= *P. zoysiae*)	+		
	P. phragmitis	+	+	+
	P. phyllostachydis	+		
	P. polygoni-amphibii var. ***tovariae***	+	+	+
	P. violae	+		
	Uromyces commelinae	+	+	+
	U. erythronii	+		
	U. truncicola	+	+	
	U. viciae-fabae var. *viciae-fabae*	+		
	U. vignae		+	
Pucciniastraceae	*Pucciniastrum circaeae*		+	
Tranzscheliaceae	***Leucotelium semiaquilegiae*** (**=** ***L. pruni-persicae, Sorataea pruni-persicae***)	+	+	+
	Tranzschelia discolor	+		
Anamorph	*U. geranii-nepalense*		+	
Total		**35**	**29**	**33**

[1)] **17** species collected in three periods are shown in bold face. [2)] +: Species collected, Red mark is species only found in 1997-1999, Green mark is species found for the first time in 2021-2023.

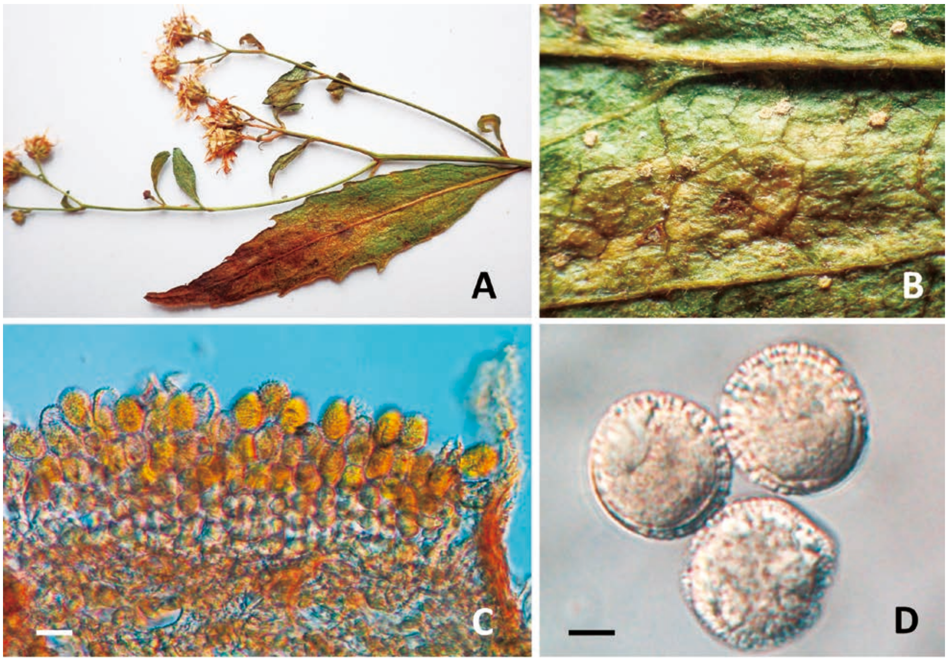

Fig. 1. *Coleosporium asterum* on *Aster ageratoides* var. *ageratoides* A, B. Uredinia on the lower leaf surface of the plant. C. Vertical section of an uredinium. D. Urediniospores. Scale bars: C= 20 μm, D= 10 μm.

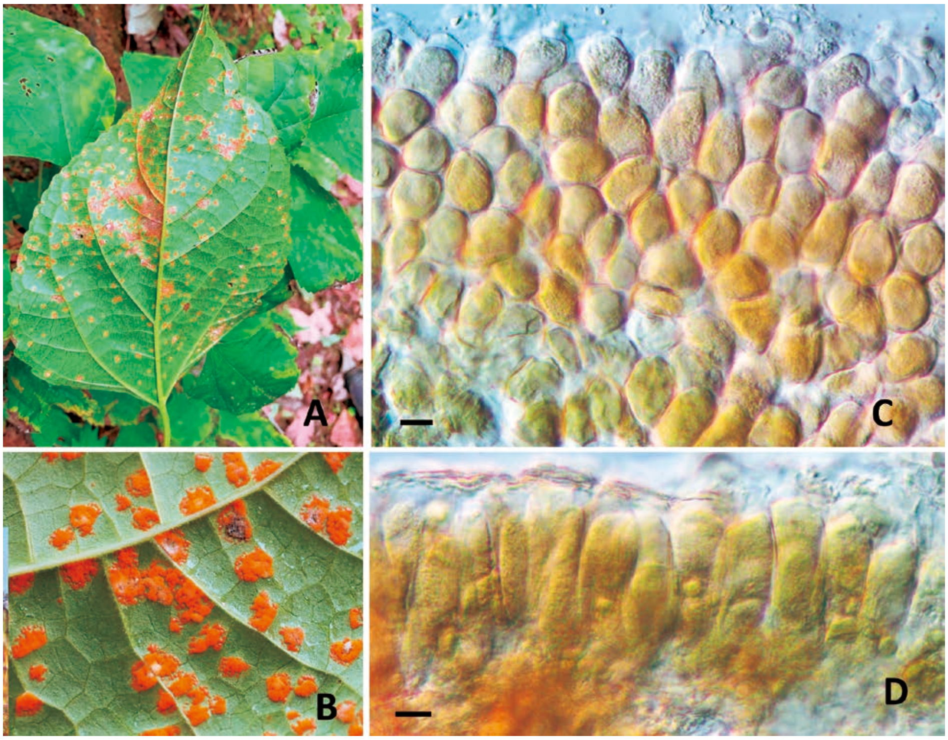

Fig. 2. *Coleosporium clerodendri* on *Clerodendrum trichotomum*. A, B. Uredinia and telia on the lower leaf surface of the plant. C. Vertical section of an uredinium. D. Vertical section of a telium. Scale bars: C, D= 10 μm.

2021, TNS F-83148).

Note: This species has hetero-macrocyclic life cycle and has been reported to produce spermogonial and aecial stages on many species of two-needle pines, including *P. densiflora* (Kaneko, 1981; Hiratsuka *et al.,* 1992), although these stages have

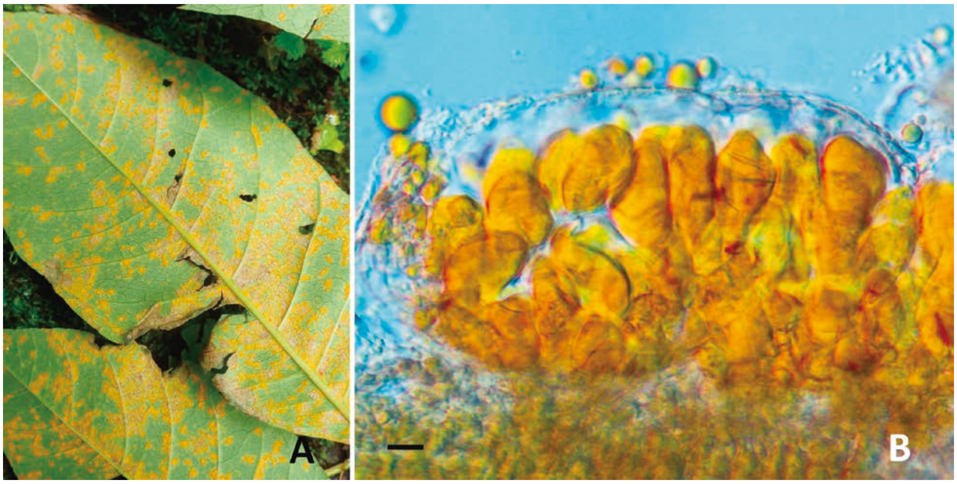

Fig. 3. *Coleosporium phellodendri* on *Phellodendron amurense.* A. Uredinia and telia on the lower leaf surface of the plant. B. Vertical section of a telium. Scale bars: B= 10 µm.

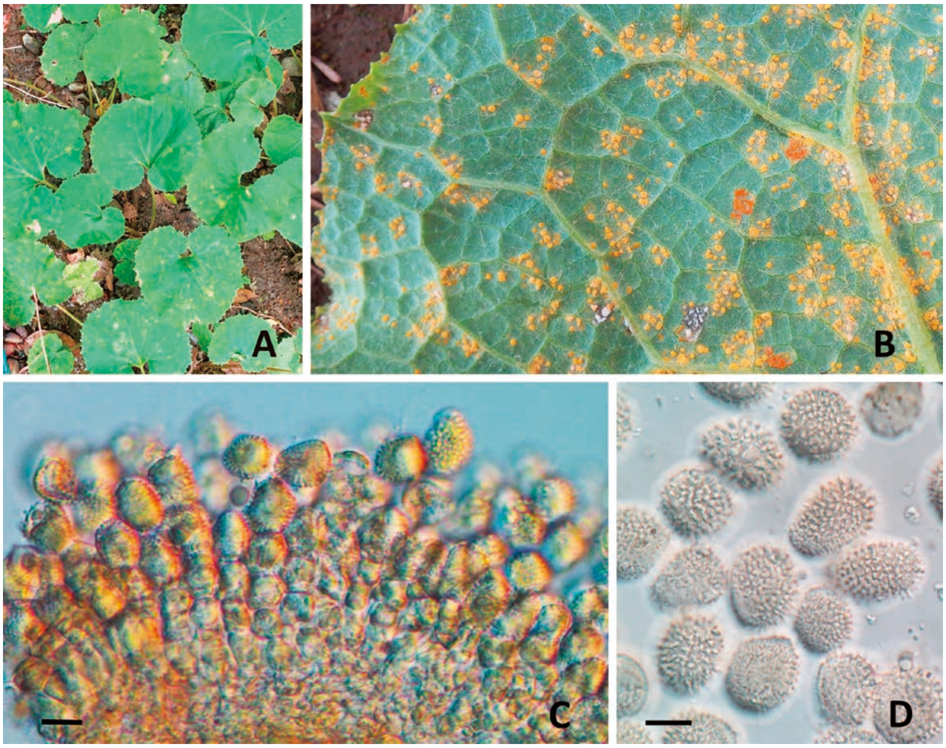

Fig. 4. *Coleosporium yamabense* on *Petasites japonicus*. A. Plants infected. B. Uredinia and telia on the lower leaf surface of the plant. C. Vertical section of an uredinium. D. Urediniospores. Scale bars: C, D= 20 µm.

not been found in the garden.

Coleosporium yamabense (Saho) Hirats. f. (Fig. 4)

Basionym: *Coleosporium petasitis* var. *yamabense* Saho

Host plant: *Petasites japonicus* (Sieb. & Zucc.) Maxim. (II, III, 27 Oct. 2021, TNS F-83192; II, III, 10 Nov. 2021, TNS F-83144; II, III, 22 Nov. 2022, TNS F-83164; II, III, 15 Nov. 2023, TNS F-83187; II, III, 18 Nov. 2021, TNS F-110291; II, 1 July 2022, TNS F-110310; II, 1 July 2022, TNS F-100327).

Note: This species has hetero-macrocyclic life cycle and has been reported to produce spermogonial and aecial stages on some species of five-needle pines, including *Pinus koraiensis* Sieb. & Zucc. (Kaneko, 1981; Hiratsuka *et al.,* 1992), although these stages have not been found in the garden. This species has been reported mainly in northern areas of Japan (Kaneko, 1981; Hiratsuka *et al.,* 1992) and is found for the first time in the garden. Therefore, its origin in this garden remains unknown.

Coleosporium xanthoxyli Dietel & P. Syd. (Fig. 5)

Host plant: *Zanthoxylum ailanthoides* Sieb. & Zucc. (II, III, Oct. 2021, TNS F-83137, 83138; II, III, 22 Nov. 2022, TNS F-83156; II, 1 July 2022, TNS F-110316).

Note: This species has hetero-macrocyclic life cy-

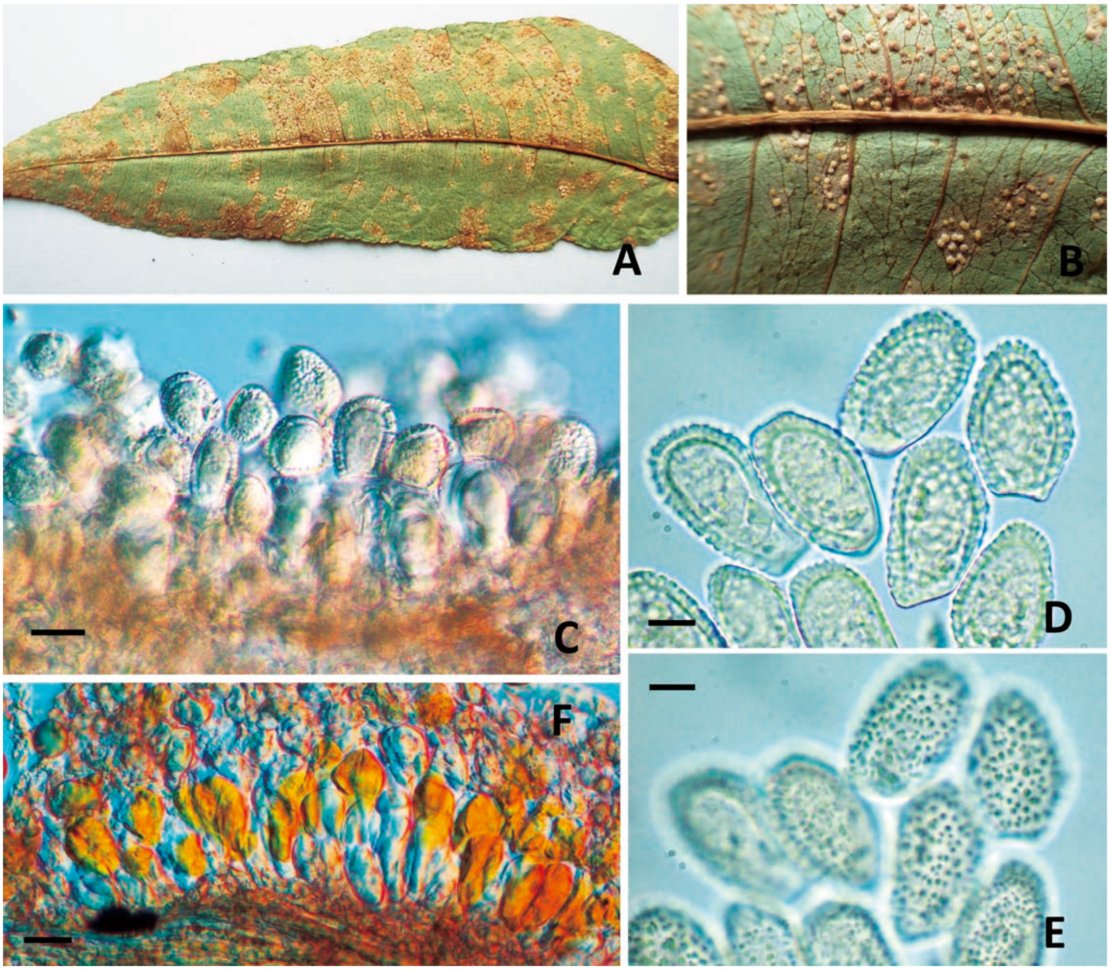

Fig. 5. *Coleosporium xanthoxyli* on *Zanthoxylum ailanthoides*. A, B. Uredinia and telia on the lower leaf surface of the plant. C. Vertical section of an uredinium. D. Urediniospores. E. Surface view of urediniospores. F. Vertical section of a telium. Scale bars: C, F= 20 µm, D, E= 10 µm.

cle and has been reported to produce spermogonial and aecial stages on some species of two-needle pines, including *Pinus thunbergii* Parl. (Kaneko, 1981; Hiratsuka *et al.,* 1992), although these stages have not been found in the garden.

Fam. Gymnosporangiaceae

Gymnosporangium koreense (Henn.) H.S. Jacks. (Fig. 6)

Basionym: *Roestelia koreensis* Henn.

Homotypic synonyms: *Tremella koreaensis* (Henn.) Arthur; *Gymnosporangium koreensis* (Henn.) H.S. Jacks.; *Gymnosporangium koreaënsis* (Henn.) H.S. Jacks.

Heterotypic synonyms: *Gymnosporangium asiaticum* Miyabe ex G. Yamada; *Gymnosporangium haraeanum* Syd. & P. Syd.; *Gymnosporangium chinense* Long

Host plant: *Pyrus pyrifolia* var. *culta* (Makino) Nakai (0, I, 17 May 2023, TNS F-83172); *Chaenomeles speciosa* (Sweet) Nakai (0, I, 1 Sept. 2025, TNS F-110023).

