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Species of *Puccinia* Pers. nom. sanct. (rust fungi) on Bambusoideae in Belgium and in Europe

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Species of *Puccinia* Pers. nom. sanct. (rust fungi) on Bambusoideae in Belgium and in Europe

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ABSTRACT
Three *Puccinia* Pers. nom. sanct. species (*Puccinia deutziae* (Dietel) Fraiture & Vanderweyen, comb. nov., *Puccinia longicornis* Pat. & Har. and *Puccinia phyllostachydis* Kusano) have been collected in Brussels and around, on cultivated bamboos. The first and the third ones are new for Belgian mycoflora. The specimens are described and illustrated. Various notes are added, including new data concerning morphology and hosts, as well as comments on two hyperparasitic fungi (*Eudarluca caricis* (Fr.) O.E.Erikss. and *Lecanicillium muscarium* (Petch) Zare & W.Gams) and a mycophagous insect (*Mycodiplosis* sp.) feeding on them. An analysis of the available data on the distribution of the three species shows that they are all very rare in Europe, unless they have only remained unnoticed. An identification key is proposed to *Puccinia* species on bamboos in Europe.

KEY WORDS
alien species, hyperparasite, identification key, distribution.

RÉSUMÉ
Les espèces de Puccinia *Pers. nom. sanct. (rouilles) sur Bambusoideae en Belgique et en Europe.*
Trois espèces de *Puccinia* Pers. nom. sanct. (*Puccinia deutziae* (Dietel) Fraiture & Vanderweyen, comb. nov., *Puccinia longicornis* Pat. & Har. et *Puccinia phyllostachydis* Kusano) ont été récoltées à Bruxelles et environs, sur des bambous cultivés. La première et la troisième sont nouvelles pour la mycoflore belge. Les spécimens sont décrits et illustrés. Diverses notes sont ajoutées, notamment des données nouvelles concernant la morphologie et les hôtes, ainsi que des observations à propos de deux champignons hyperparasites (*Eudarluca caricis* (Fr.) O.E.Erikss. et *Lecanicillium muscarium* (Petch) Zare & W.Gams) et d'un insecte mycophage (*Mycodiplosis* sp.) se nourrissant de ces rouilles. L'analyse des données disponibles sur la distribution des trois espèces montre qu'elles sont toutes trois très rares en Europe, à moins qu'elles soient seulement passées inaperçues. Une clé est proposée pour l'identification des espèces de *Puccinia* croissant sur les bambous en Europe.

MOTS CLÉS
espèce non-indigène, hyperparasite, clé d'identification, distribution.

INTRODUCTION

The Parc Tenbosch is situated in Ixelles (Brussels, Belgium). It covers 1.8 ha and contains an interesting collection of rare trees and plants. This collection has been constituted and progressively enriched during the period 1953-1980 by the owner, Jean-Louis Semet, who was a dendrologist. In 1982, the park became the property of the Brussels-Capital Region and is now maintained by Brussels Environment. During an excursion in the Parc Tenbosch in May 2018, a rust fungus has been collected by one of us (AF) on a cultivated bamboo. Subsequent visits to the park, with an examination of the different bamboo species planted there, led finally to the discovery of three species of *Puccinia* Pers. nom. sanct.: *P. deutziae* (Dietel) Fraiture & Vanderweyen, comb. nov., *P. longicornis* Pat. & Har. and *P. phyllostachydis* Kusano. Examination of the Bambusoideae cultivated in the collections of the Botanic Garden Meise (BR) and in private gardens in Auderghem (Brussels), Brugelette (prov. Hainaut) and Braine-l'Alleud (prov. Walloon Brabant) also allowed the observation of the same three species.

These three rust fungi are well known in Asia, where they live as parasites on the leaves of various Bambusoideae species (Boa 1985; Boedijn 1959; Cummins 1971; Hiratsuka 1958; Hiratsuka & Chen 1991; Hiratsuka *et al.* 1992; Ito 1909; Kusano 1908; Morimoto 1973; Reinking 1919; Shen *et al.* 2016 aecial stage; Shen *et al.* 2017; Tai 1979; Teng 1996; Wang & Zhuang 1998; Zhang *et al.* 1997; Zhuang 2001 and 2005). They have been very rarely reported from Europe (Beenken & Senn-Irlet 2016; Brodtbeck 2011; Henderson & Bennell 1979; Henderson 2000, 2004; Ing 1983; Jones & Baker 2007; Klenke & Scholler 2015; Lane *et al.* 2009; Reid 1978, 1984; Senn-Irlet *et al.* 2016; Termorshuizen & Swertz 2011; Woods *et al.* 2015), perhaps because they remain overlooked. Since the three species are always growing on plants (bamboos) which are not native to Europe, they must be considered as aliens on that territory (Beenken & Senn-Irlet 2016; Daisie 2009; Henderson 2000). As already stressed by Reid (1978), the parasites are probably dispersed together with their host plants, since the latter are propagated vegetatively. We therefore think likely that the three species of *Puccinia* treated here are more widely distributed in Europe than one might think by consulting the literature.