Note: This species has been known as *G. asiaticum* (Hiratsuka *et al.,* 1992). However, we adopt

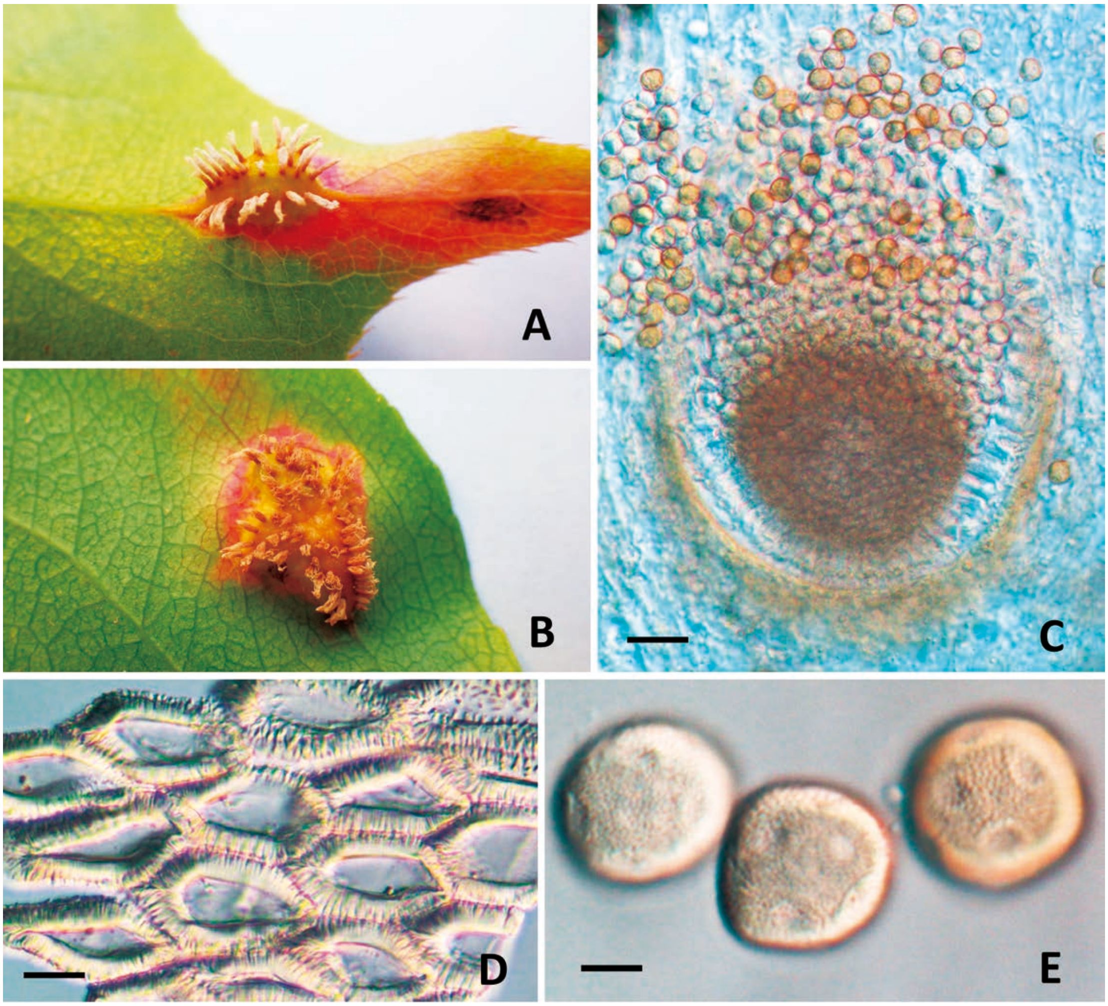

Fig. 6. *Gymnosporangium koreense* on *Pyrus pyrifolia* var. *culta*. A, B. Roestelioid-aecia on the lower leaf surface of the plant. C. Vertical section of an aecium. D. Peridial cells of aecia. E. Aeciospores. Scale bars: C= 40 µm, D, E= 10 µm.

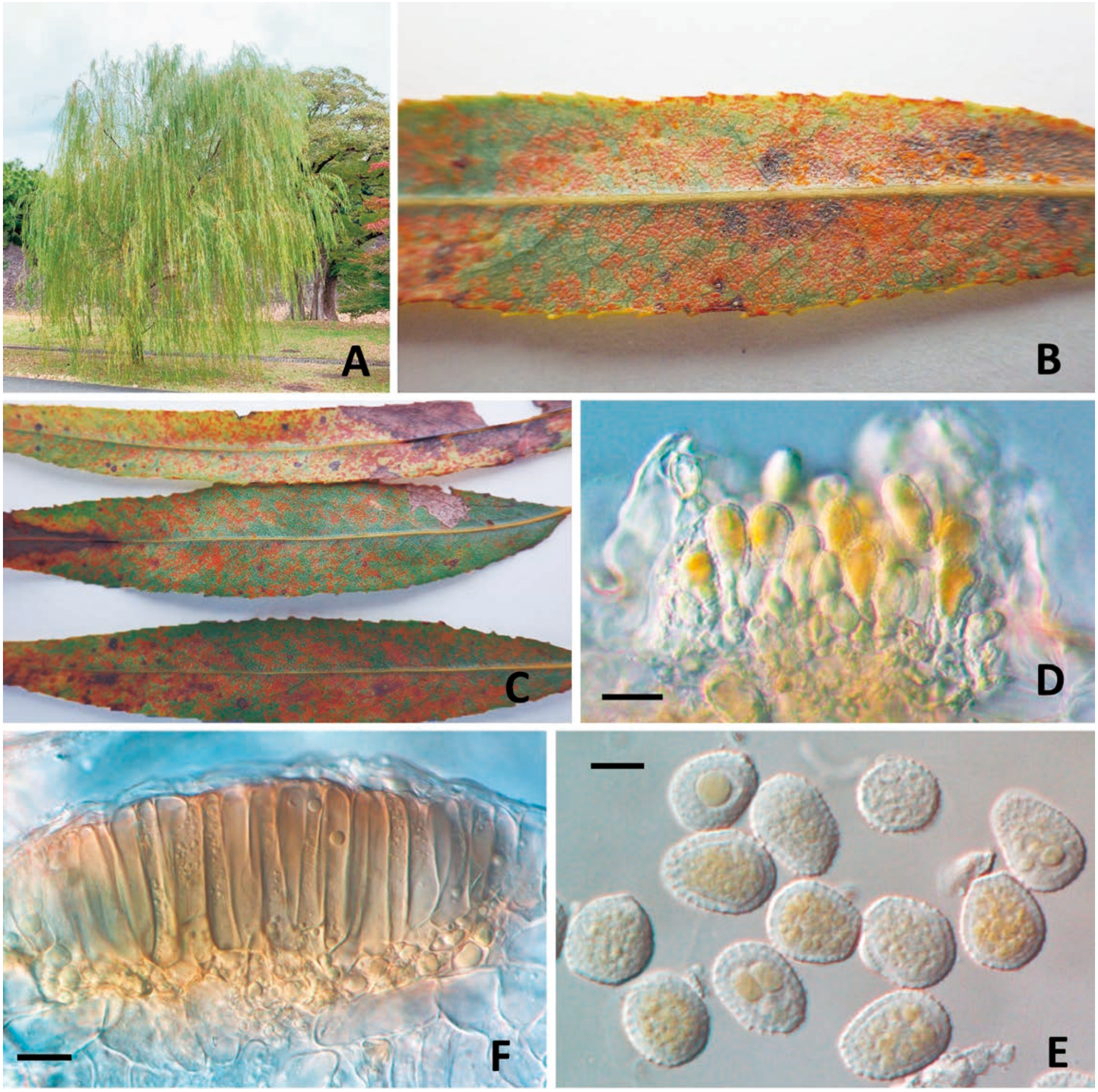

Fig. 7. *Melampsora coleosporioides* on *Salix babylonica*. A. Plant infected. B, C. Uredinia and telia on the lower leaf surface of the plant. D. Vertical section of an uredinium. E. Urediniospores. F. Vertical section of a telium. Scale bars: D= 30 μm, E, F= 10 μm.

name *G. koreense*, combined from *R. koreensis,* as the appropriate species name under the ICNafp Shenzhen Code (Turland *et al.,* 2018, Kakishima *et al.*, 2023).

In the garden, only spermogonial and aecial stages were observed, even though some *Juniperus* species, reported as telial hosts of this fungus, are cultivated there. This species is an important pathogen of pears and causes serious damage in their cultivation.

Fam. Melampsoraceae

Melampsora coleosporioides Dietel (Fig. 7)

Host plant: *Salix babylonica* L. (II, III, 15 Nov. 2023, TNS F-83127, 83128).

Note: This species is common rust fungus on *S. babylonica* in Japan, but this is the first record of this species in the garden. Recently, its spermogonial

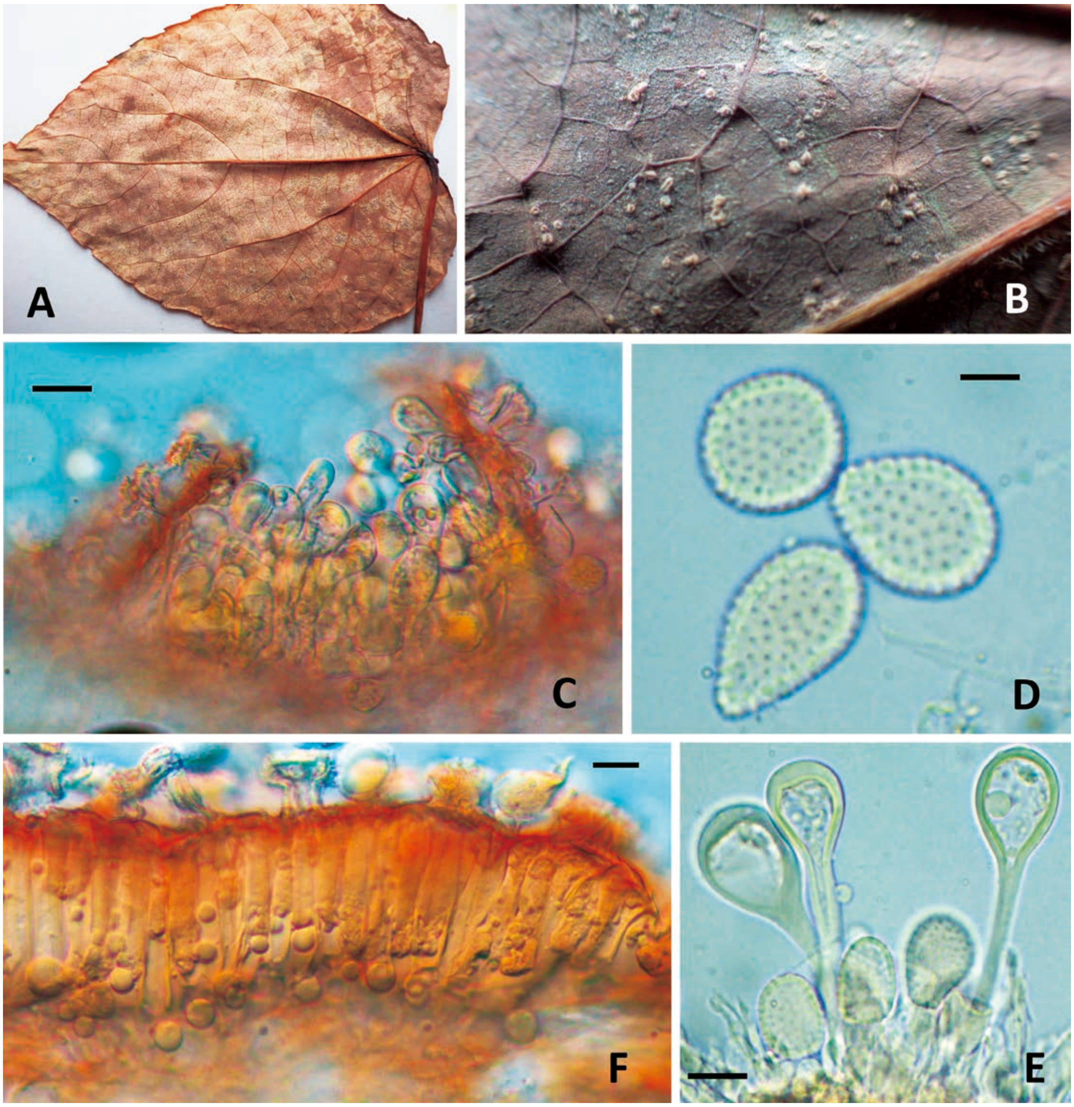

Fig. 8. *Melampsora idesiae* on *Idesia polycarpa*. A, B. Uredinia and telia on the lower leaf surface of the plant. C. Vertical section of an uredinium. D. Urediniospores. E. Paraphyses and urediniospores. F. Vertical section of a telium. Scale bars: C= 30 µm, D, F= 10 µm, E= 20 µm.

and aecial stages were reported on *Colydalis incisa* (Thunb.) Pers. by Okane *et al.* (2014), although these stages have not been found in the garden.

Melampsora idesiae Miyabe (Fig. 8)

Host plant: *Idesia polycarpa* Maxim. (II, 27 Oct. 2021, TNS F-83141; II, 22 Nov. 2022, TNS F-83158; II, 18 Nov. 2021, TNS F-110294; II, 1 July 2022, TNS F-110317).

Note: This species is widely distributed in Japan (Hiratsuka *et al.,* 1992). Recently, its spermogonial and aecial stages were reported on *Corydalis incisa* (Thunb.) Pers. by Yamaoka and Okane (2019), but these stages were not found in the garden.

***Melampsora* sp**. on unidentified species of *Salix* (II, 1 July 2022, TNS F-110326).

Fam. Milesinaceae

Uredinopsis struthiopteridis F.C.M. Störmer (Fig.

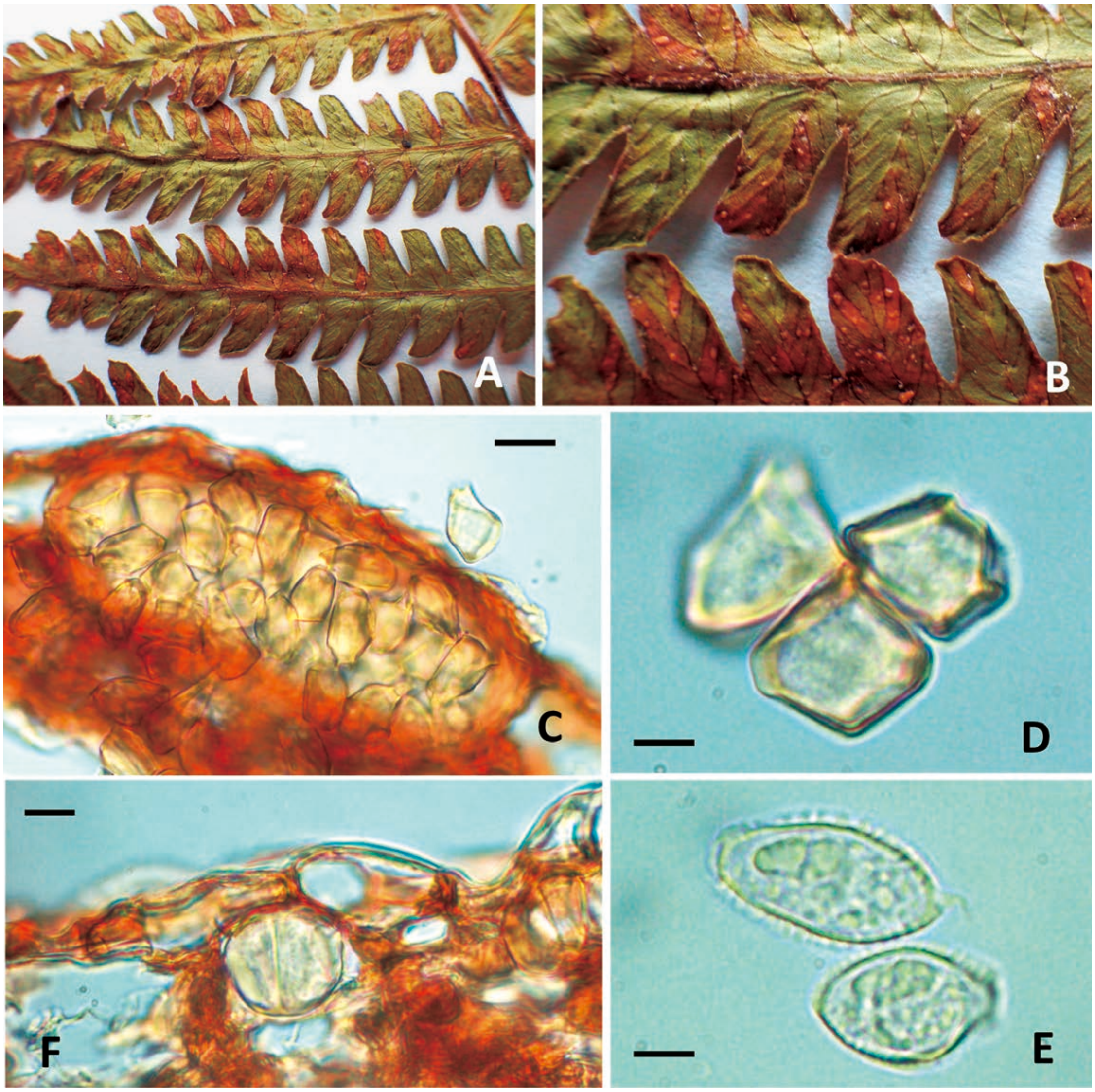

Fig. 9. *Uredinopsis struthiopteridis* on *Matteuccia struthiopteris*. A, B. Sori on the lower leaf surface of the plant. C. Vertical section of a sorus producing amphispores. D. Amphispores. E. Urediniospores. F. Teliospores. Scale bars: C, F= 20 μm, D, E= 10 μm.

9)

Host plant: *Matteuccia struthiopteris* (L.) Tod. [= *Onoclea struthiopteris* (L.) Hoffm.] (II, III, 1 July 2022, TNS F-110314).

Note: This species has hetero-macrocyclic life cycle and reported to produce its spermogonial and aecial stages on species of *Abies,* including *A. firma* Sieb. & Zucc. (Hiratsuka *et al.*, 1992), but these stages have not been found in the garden. It had been reported mainly in northern area of Japan. Therefore, its origin in the garden remains unknown.

***Uredinopsis* sp.** on unidentified species of fern (III, 18 Nov. 2021, TNS F-110305).

Fam. Neophysopellaceae

Neophysopella kraunhiae (Dietel) Aime & McTaggart (Fig. 10)

Basionym: *Phakopsora kraunhiae* Dietel

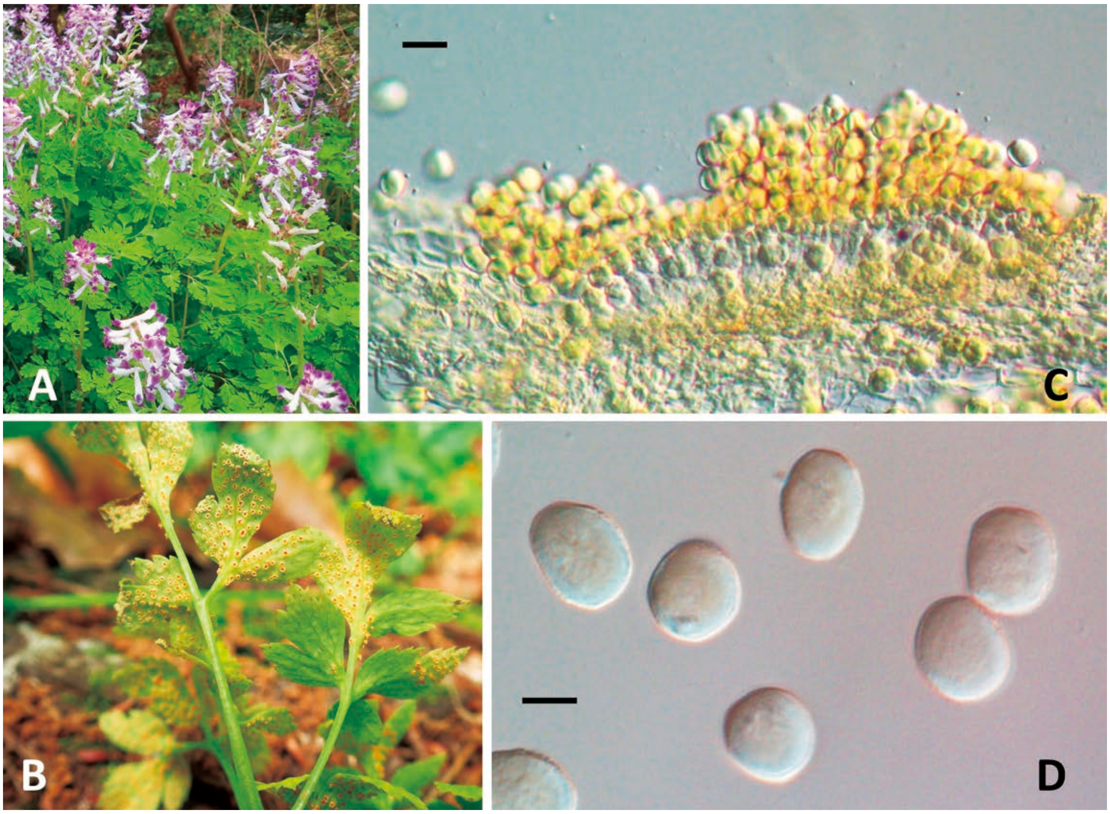

Fig. 10. *Neophysopella kraunhiae* on *Corydalis incisa*. A. Plants infected. B. Aecia on the lower leaf surface of the plant. C. Vertical section of an aecium. D. Aeciospores. Scale bars: C= 30 µm, D= 10 µm.

Homotypic synonym: *Ochropsora kraunhiae* (Dietel) Dietel

Heterotypic synonym: *Aecidium corydalinum* Syd. & P. Syd.

Host plant: *Corydalis incisa* (Thunb.) Pers. (0, I, 17 May 2023, TNS F-83168).

Note: The hetero-macrocyclic life cycle of this species, producing uredinial and telial stages on *Wisteria floribunda* (Willd.) DC., was proved by Hiratsuka and Kaneko (1978), but these stages have not been confirmed in the garden. Although this species is widely distributed in Japan (Hiratsuka *et al.*, 1992), this is the first record of its occurrence in the garden. Recently, it was transferred from *Ochropsora* to *Neophysopella,* established by Ji *et al.* (2019), based on phylogenetic analyses by Aime and McTaggart (2021). However, Ono (2025) doubted this taxonomic treatment.

Fam. Nothopucciniastraceae

Nothopucciniastrum boehmeriae (Dietel) P. Zhao & L. Cai (Fig. 11)

Basionym: *Uredo boehmeriae* Dietel

Homotypic synonyms: *Pucciniastrum boehmeriae* (Dietel) Syd. & P. Syd.; *Nothopucciniastrum boehmeriae* (Dietel) P. Zhao & L. Cai, Mycology 14: 30 (2022) (nom. inval.)

Host plant: *Boehmeria platanifolia* Sieb. & Zucc. ex C.H.Wright (II, 27 Oct. 2021, TNS F-83136; II, 10 Nov. 2021, TNS F-83150; II, 22 Nov. 2022, TNS F-83163; II, 15 Nov. 2023, TNS F-83192, 83193, 83194; II, 18 Nov. 2021, TNS F-110295, 100299).

Note: This species was previously known as *P. boehmeriae* (Hiratsuka *et al.*, 1992), but it was recently transferred to a new genus, *Nothopucciniastrum* in the new family Nothopucciniastraceae, and renamed as *N. boehmeriae* by Zhao *et al.* (2023) and Liu *et al.* (2025). It has a hetero-macrocyclic life

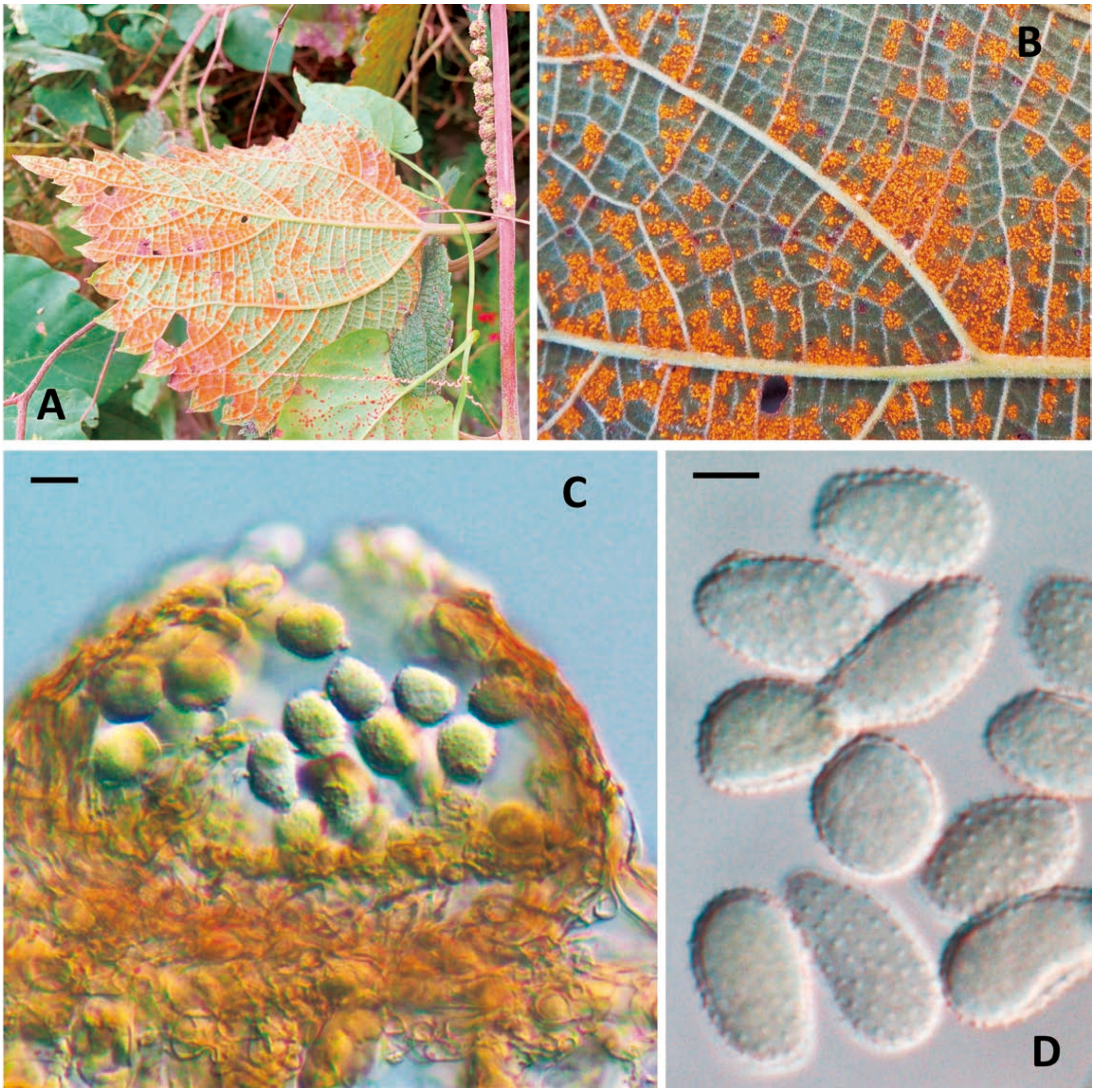

Fig. 11. *Nothopucciniastrum boehmeriae* on *Boehmeria platanifolia*. A, B. Uredinia on the lower leaf surface of the plant. C. Vertical section of an uredinium. D. Urediniospores. Scale bars: C, D= 10 μm.

cycle, producing spermogonial and aecial stages on *Abies firma* Sieb. & Zucc., although these stages were not found in the garden. This species is widely distributed in Japan and many *Boehmeria* species have been reported as host plants of uredinial and telial stages. Because this species has been consistently recorded in the garden (Kakishima *et al.*, 2000, 2014) it is suspected to persist in the garden through repeated infections by urediniospores.

Fam. Nyssopsoraceae

Nyssopsora cedrelae (Hori) Tranzschel (Fig. 12)

Host plant: *Toona sinensis* (A.Juss.) M. Roem. (= *Cedrela sinensis* A.Juss.) (II, III, 18 Nov. 2021, TNS F-110304; II, 1 July 2022, TNS F-110313).

Note: This species is commonly distributed in Japan (Lohsomboon *et al*., 1990; Hiratsuka *et al.*, 1992), but this is the first record for this species in the garden. Although an autoecious life cycle of this species was reported by Kakishima *et al.* (1984)

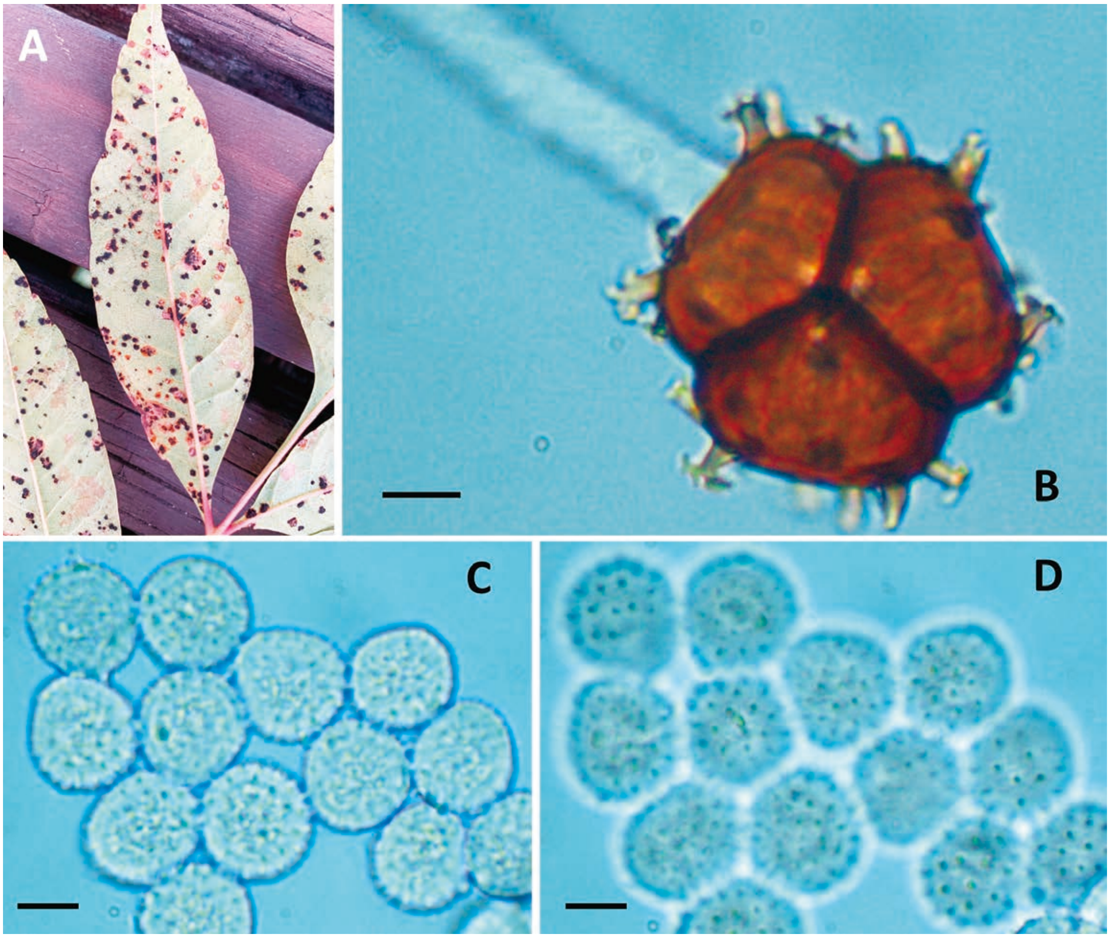

Fig. 12. *Nyssopsora cedrelae* on *Toona sinensis*. A. Uredinia and telia on the lower leaf surface of the plant. B. Teliospores with appendages on the surfaces and a pedicel attached to teliospores. C. Urediniospores. D. Surface view of urediniospores. Scale bars: B= 20 µm, C, D= 10 µm.

its macro-heteroecious life cycle, producing spermogonial and aecial stages on *Aralia elata* (Miq.) Seem. was demonstrated more recently by Lee *et al.* (2024). However, these stages were not found in the garden.

Fam. Phakopsoraceae

Cerotelium fici (Castagne) Arthur (Fig. 13)

Basionym: *Uredo fici* Castagne

Heterotypic synonym: *Phakopsora fici* Nishida

Host plant: *Morus australis* Poir. (=*M. bombycis* Koidz.) (II, III, 18 Nov. 2021, TNS F-110329); *M. alba* L. (II, III, 18 Nov. 2021, TNS F-110302).

Note: This species has been recorded in southern areas of Japan (Hiratsuka *et al.,* 1992). Its origin in the garden is unknown. Recently, *Phakopsora nishidana* S. Ito reporting on *Ficus carica* L. (Fig tree) was treated as a synonym of this species (Species Fungorum, https://www.speciesfungorum.org/Names/SynSpecies.asp?RecordID=100242) Kakishima *et al.*, 2023). However, this taxonomic treatment requires reconfirmation, as suggested by Padamsee and McKenzie (2024).