We give hereunder, for each of the three species, nomenclatural data, a description of our specimens and of the host plants on which we collected them, as well as various notes concerning a.o. the host-plants and the distribution of the three rust species in the world. Study of the specimens with the binocular and the microscope revealed two hyperparasitic fungi (*Eudarluca caricis* (Fr.) O.E.Erikss. and *Lecanicillium muscarium* (Petch) Zare & W.Gams) and one mycophagous insect (*Mycodiplosis* sp.), feeding on the *Puccinia*. These fungi are briefly described. An identification key to the three *Puccinia* species is provided.

MATERIAL AND METHODS

Host plants have been identified with Chao (1989) and Verhaeghe (2001). The specimens have been dried between newspaper sheets, as it is commonly done with higher plants herbaria. They have been examined with a binocular Olympus SZ61 and also with a microscope Olympus BX51 and a microscope Leitz Dialux 20EB, at a magnification up to 2000 (with immersion oil), in ammoniacal Congo red with glycerin and in lactophenol cotton blue. Measurements have been made with a camera lucida. In the descriptions, the underlined figures are averages. Macro pictures of sori have been made with a Keyence VHX digital microscope.

Protocol field emission scanning electron microscopy (Botanic Garden Meise): each sample is placed in a convolute of filter paper (medium filtration rate; particle retention >5 µm; VWR) in a stainless steel tube with meshed top and bottom, for critical point drying. The holders are immersed respectively for 30 min in 25% ammonia, 2 × 20 min in 70% ethanol, 2 × 30 min in dimethoxymethane and left overnight, then 4 × 15 min in acetone, hereafter the samples are dried in a critical point dryer (Leica EP CDP 300). The samples are placed in a High Resolution Fine Sputter Coater for FE-SEM (JFC-2300HR Coating Unit, JEOL) and coated with a layer of approximately 6 nm Pl/Pd (using Argon-gas, under 0.05 mbar pressure). The scanning electron microscopy was carried out with a JEOL JSM-7100FLV Field Emission SEM with a tension of 1 kV and working distance of 3.5-4.0 mm.

SYSTEMATICS

Family Pucciniaceae Chevall.
Genus *Puccinia* Pers. nom. sanct.

1. ***Puccinia deutziae*** (Dietel) Fraiture & Vanderweyen, comb. nov.
(Figs 1C, E, F; 2A, B; 3A-C, E, F, K)

Puccinia kusanoi Dietel, *in Engler's Botanische Jahrbücher* 27 (4): 568, 576, table 7 figs 14-15 (1899). — *Puccinia kusanoi* var. *azuma* Kusano, *Bulletin of the College of Agriculture, Tokyo Imperial University* 8 (1): 44 (1908). — *Dicaeoma kusanoi* (Dietel) Syd., *Annales mycologici* 20 (3/4): 118 (1922).

Anamorphs:

Aecidium deutziae Dietel, *Hedwigia* 37: 212 (1898) (basionym).

Uredo arundinariae P. Syd., *Hedwigia* 37 (Beibl. 6): (208) (1898) [non *Puccinia arundinariae* Schwein. (1822)].