Phakopsora fici-erectae S. Ito & Otani ex S. Ito & Muray. (Fig. 14)

Host plant: *Ficus erecta* Thunb. (II, 27 Oct. 2021, TNS F-83135; II, 22, Nov. 2022, TNS F-83160; II, 15 Nov. 2023, TNS F-83182; II, 18 Nov. 2021, TNS

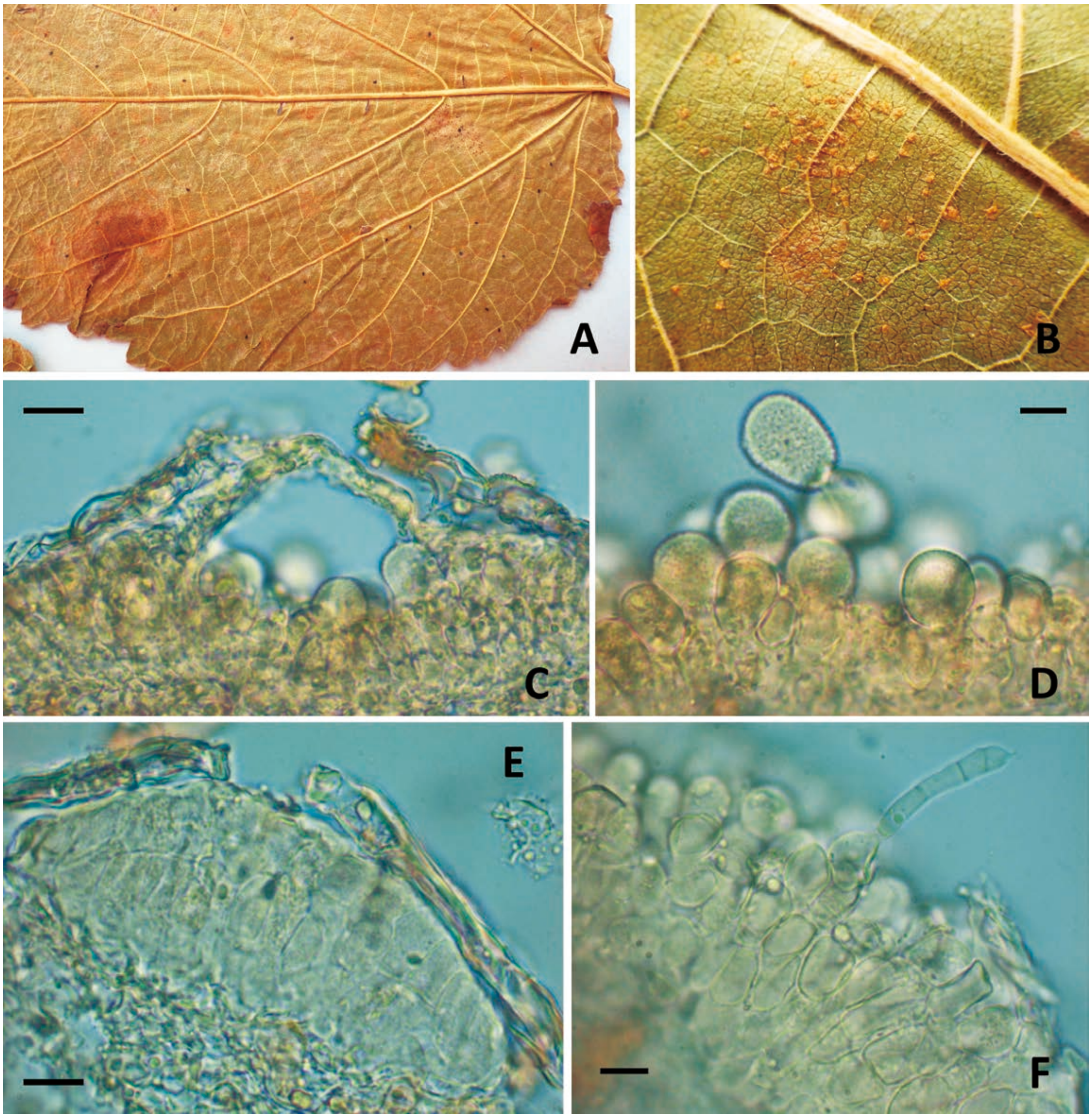

Fig. 13. *Cerotelium fici* on *Morus australis*. A, B. Uredinia and telia on the lower leaf surface of the plant. C. Vertical section of an uredinium. D. Urediniospores in an uredinium. E. Vertical section of a telium. F. Teliospores and germination of a teliospore. Scale bars: C, E= 20 µm, D, F= 10 µm.

F-110292, 110297).

Note: The life cycle of this species remains unknown, but it may persist in the garden through repeated infections by urediniospores, as it has been continuously recorded in the garden (Kakishima *et al.*, 2000; Kakishima and Okane, 2014).

Phakopsora sojae (Henn.) Sawada (Fig. 15)

Basionym: *Uredo sojae* Henn.

Homotypic synonyms: *Uromyces sojae* (Henn.) Syd. & P. Syd.; *Malupa sojae* (Henn.) Y. Ono, Buriticá & J.F. Hennen

Heterotypic synonyms: *Phakopsora pachyrhizi* Syd. & P. Syd.; *Physopella pachyrhizi* (Syd. & P. Syd.) Azbukina; (nom. inval.).

Host plant: *Amphicarpaea edgeworthii* Benth. [= *A. edgeworthii* var. *trisperma* (Miq.) Ohwi] (II, 27 Oct. 2021, TNS F-83134); *Pueraria montana* var. *lobata* (Willd.) Maesen & S.M.Almeida ex

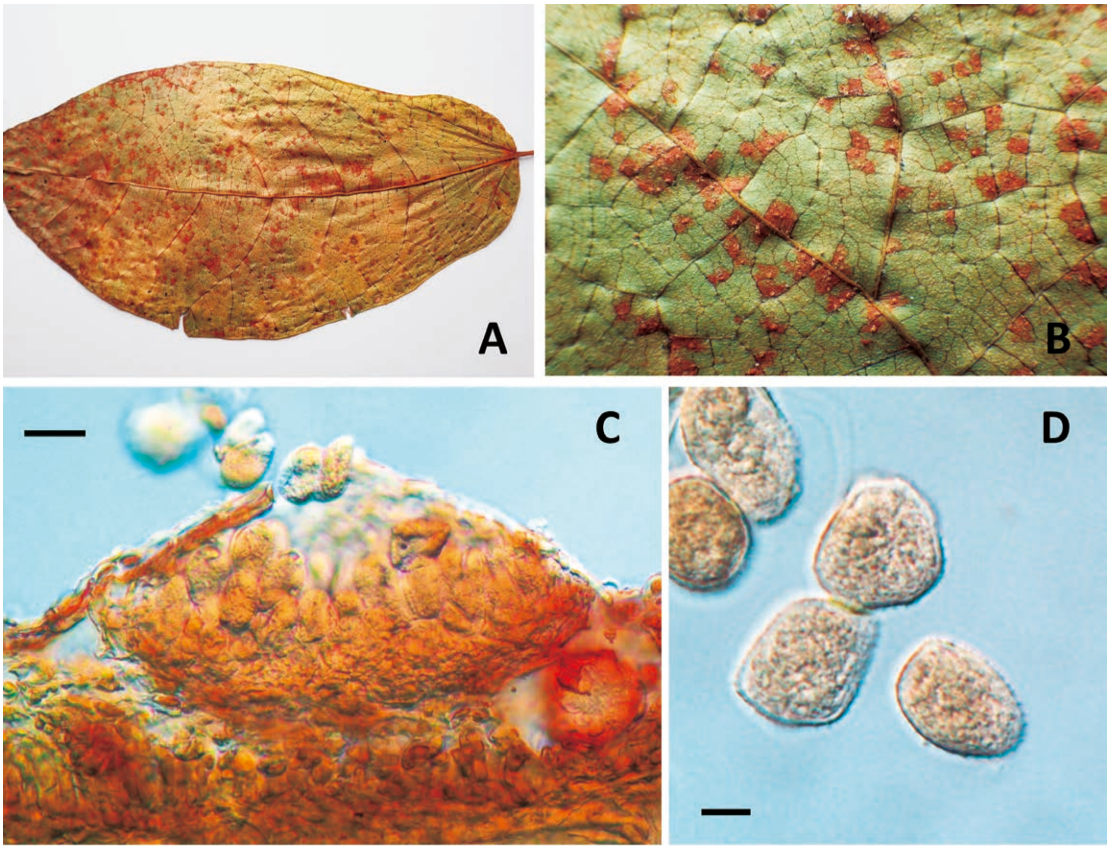

Fig. 14. *Phakopsora fici-erectae* on *Ficus erecta*. A, B. Uredinia on the lower leaf surface of the plant. C. Vertical section of an uredinium. D. Urediniospores. Scale bars: C= 20 μm, D= 10 μm.

Sanjappa & Pradeep [= *P. lobata* (Willd.) Ohwi] (II, 27 Oct. 2021, TNS F-83139; II, 22 Nov. 2022, TNS F-83153; II, III, 18 Nov. 2021, TNS F-110298; II, 18 Nov. 2021, TNS F-110303; II, 10 Nov. 2021, TNS F-110022).

Note: This species has been known as *P. pachyrhizi* (Hiratsuka, 1935; Hiratsuka *et al.,* 1992; Ono *et al.,* 1992). However, *P. sojae* (Sawada, 1931, 1933), combined from *Uredo sojae,* is considered the appropriate species name under the ICNafp Shenzhen Code (Turland *et al.,* 2018; Kakishima *et al.* 2023), although Aime *et al.* (2019) proposed *P. pachyrhizi* as a conserved name for this species. This species causes an important disease of soybean and is widely distributed in Asia (Hiratsuka *et al.,* 1992; Ono *et al.*, 1992).

Fam. Phragmidiaceae

Gerwasia rubi Racb. (Fig. 16)

Host plant: *Rubus* sp. (II, 10 Nov. 2021, TNS F-83147).

Note: This species has an auto-macrocyclic life cycle, but only uredinial stage has been found in the garden. This is the first record of the species in the garden, although it is widely distributed in East Asia (Hiratsuka *et al.*, 1992).

Phragmidium duchesneae (Arthur) P. Syd. & Syd**.** (Fig. 17)

Basionym: *Kuehneola duchesneae* Arthur

Heterotypic synonyms: *Frommea mexicana* Mains; *Frommeëlla mexicana* (Mains) J.W. McCain & J.F. Hennen; *Phragmidium mexicanum* (Mains) H.Y. Yun, Minnis & Aime; *Phragmidium duchesneae-indicae* P. Zhao & L. Cai

Host plant: *Potentilla indic*a (Andrews) Th.

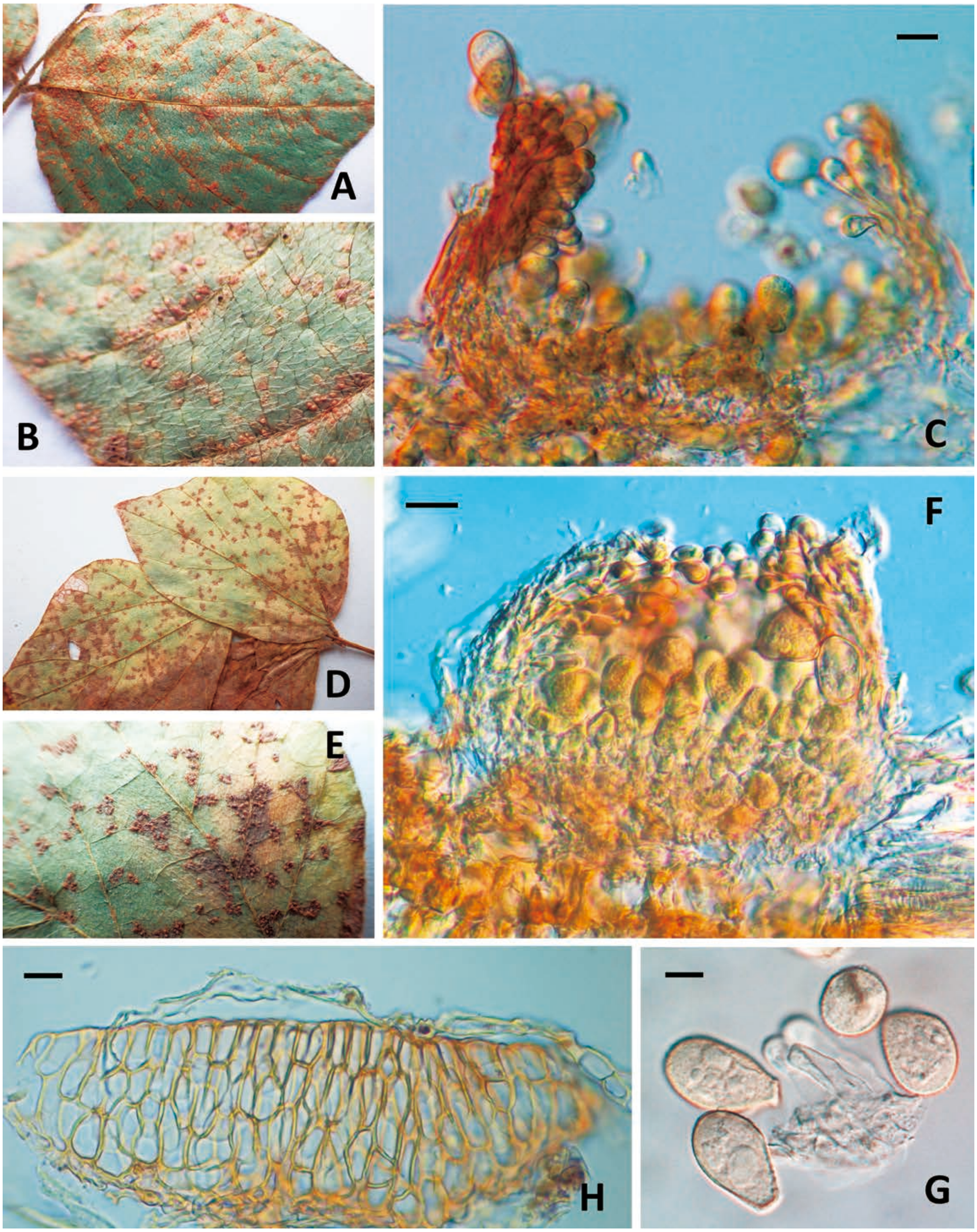

Fig. 15. *Phakopsora sojae* on *Amphicarpaea edgeworthii* (A-C) and *Pueraria montana* var. *lobata* (D-H). A, B, D, E. Uredinia on the lower leaf surface. C, F. Vertical section of an uredinium. G. Urediniospores and paraphyses. H. Vertical section of a telium. Scale bars: C, F, H= 20 µm, G= 10 µm.

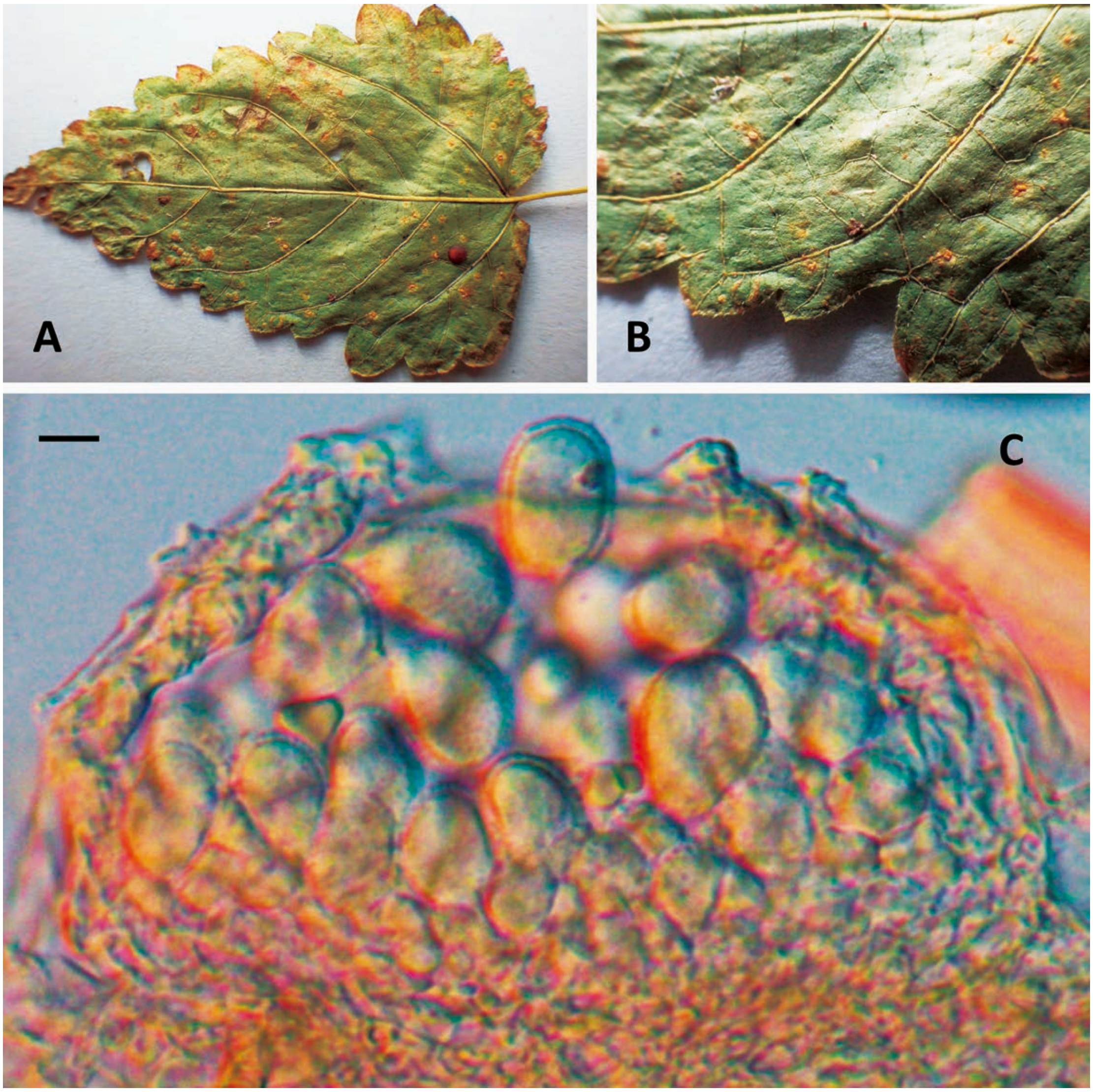

Fig. 16. *Gerwasia rubi* on *Rubus* sp. A, B. Uredinia on the lower leaf surface of the plant. C. Vertical section of an uredinium. Scale bars: C= 10 µm.