Distribution. — *Puccinia deutziae*, comb. nov. (sub *P. kusanoi*) is mostly known from Japan (Hiratsuka 1958; Hiratsuka *et al.* 1992; Ito 1909; Kusano 1908; Morimoto 1973). It has also been mentioned from China (Tai 1979; Zhuang 2001), Taiwan (Hiratsuka & Chen 1991; Hiratsuka *et al.* 1992; Shen *et al.* 2016 aecial stage; Shen *et al.* 2017; Zhuang 2001), Indonesia (Boedijn 1959), India, Russian Federation (far east, Azbukina 1984), Cuba (Arnold 1986), United Kingdom (Reid 1978; Henderson & Bennell 1979; Ing 1983; Henderson 2000, 2004) and Germany (Kruse *et al.* 2018, sub *P. phyllostachydis*). Apart from Belgium (our observations) and Germany (Bochum, in Kruse *et al.* 2018, sub *P. phyllostachydis*; J. Kruse confirmed us in e-litt. that the specimen has been misidentified), United Kingdom seems to be the only country in Europe in which the species had been observed until now (Termorshuizen & Swertz 2011; Klenke &

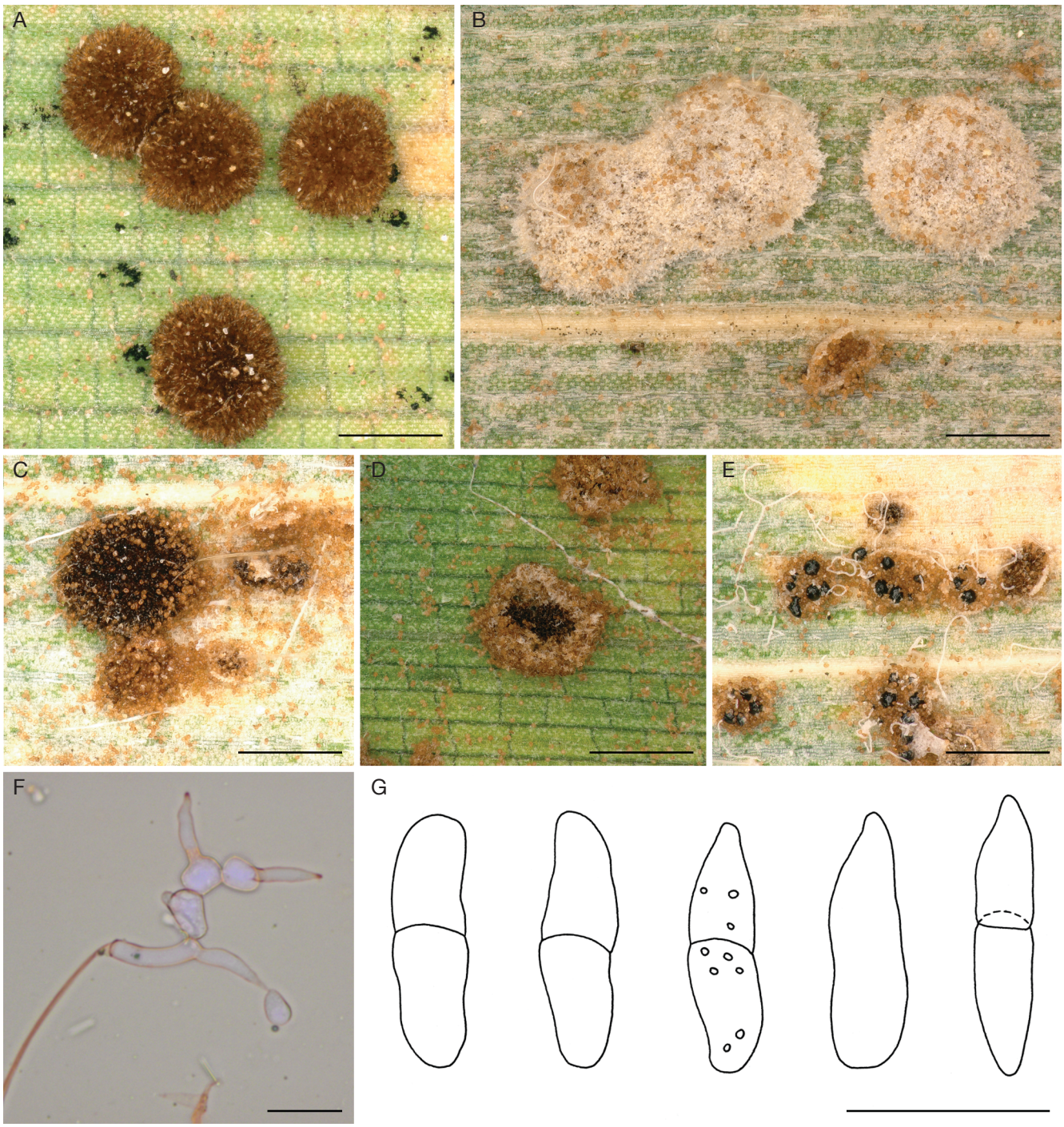

Fig. 1. — *Puccinia longicornis* Pat. & Har.: **A**, teleutosores in February (AF 3760); **B**, teleutosores in May (covered with a layer of basidia and basidiospores) with an erumpent uredosore (AF 3739). – *Puccinia deutziae* (Dietel) Fraiture & Vanderweyen, comb. nov. (AF 3738): **C**, teleutosore and uredosore – *Puccinia phyllostachydis* Kusano (AF 3761); **D**, teleutosore growing from the centre of an uredosore. – *Puccinia deutziae* (AF 3738): **E**, uredosores parasitized by *Sphaerellopsis filum* (Biv.) Sutton (pycnidia and cirrhi); **F**, basidium with a basidiospore; **G**, conidia of *Sphaerellopsis filum*. Scale bars: A-E, 500 µm; F, 20 µm; G, 10 µm.

Scholler 2015). These observations have been made during the period 1967-2000 in four different places in SE England and Cornwall:
– Wakehurst Place, Ardingly, East Sussex (TQ33), 17.V.1967 and 26.XI.1967 (Reid 1978);
– St. Catherine's Point, Fowey, East Cornwall (SX15), 24.IV.1983 (Ing 1983);
– Oxshott Heath, Oxschott, Surrey (TQ16), XI.1994 (Kirk & Spooner, unpubl.);
– Braywick Nature Centre, Berkshire (SU87), 02.IV.2000 (Storey, unpubl.).

The species is new for the Belgian mycoflora and has been observed in two places:
– Brussels (Ixelles), Parc Tenbosch, 13.V.2018, 05.VI.2018 and 22.VI.2018 (our specimens);