Wolf [= *Duchesnea indica* (Andrews) Focke] (II, 22 Nov. 2022, TNS F-83167; II, 17 May 2023, TNS F-83175; II, 15 Nov. 2023, TNS F-83179; II, III, 18 Nov. 2022, TNS F-110283; II, 1 July 2022, TNS F-110312).

Note: This species was previously reported as *P. mexicanum* (Yun *et al*., 2011), but *P. duchesneae* was adapted as the correct name under the ICNafp Shenzhen Code (Turland *et al.,* 2018; Uzuhashi *et al.*, 2022). Although this species is widely distributed in the world (Yun *et al*., 2011), but its presence in Japan was confirmed for the first time by Uzuhashi *et al.* (2022), despite earlier suggestions of its occurrence in the garden by Kakisima and Okane (2014).

Fam. Pucciniaceae

Puccinia caricis-gibbae Dietel (Fig. 18)

Heterotypic synonym: *Puccinia fukienensis* Y.C. Wang & J.Y. Zhuang

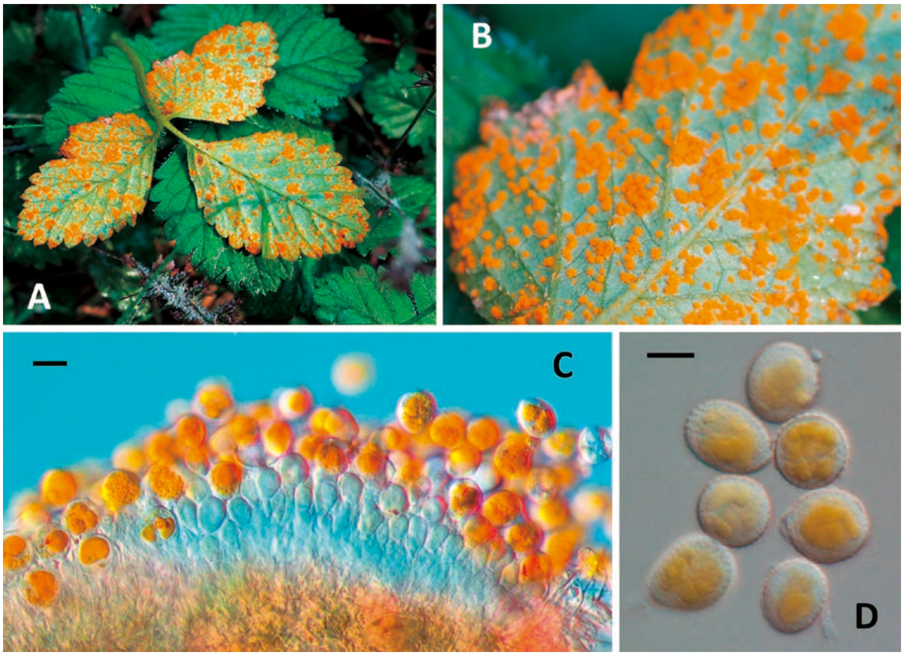

Fig. 17. *Phragmidium duchesneae* on *Potentilla indic*a. A, B. Uredinia on the lower leaf surface of the plant. C. Vertical section of an uredinium. D. Urediniospores. Scale bars: C= 20 µm, D= 10 µm.

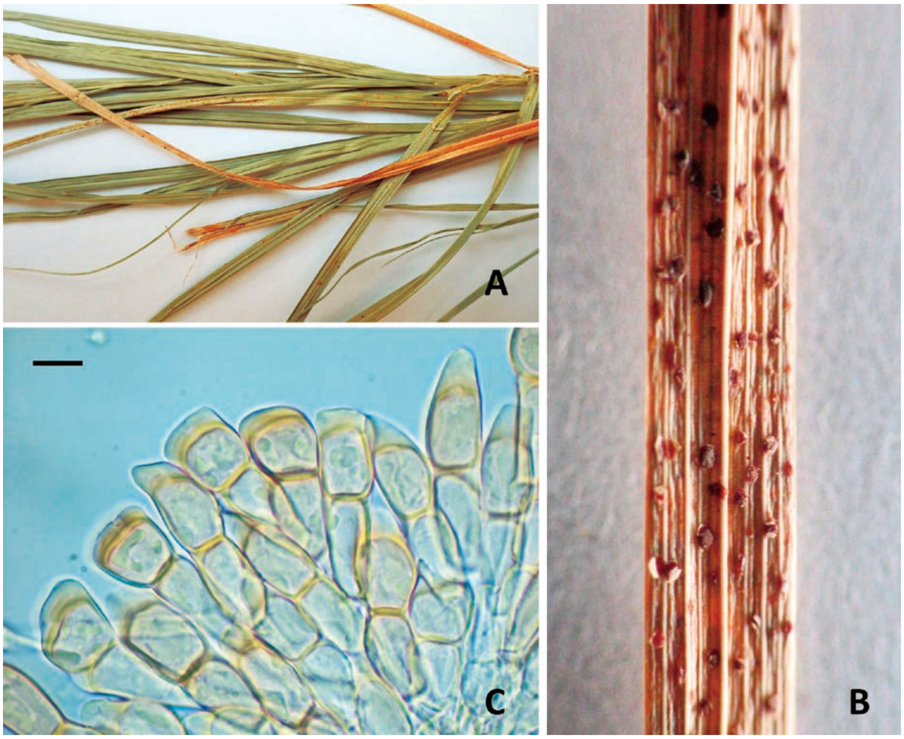

Fig. 18. *Puccinia caricis-gibbae* on *Carex* sp. A. Plant infected. B. Telia on the lower leaf surface of the plant. C. Teliospores. Scale bars: C= 10 µm.

Host plant: *Carex* sp. (II, III, 18 Nov. 2021, TNS F-110282, 110285).

Note: This species is widely distributed in Japan (Hiratsuka *et al.*, 1992; Kakishima *et al.*, 2024), but this is the first record for this species in the garden.

Puccinia crepidis-japonicae (Lindr.) Dietel (Fig. 19)

Host plant: *Youngia japonica* (L.) DC. (II, 17 May 2023, TNS F-83177).

Note: This species has an auto-macrocyclic life cycle and is widely distributed in Japan (Hiratsuka *et al.*, 1992), but its uredinial stage has been recorded in the garden for the first time.

Puccinia deutziae (Dietel) Kakish., K.Hosaka & Hosoya (Fig. 20)

Basionym: *Aecidium deutziae* Dietel

Homotypic synonym: *Puccinia deutziae* (Dietel) Fraiture & Vanderweyen (nom. inval.).

Heterotypic synonyms: *Puccinia kusanoi* Dietel; *Dicaeoma kusanoi* (Dietel) Syd.

Host plant: *Deutzia crenata* Sieb. & Zucc. var. *crenata* (0, I, 17 May 2023, TNS F-83173); *Pleioblastus chino* Mak. (II, 18 Nov. 2021, TNS F-110286, 110289; II, 1 July 2022, TNS F-110308, 110309).

Note: This species has been known as *P. kusanoi*, and its spermogonial and aecial stages has been reported as *A. deutziae* (Hiratsuka *et al.,* 1992). However, a new combination name, *P. deutziae,* was adapted for this species under the ICNafp Shenzhen Code (Turland *et al.,* 2018; Kakishima *et al.*, 2023). This species is suspected to complete its life

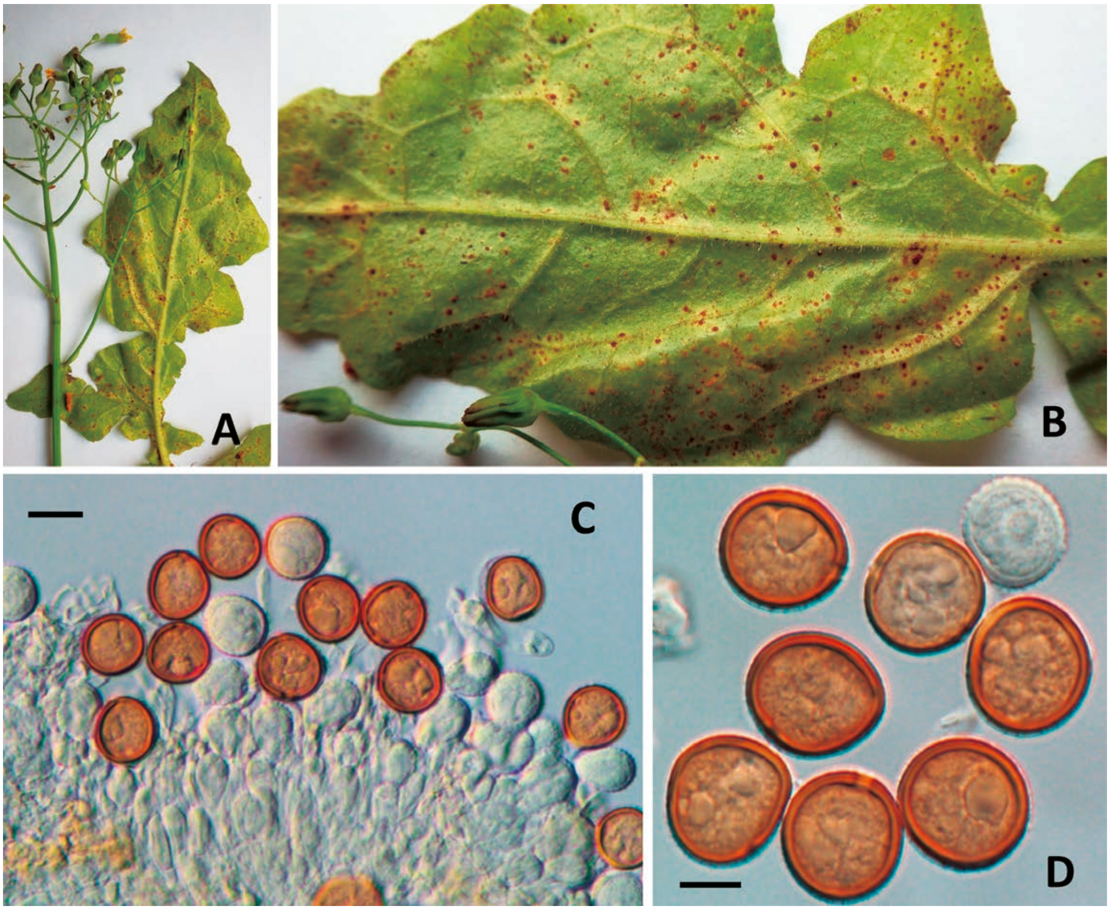

Fig. 19. *Puccinia crepidis-japonicae* on *Youngia japonica*. A, B. Uredinia on the lower leaf surface of the plant. C. Vertical section of an uredinium. D. Urediniospores. Scale bars: C= 20 µm, D= 10 µm.

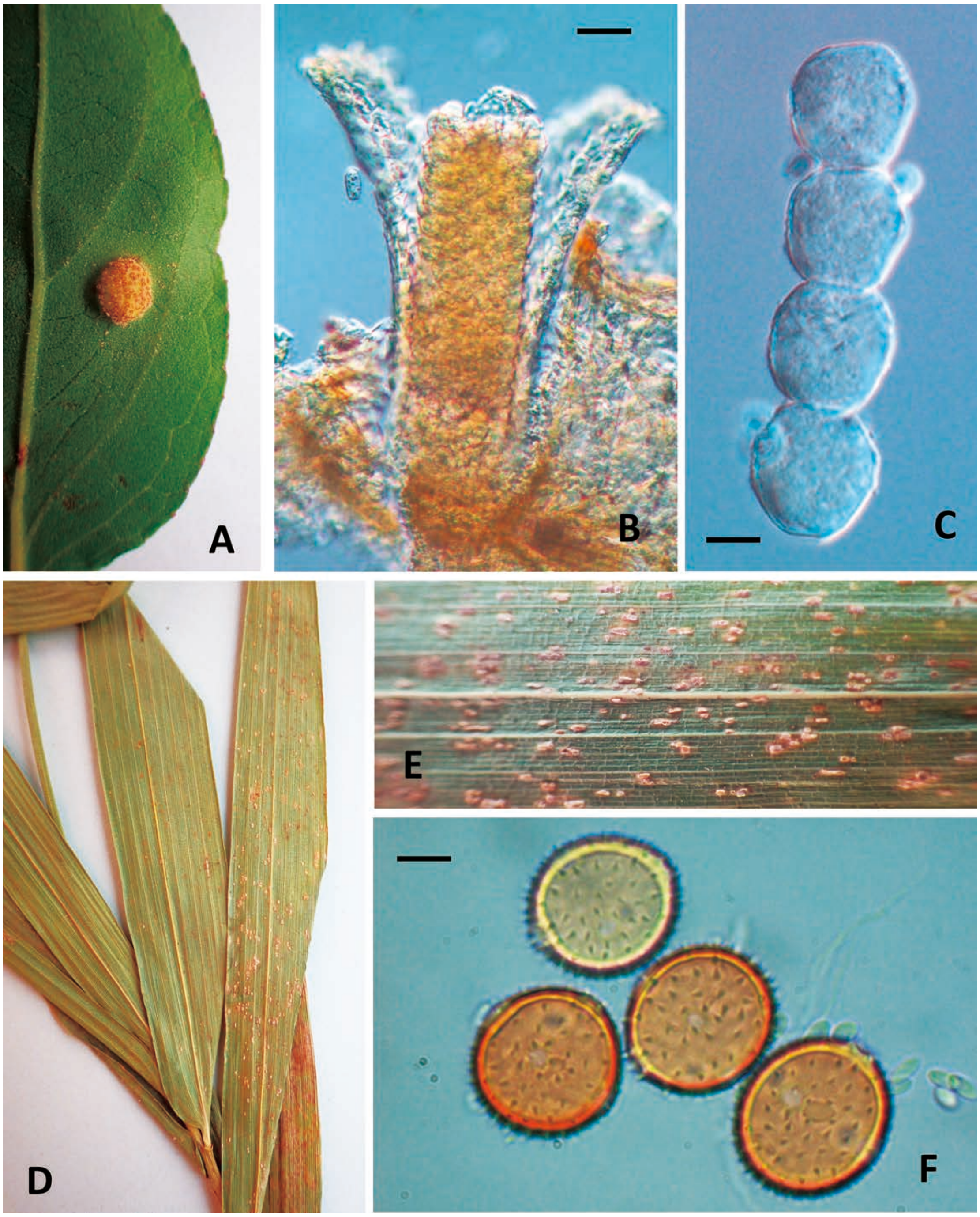

Fig. 20. *Puccinia deutziae* on *Deutzia crenata* var. *crenata* (A-C) and *Pleioblastus chino* (D-F). A. Aecia on the lower leaf surface of the plant. B. Vertical section of an aecium. C. Aeciospores. D-E. Uredinia on the lower leaf surface of the plant. F. Urediniospores. Scale bars: B= 40 µm, C, F= 10 µm.