– Meise, Domain of Bouchout (BR), outdoor bamboo collection, 20.VI.2018 and 13.VII.2018 (our specimens).

Material examined. — **Belgium**, Brussels (Ixelles), Parc Tenbosch, 13.V.2018. On the underside of the leaves of *Sasa ramosa*. Specimens *A. Fraiture 3738* (BR) and *A. Vanderweyen F 1090*. – *Ibid.*, 05.VI.2018. On *Sasa ramosa*. Specimens *A. Fraiture 3741* (BR) and *A. Vanderweyen F 1092* (KR-M-0006375). – *Ibid.*, 22.VI.2018. On *Sasa ramosa*. Specimen *A. Fraiture 3748* (BR). – Belgium, Meise, Domain of Bouchout (BR), outdoor bamboo collection, 20.VI.2018. On the underside of the leaves of *Sasa ramosa*. Specimens *A. Fraiture 3747* (BR) and *A. Vanderweyen F 1097*. – *Ibid.*, 13.VII.2018. On *Sasa ramosa*. Specimen *A. Fraiture 3750* (BR). – *Ibid.*, 05.II.2019. On *Sasa ramosa*. Specimen *A. Fraiture 3759* (BR).

Description

Aecia

Not seen (unsuccessfully searched on the Deutzia present in the Parc Tenbosch).

Uredinia

Hypophyllous, erumpent, 0.2-1.0 mm diam., cinnamon, each of them producing on the upper surface of the leaf a small square to rectangular yellowish spot, 0.2-1.0 × 0.2-0.5 mm, extending between two little veins.

Urediniospores

(25-)26-30.1-34(-35) × (20-)22-23.7-26 µm, Q = 1.15-1.26-1.38, subglobose, obovoid or ellipsoid, with a pedicel up to 67 µm long rarely remaining attached to the spore, with a brownish wall (1.0-)2.0-2.5 µm thick appearing two layered, provided with acute spines 1.0-1.5 µm long and with four approximately equatorial germ-pores.

Paraphyses

Not seen.

Telia

Hypophyllous, erumpent, appearing in winter, dark cinnamon to blackish, not discolouring leaf tissues.

Teliospores

(50-)57-65.8-77(-89) × (14-)15-18.4-20(-22) µm, Q = 2.86-3.51-5.17, fusoid, 2-celled, with a smooth to very finely punctuated wall which is 1.0-2.5 µm thick in the sides and 5-11.5 µm thick in the conical top of the spore, inserted on an up to 190 µm long pedicel which is (1-)2(-3) µm thick walled and very light brownish. These spores are mixed with a lower proportion of less elongated spores (dimorphism), 37-40.0-44 × 19-23.2-27 µm, Q = 1.37-1.74-2.26, with a broadly rounded apex and a punctuated wall. Very rare mesospores have been found.