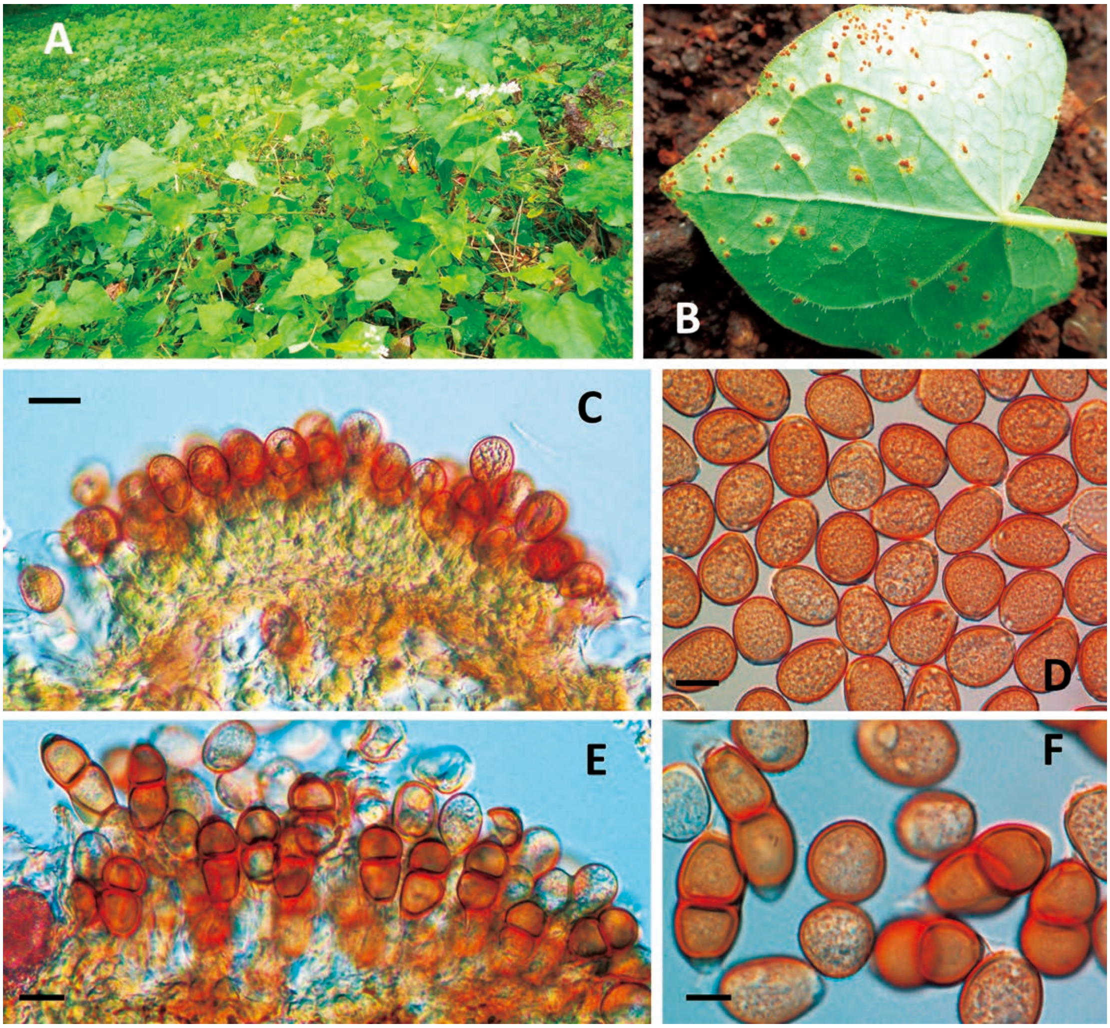

Fig. 21. *Puccinia fagopyricola* on *Polygonum cymosum*. A. Plant infected. B. Uredinia on the lower leaf surface of the plant. C. Vertical section of an uredinium. D. Urediniospores. E. Vertical section of a telium contaminated with urediniospores. F. Teliospores and urediniospores. Scale bars: C, E= 20 µm, D, F=10 µm.

cycle in the garden and persist there continuously (Kakishima and Okane, 2014).

Puccinia fagopyricola Jørst. (Fig. 21)

Host plant: *Fagopyrum cymosum* (Trevir.) Meisn. (= *Polygonum cymosum* Trevir.) (II, III, 27 Oct. 2021, TNS F-83133; II, III, 22 Nov. 2022, TNS F-83157; II, III, 15 Nov. 2023, TNS F-83180; II, III, 18 Nov. 2021, TNS F-110290).

Note: The life cycle of this species is unknown, but it appears to persist continuously in the garden (Kakishima *et al*., 2000, Kakishima and Okane, 2014).

Puccinia glechomae DC. (Fig. 22)

Homotypic synonym: *Puccinia glechomatis* DC.

Host plant: *Glechoma hederacea* subsp. *grandis* (A.Gray) H.Hara (III, 17 May 2023, TNS F-83176; III, 1 July 2022, TNS F-110320).

Note: This species has a microcyclic life cycle, producing only telial stage and is widely distributed in Japan (Hiratsuka *et al.,* 1992), although this is the first record of this species in the garden.

Puccinia hemerocallidis Thüm. (Fig. 23)

Host plant: *Hemerocallis fulva* (L.) L. (II, 10 Nov. 2021, TNS F-83146; II, 22 Nov. 2022, TNS

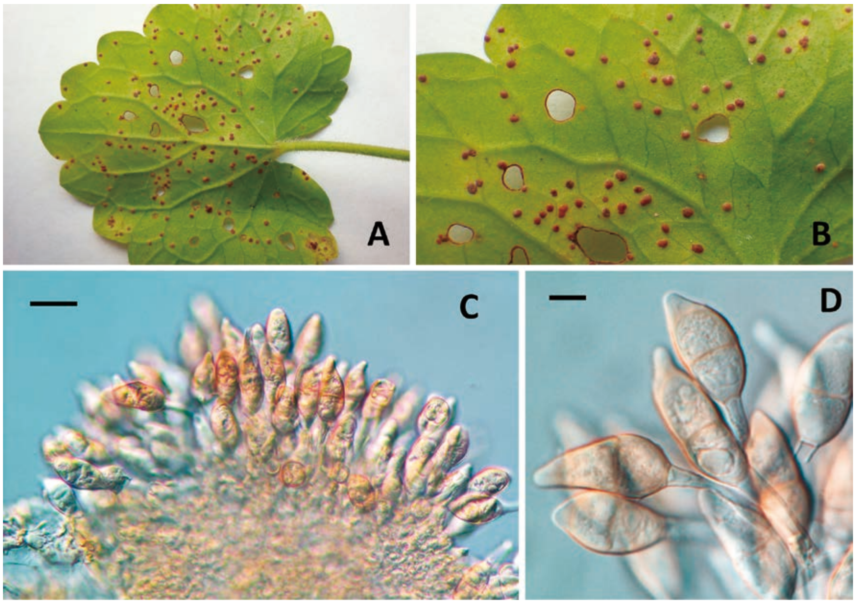

Fig. 22. *Puccinia glechomae* on *Glechoma hederacea* subsp. *grandis*. A, B. Telia on the lower leaf surface of the plant. C. Vertical section of a telium. D. Teliospores. Scale bars: C= 20 µm, D= 10 µm.

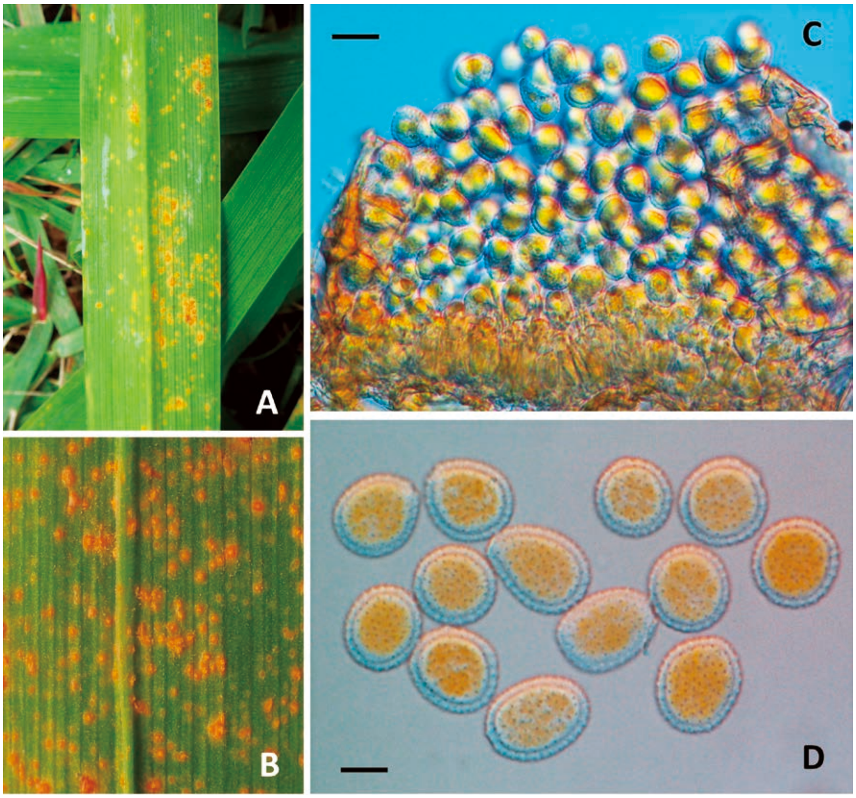

Fig. 23. *Puccinia hemerocallidis* on *Hemerocallis fulva.* A, B. Uredinia on the lower leaf surface of the plant. C. Vertical section of an uredinium. D. Urediniospores. Scale bars: C= 20 µm, D= 10 µm.

F-83155; II, 17 May 2023, TNS F-83169; II, 15 Nov. 2023, TNS F-83190; II, 1 July 2022, TNS F-110324).

Note: This species has a hetero-macrocyclic life cycle, producing spermogonial and aecial stages on plant species of *Patrinia* (Hiratsuka *et al.,* 1992), although these stages were not found in the garden. It is suspected to persist in the garden through the uredinial stage, as it was recorded in a survey conducted 10 years ago (Kakishima *et al*., 2014).

Puccinia lantanae Farl. (Fig. 24)

Host plant: *Justicia procumbens* L. (III, 27 Oct. 2021, TNS F-83131; III, 22 Nov. 2022, TNS F-83161; III, 15 Nov. 2023, TNS F-83183).

Note: This species has a microcyclic life cycle, producing only telial stages (Hiratsuka *et al.,* 1992) and is suspected to persist in the garden (Kakishima *et al.*, 2000; Kakishima and Okane, 2014).

Puccinia longicornis Pat. & Har. (Fig. 25)

Host plant: *Sasa veitchii* (Carrière) Rehder var. *veitchii* (II, 10 Nov. 2021, TNS F-83151; II, 17 May 2023, TNS F-83170; II, III, 1 July 2022, TNS F-110318).

Note: This species is suspected to persist through the uredinial stage, as this stage is observed year-round.

Puccinia miscanthi Miura (Fig. 26)

Host plant: *Miscanthus sinensis* Andersson (II, III, 27 Oct. 2021, TNS F-83132; II, III, 22 Nov. 2022, TNS F-83162; II, III, 15 Nov. 2023, TNS F-83188; II, III, 6 Oct. 2021, TNS F-110021).

Note: This species is common rust fungus in Japan and has a hetero-macrocyclic life cycle, producing spermogonial and aecial stages on plant species of *Plantago* (Hiratsuka *et al.,* 1992), although these stages have not been found in the garden. Therefore, it is suspected to persist in the garden through repeated infections with urediniospores (Kakishima *et al.*, 2000; Kakishima and Okane, 2014).

Puccinia nishidana Henn. (Fig. 27)

Host plant: *Cirsium oligophyllum* (Franch. & Sav.) Matsum. (II, III, 27 Oct. 2021, TNS F-83130; II, III, 10 Nov. 2021, TNS F-83145; II, III, 22 Nov. 2022, TNS F-83152; II, III, 15 Nov. 2023, TNS F-83189).

Note: This species has been reported to produce uredinial and telial stages on various plant species of *Cirsium* and is widely distributed in Japan (Hiratsuka *et al.,* 1992). It is suspected to persist in

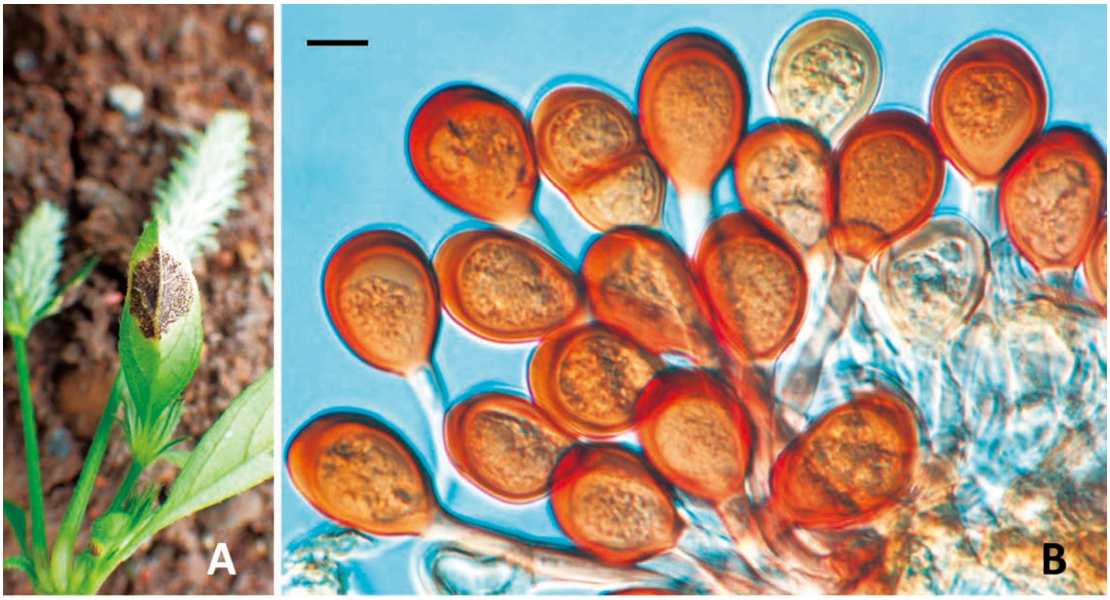

Fig. 24. *Puccinia lantanae* on *Justicia procumbens*. A. Telia on the lower leaf surface of the plant. B. Teliospores. Scale bar: B= 10 µm.

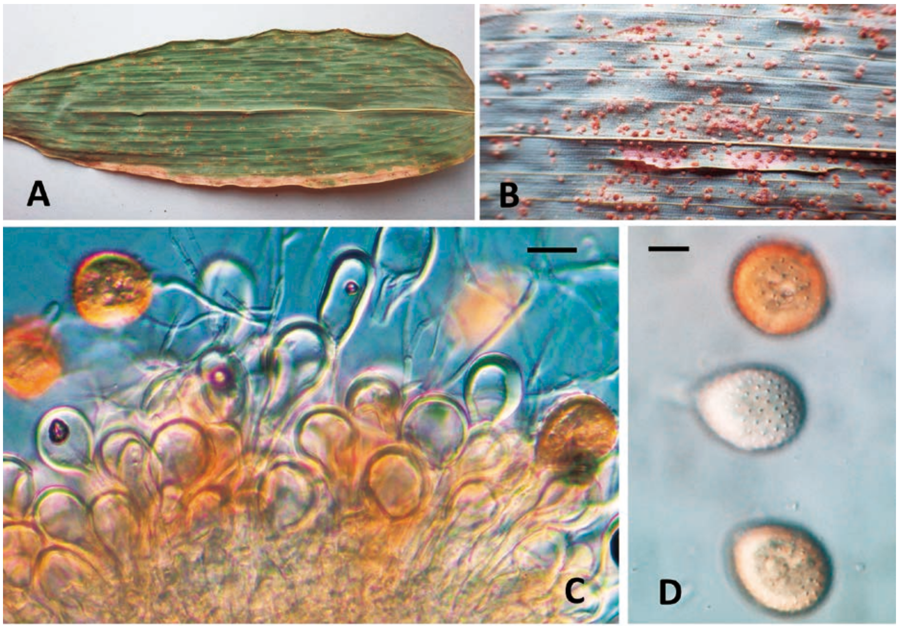

Fig. 25. *Puccinia longicornis* on *Sasa veitchii* var. *veitchii*. A, B. Uredinia on the lower leaf surface of the plant. C. Vertical section of an uredinium. D. Urediniospores. Scale bars: C= 20 µm, D= 10 µm.

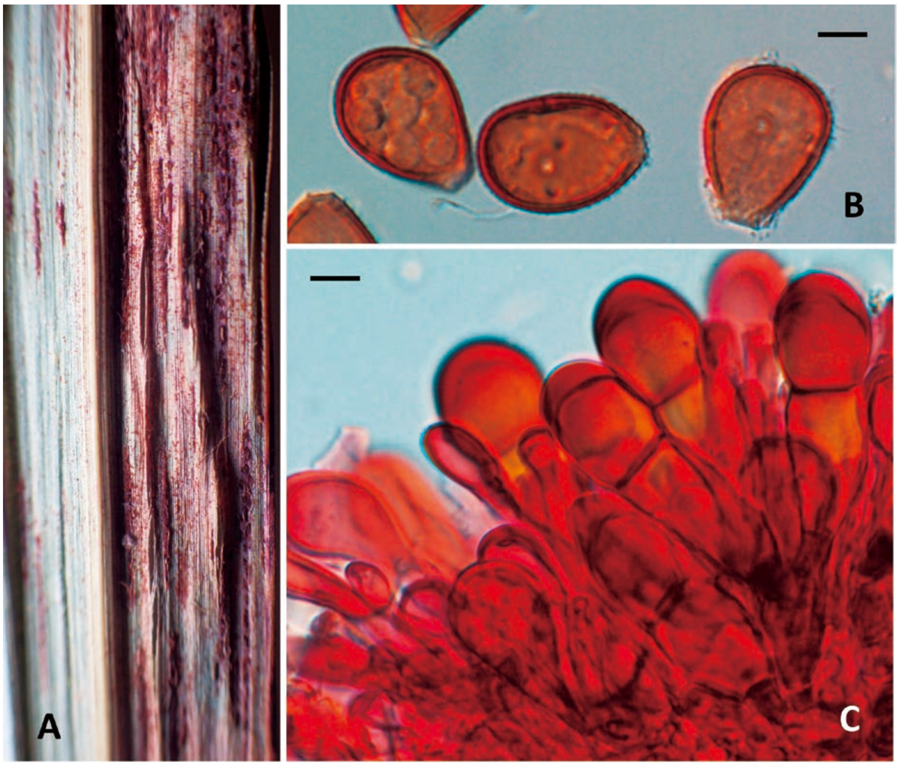

Fig. 26. *Puccinia miscanthi* on *Miscanthus sinensis*. A. Uredinia and telia on the lower leaf surface of the plant. B. Urediniospores. C. Vertical section of a telium. Scale bars: B, C= 10 µm.

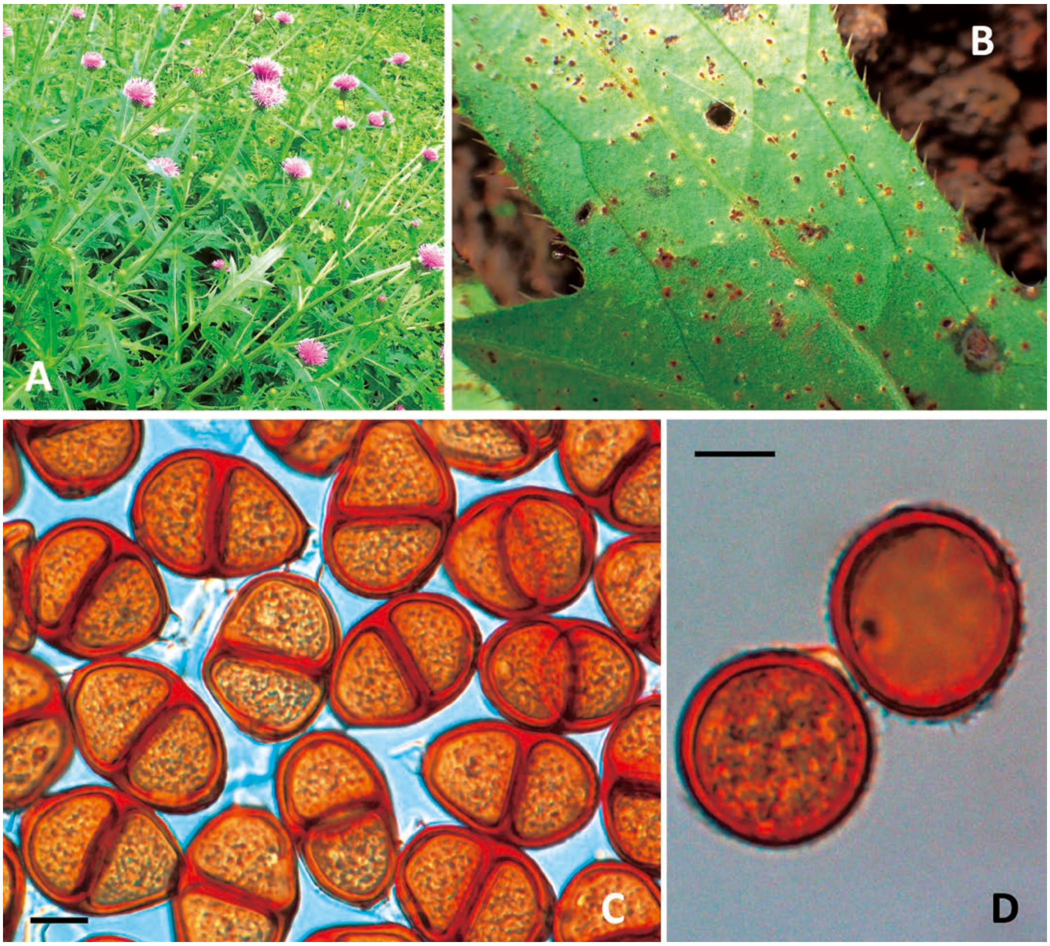

Fig. 27. *Puccinia nishidana* on *Cirsium oligophyllum*. A. Plant infected. B. Uredinia and telia on the lower leaf surface of the plant. C. Teliospores. D. Urediniospores. Scale bars: C, D= 10 µm.

the garden through repeated infections with urediniospores (Kakishima *et al*., 2000; Kakishima and Okane, 2014).

Puccinia oenanthes-stoloniferae S. Ito ex Tranzschel (Fig. 28)

Basionym: *Uredo oenanthes* Dietel

Homotypic synonym: *Puccinia oenanthes* (Dietel) T. Miyake

Host plant: *Oenanthe javanica* (Blume) DC. (II, III, 18 Nov. 2021, TNS F-110301; II, 1 July 2022, TNS F-110321).

Note: This species has an auto-macrocyclic life cycle and is widely distributed in Japan (Hiratsuka *et al.,* 1992), although this is the first record for this species in the garden.

Puccinia oxalidis Dietel & Ellis (Fig. 29)

Homotypic synonym: *Dicaeoma oxalidis* (Dietel & Ellis) Kuntze

Heterotypic synonyms: *Uredo oxalidis* Lév.; *Uromyces oxalidis* (Lév.) Lév.

Host plant: *Oxalis corniculata* L. (II, 1 July 2022, TNS F-110311).

Note: The species name of this fungus was adopted under the ICNafp Shenzhen Code (Turland *et al*., 2018; Kakishima *et al*., 2023). It is an important pathogen of cultivated *Oxalis* species and is commonly found in Japan (Hiratsuka *et al*., 1992). The species is suspected to persist in the garden through repeated infections with urediniospores, as no telial stage has been observed (Kakishima *et al*., 2000;

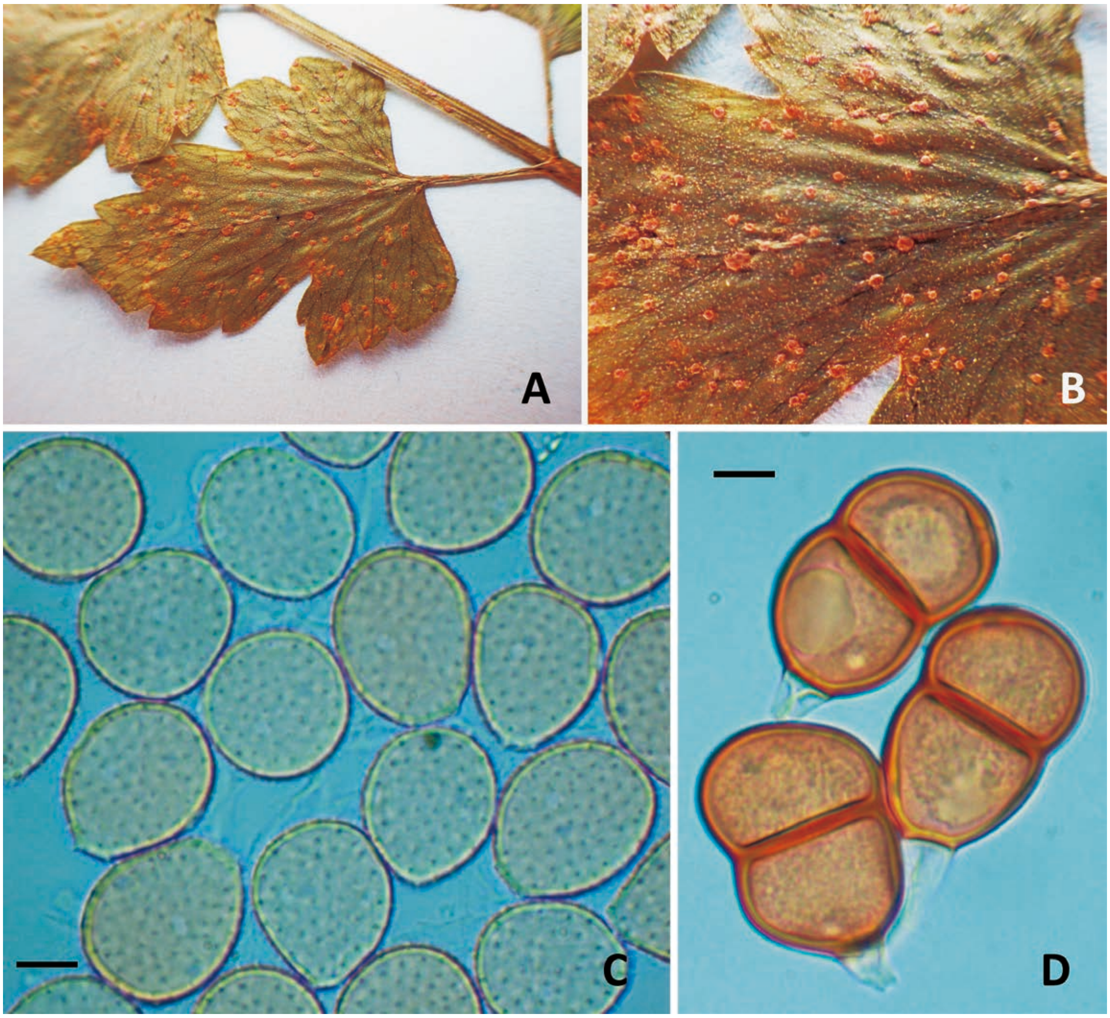

Fig. 28. *Puccinia oenanthes-stoloniferae* on *Oenanthe javanica*. A, B. Uredinia and telia on the lower leaf surface of the plant. C. Urediniospores. D. Teliospores. Scale bars: C, D= 10 μm.

Kakishima and Okane, 2014).

Puccinia phragmitis (Schumach.) Körn. (Fig. 30)

Host plant: *Phragmites communis* Trin. (II, III, 22 Nov. 2022, TNS F-83165).

Note: This species has an hetero-macrocyclic life cycle, producing spermogonial and aecial stages on species of *Polygonum* and *Rumex*, and is widely distributed in Japan (Hiratsuka *et al.,* 1992), but these stages were not found in the garden. This species is suspected to persist in the garden through repeated infections with urediniospores (Kakishima *et al.*, 2000; Kakishima and Okane, 2014).

Puccinia polygoni-amphibii* var. *tovariae Arthur (Fig. 31)

Host plant: *Reynoutria multiflora* (Thunb.) Moldenke (II, 17 May 2023, TNS F-83174; II, III, 15 Nov. 2023, TNS F-83185, 83186; II, 18 Nov. 2021, TNS F-110284, 110287; II, 1 July 2022, TNS F-110325).

Note: This variety is common rust fungus in Japan, but its life cycle remains unknown (Hiratsuka *et al.,* 1992). It is suspected to persist continuously through the uredinial stage (Kakishima *et al*., 2000; Kakishima and Okane, 2014).

***Puccinia* spp.** on unidentified species of *Carex* (II, 17 May 2023. TNS F-83178; II, III, 15 Nov. 2023,

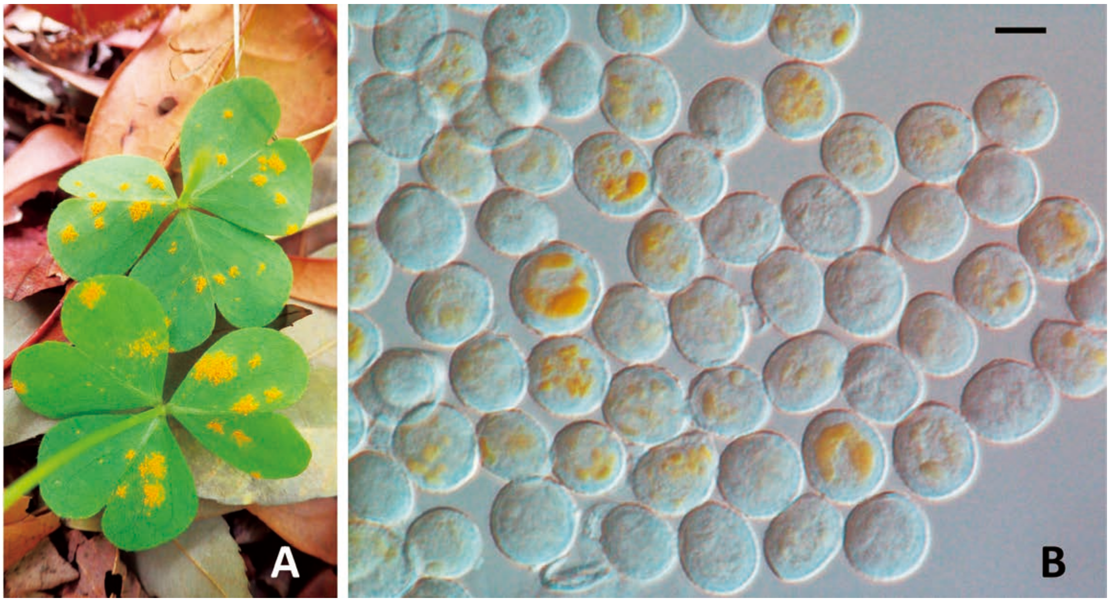

Fig. 29. *Puccinia oxalidis* on *Oxalis corniculata.* A. Uredinia on the lower leaf surface of the plant. B. Urediniospores. Scale bars: B= 10 μm.

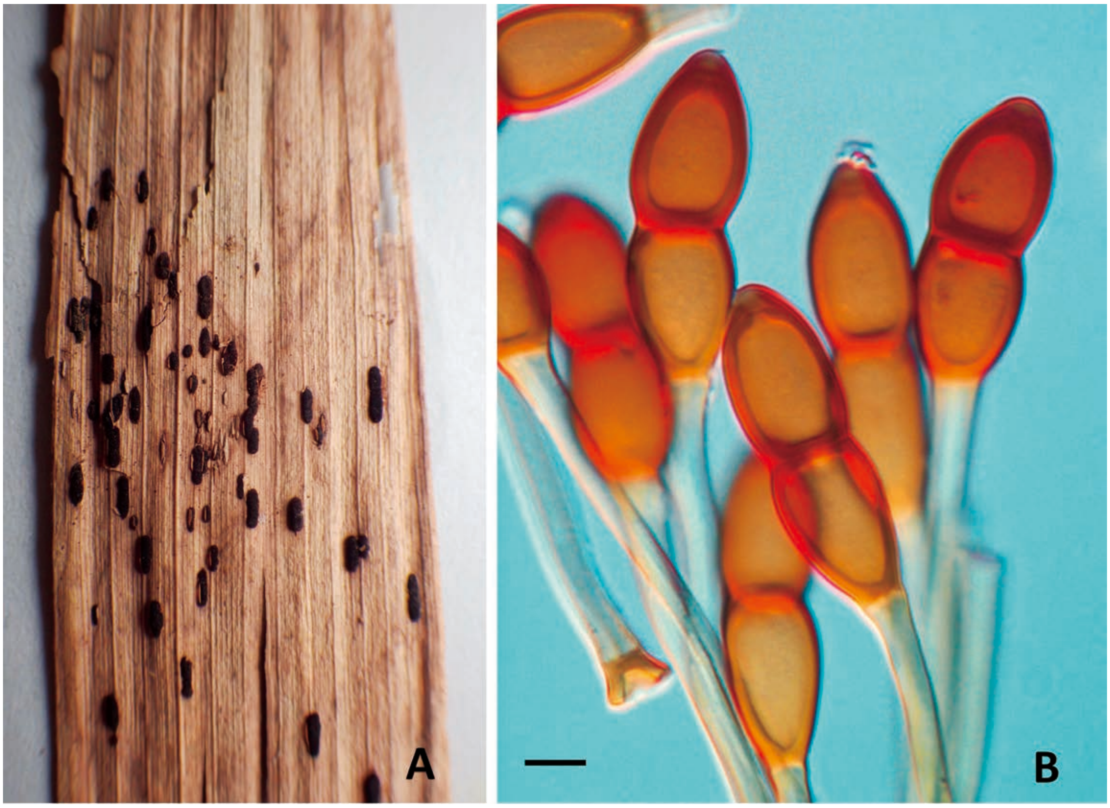

Fig. 30. *Puccinia phragmitis* on *Phragmites communis*. A. Telia on the lower leaf surface of the plant. B. Teliospores. Scale bars: B= 10 μm.