Basidiospores

12-14 × 8.5-9.0 µm, ellipsoid to ovoid, with a hyaline, smooth and thin wall.

Host plant

Sasa ramosa (Makino) Makino & Shibata (*Sasaella ramosa* (Makino) Makino, × *Sasinaria ramosa* (Makino) Demoly).

Culms not caespitose, about 1.0-1.5 m high, with cylindrical internodes and single branch-complement on the nodes. Leaf-blades 9-20 × 1.3-3.0 cm, pubescent on the underside and very sparsely on the upper side, with (4-)5-6 pairs of secondary veins, leaf-sheaths glabrous except for the margins.

Hyperparasitic fungi and mycophagous insect

During the study of our specimens we observed the following organisms, parasitizing *Puccinia deutziae*, comb. nov., or feeding on it. We already observed them (Fraiture & Vanderweyen 2007) on another rust fungus, *Frommeëlla mexicana* Fraiture & Vanderweyen (2007), and it seems they are frequent on Uredinales.

Sphaerellopsis filum (Biv.) Sutton (Ascomycota, Pleosporales).

Pycnidia of *S. filum* are frequent in the sores. They produce long whitish threads (cirrhi, Fig. 1E) entirely composed of conidia. Conidia fusiform, 12-18 × (3.5-)4.0(-5.0) µm, hyaline, with 0-1 septum and a thin and smooth wall (Fig. 1G).

Lecanicillium muscarium (Petch) Zare &W. Gams (Ascomycota, Hypocreales).

Whitish mould covering some sori and sometimes extending on the leaf surface. Phialides hyaline, smooth, very narrowly conical, straight, 20-32 × 1.5-2.5 µm, verticillate, 2-5 in whorls or sometimes solitary, inserted on hyaline, smooth, (1.5-)2 µm diam. hyphae. Conidia (2-)3.5-7.5 × 1-2(-2.5) µm, produced in globose heads, hyaline, with a thin and smooth wall, subglobose to ellipsoidal-diamond shaped to subcylindrical, with rounded ends, straight, non-septate, often with three guttules.

Mycodiplosis sp. (Diptera, Cecidomyiidae).

Several larvae feeding on *Puccinia* uredinia.

Discussion and notes

Nomenclature

For many years, the Code has prohibited the use of names of anamorphs as basionyms for the composition of correct names of pleomorphic species. However, in recent years this requirement has been removed and the current version of the Code (Turland *et al.* 2018) states that "all legitimate fungal names are treated equally for the purposes of establishing priority, regardless of the life-history stage of the type" (Art. F.8.1). We followed this rule here, publishing *Puccinia deutziae*, comb. nov., to replace *P. kusanoi* as the correct name of the species. It seems obvious, however, that the application of this rule will result in the replacement of many names in current use. In addition, new names created will often seem strange. For example, in the current case, the Puccinia stage (teleomorph) of *Puccinia deutziae*, comb. nov., never grows on Deutzia. A solution to this problem would be that plant pathologists use Art. F.2.1 and propose a list of names for protection.

Descriptions

Descriptions of *Puccinia deutziae*, comb. nov. (sub *P. kusanoi*) are given by Cummins (1971: 269), Henderson & Bennell (1979), Hiratsuka (1958), Hiratsuka *et al.* (1992), Kusano (1908, also descr. of the var. *azuma*), Reid (1978) and Sydow & Sydow (1904).