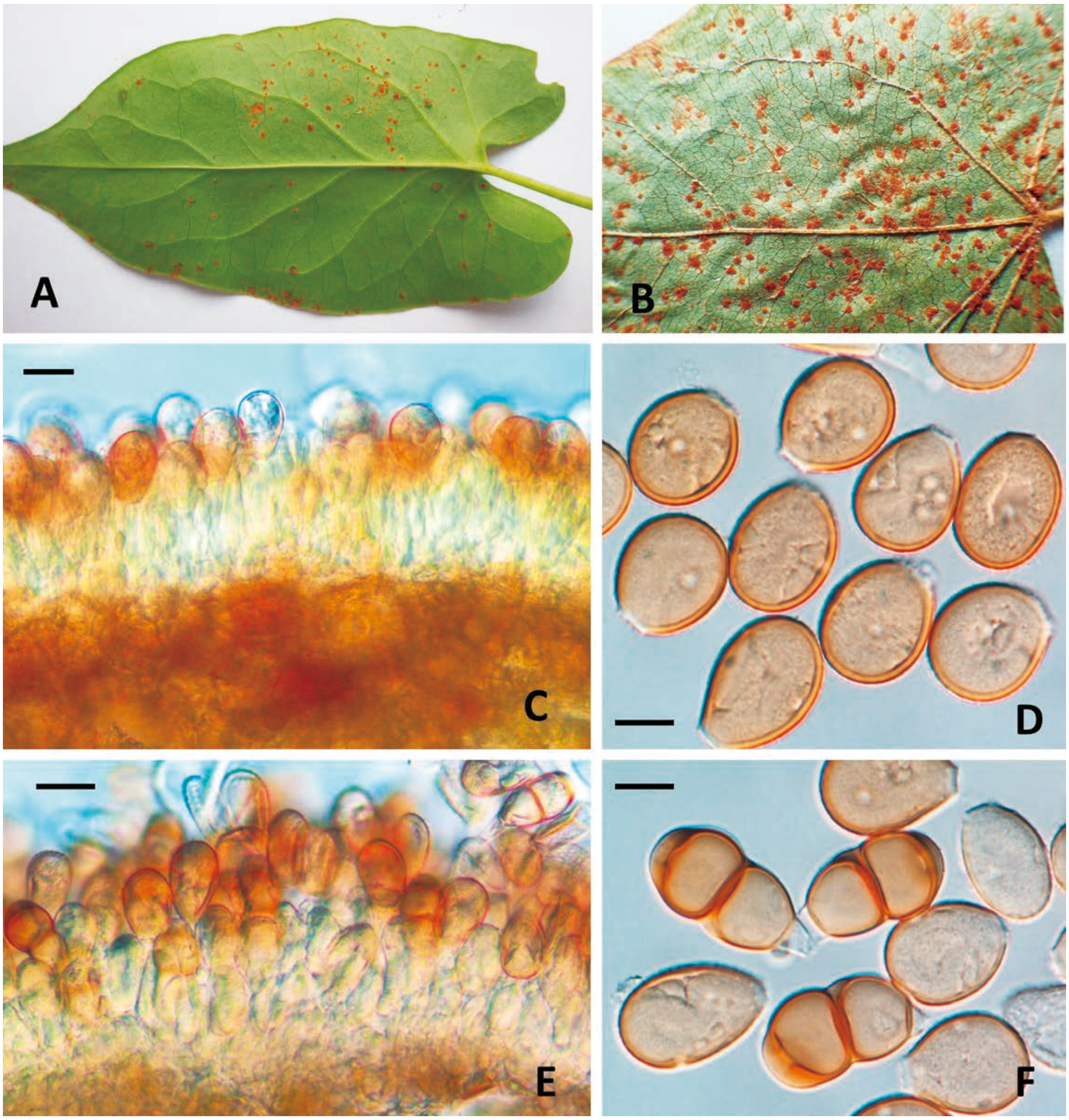

Fig. 31. *Puccinia polygoni-amphibii* var. *tovariae* on *Reynoutria multiflora*. A, B. Uredinia and telia on the lower leaf surface of the plant. C. Vertical section of an uredinium. D. Urediniospores. E. Vertical section of a telium contaminated with teliospores. F. Teliospores and urediniospores. Scale bars: C, E= 20 µm, D, F= 10 µm.

TNS F-110281; II, 18 Nov. 2021, TNS F-110293; II. 18 Nov. 2021, TNS F- 110296; II, 1 July 2022, TNS F-110306; II, 1 July 2022, TNS F-110307; II, 1 July 2022, TNS F-110315).

Note: It is suspected that some unidentified species are present on different *Carex* species.

***Puccinia* spp.** on unidentified species of Poaceae (II, 18. Nov. 2021, TNS F-110300; III, 1 July 2022, TNS F-110319; II, 1 July 2022, TNS F-110328; II, 1 July 2022, TNS F-110330).

Note: It is suspected that some unidentified species are present on different species of Polygonaceae.

Uromyces commelinae Cooke (Fig. 32)

Host plant: *Commelina communis* L. (II, 22 Nov. 2022, TNS F-83166; II, 6 Oct. 2021, TNS

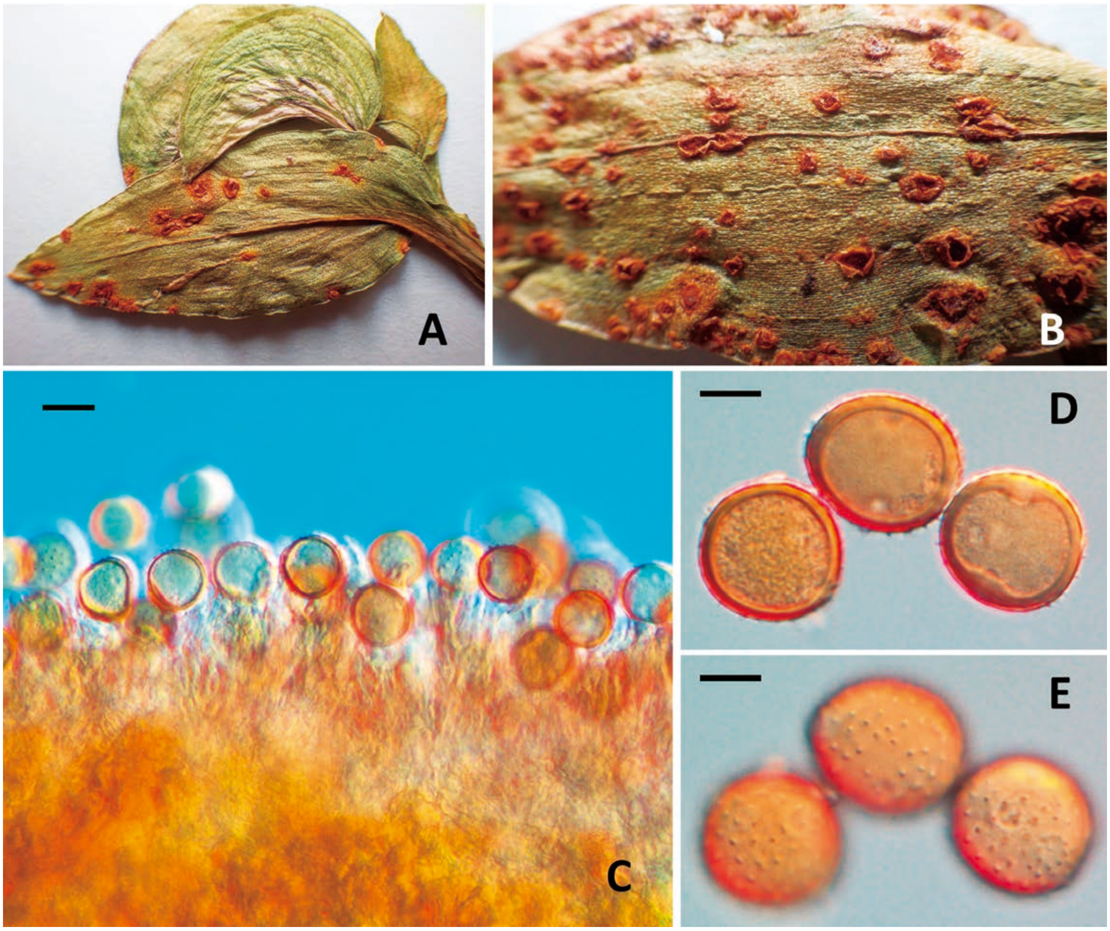

Fig. 32. *Uromyces commelinae* on *Commelina communis*. A, B. Uredinia on the lower leaf surface of the plant. C. Vertical section of an uredinium. D. Urediniospores. E. Surface view of urediniospores. Scale bars: C= 20 µm, D, E= 10 µm.

F-110020).

Note: This species is a common rust fungus in Japan, but its life cycle remains unknown (Hiratsuka *et al.*, 1992). It is suspected to persist in the garden through repeated infections with urediniospores (Kakishima *et al.*, 2000; Kakishima and Okane, 2014).

Fam. Tranzscheliaceae

Leucotelium semiaquilegiae (Dietel) Kakish., K. Hosaka & Hosoya (Fig. 33)

Basionym: *Aecidium semiaquilegiae* Dietel

Heterotypic synonyms: *Puccinia pruni-persicae* Hori; *Leucotelium pruni-persicae* (Hori) Tranzschel; *Sorataea pruni-persicae* (Hori) Cummins & Y. Hirats.

Host plant: *Prunus mume* Sieb. & Zucc. (III, 15 Nov. 2023, TNS F-83191).

Note: This species has been known as *Leucotelium pruni-persicae*, and its spermogonial and aecial stages have been reported as *Aecidium semiaquilegiae* (Hiratsuka, 1952; Hiratsuka *et al.*, 1992). Based on this taxonomic status, *L. semiaquilegiae* was adopted for the species under the ICNafp Shenzhen Code (Turland *et al.*, 2018; Kakishima *et al.*, 2023). It has a hetero-macrocyclic life cycle, producing spermogonial and aecial stages on *Semiaquilegia adoxoides* (DC.) Makino [= *Aquilegia*

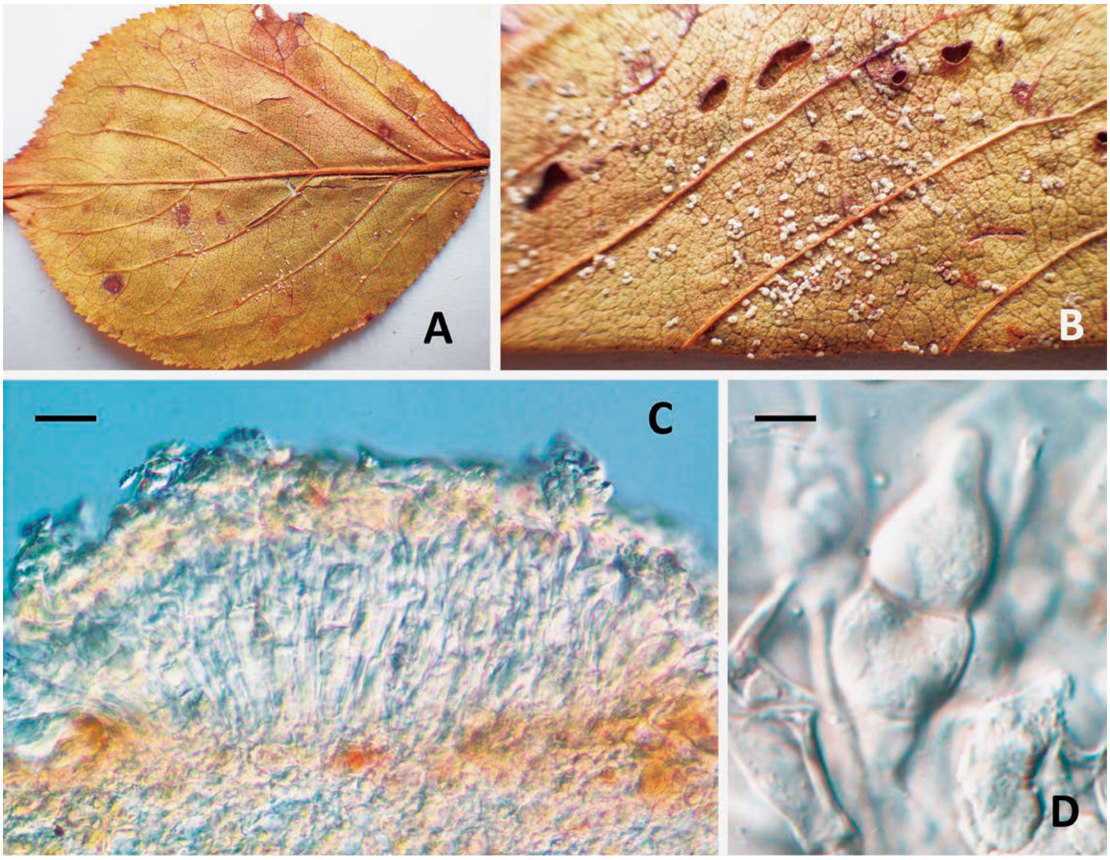

Fig. 33. *Leucotelium semiaquilegiae* on *Prunus mume*. A, B. Telia on the lower leaf surface of the plant. C. Vertical section of a telium. D. Teliospores. Scale bars: C= 20 µm, D= 10 µm.

adoxoides (DC.) Ohwi] (Hiratsuka *et al*., 1992), although these stages have not been observed in the garden. Therefore, it is suspected to persist in the garden through the uredinial stage, as it has been recorded continuously (Kakishima *et al*., 2000; Kakishima and Okane, 2014).

Discussion

In the survey of rust fungi conducted from 2021 to 2023 in the garden, 33 species representing 11 families and 13 genera were identified (Table 1). The species diversity of rust fungi in the garden is considered relatively high despite the limited area of the garden. This diversity may be attributed to the richness of host plant species and their management within the garden (Koyama *et al.*, 2000). However, the compositions of rust fungi have changed markedly compared with the previous surveys conducted in 1997-1999 and 2012-2013, which recorded 35 and 29 species, respectively (Kakishima *et al*., 2000; Kakishima and Okane, 2014). This floristic change in rust fungi is likely as a result of continuous changes in environmental conditions and plant growth in and around the garden. Twelve species (*Coleosporium yamabense, Melampsora coleosporioides, Uredinopsis struthiopteridis, Neophysopella kraunhiae, Nyssopsora cedrelae, Cerotelium fici, Gerwasia rubi, Puccinia caricis-gibbae, P. crepidis-japonicae, P. glechomae, P. longicornis, P. oenanthes-stoloniferae*) are newly recorded in the garden. These species are presumed to have entered the garden from surrounding areas, as they are common in Japan (Hiratsuka *et* *al*., 1992). Whereas nine species (*Neophysopella ampelopsidis, Nothopucciniastrum styracinum, Phakopsora artemisiae-japonicae, Phragmidium rubi-thunbergii, Pileolaria klugkistiana, P. caricis-incisae, P. phyllostachydis, Uromyces viciae-fabae* var. *viciae-fabae, Tranzschelia discolor*) recorded in the first survey were not found in second and present surveys, and presumed to have disappeared from the garden. These species might have failed to adapt to environmental conditions including climate factors, even though their host plants have continued to grow in the garden. Despite these changes, 17 species (*Coleosporium asterum, C. clerodendri, C. phellodendri, C. xanthoxyli, Gymnosporangium koreense, Nothopucciniastrum boehmeriae, Phakopsora fici-erectae, P. sojae, Puccinia fagopyricola, P. lantanae, P. miscanthi, P. nishidana, P. oxalidis, P. phragmitis, P. polygoni-amphibii* var. *tovariae, Uromyces commelinae, Leucotelium semiaquilegiae*) were consistently recorded in all three survey periods, confirming their colonization and persistence in the garden. These species are presumed to maintain their populations by completing their life cycles or through repeated infections via urediniospores within the garden.

The results of the survey indicate that the rust flora in the garden is continuously changing, influenced not only by environmental conditions and the growth of plants within the garden, but also by rust species present in the surrounding areas. These floristic changes were also reported in the survey of the Botanical Garden at Tsukuba, Ibaraki (Kakishima et al. 2023). Characteristics of each rust species, including their life cycle, spore stages, and adaptability to environmental conditions, are also likely to limit their distribution. Continued surveys of rust flora in the garden will be valuable for clarifying the mechanisms underlying these floristic changes.

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皇居から2021–2023年に採集されたさび菌類（サビキン目）

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2021年から2023年にかけて実施した皇居庭園の調査において，さび菌類(Pucciniales) 33種が採集された．そのうち12種は，1997～1999年および2012～2013年に行われた以前の調査（それぞれ35種および29種を記録）では確認されていなかったため，新たな分布記録となる．また，17種は庭園内で定着・生存していることが確認された一方で，9種は消失したと推定された．種構成は過去の調査と比べても変化しており，こうしたさび菌相の変化は，庭園における環境条件や植物の生育状況の継続的な変化によるものと考えられる．