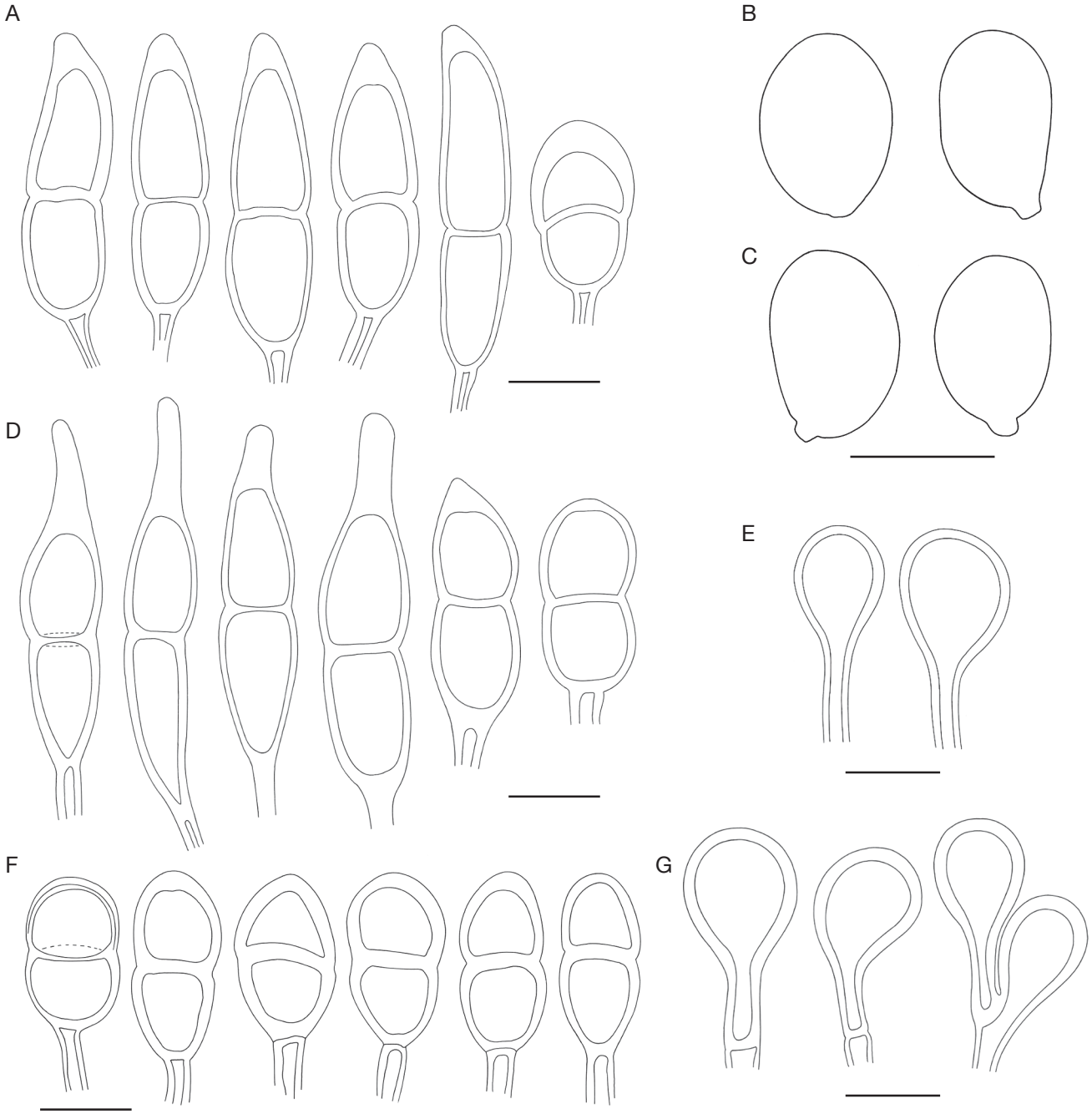

FIG. 2. — *Puccinia deutziae* (Dietel) Fraiture & Vanderweyen, comb. nov. (AF 3738): **A**, teleutospores; **B**, basidiospores. – *Puccinia longicornis* Pat. & Har. (AF 3739): **C**, basidiospores; **D**, teleutospores; **E**, paraphyses. – *Puccinia phyllostachydis* Kusano: **F**, teleutospores (AF 3743); **G**, paraphyses (AF 3749). Scale bars: B, C, 10 µm; A, D-G, 20 µm.

Aecial stage

Asuyama (1936) realized inoculation experiments with the teliospores of *P. deutziae*, comb. nov., and showed that the aecial form is growing a.o. on *Deutzia scabra* var. *crenata* Makino and must be identified with *Aecidium deutziae* Diet. Recently, Shen *et al.* (2016) described the same aecial stage, collected on *Deutzia pulchra* S.Vidal in Taiwan.

Teliospore variability

Ito (1909) mentions the occasional existence of transitional forms with *P. longicornis* : some teliospores of *P. deutziae*, comb. nov., have an apex up to 18 µm thick while, on the other hand, some teliospores of *P. longicornis* have an apex which is only 8 µm thick. Similarly, Reid (1984) observed that, in *P. longicornis*, teliospores can be "extraordinarily

variable" and that "The fact that in some mixed sori all the teliospores lacked a rostrate apex, while in others all the teliospores showed this feature inevitably raises the possibility of the host being infected by both *P. longicornis* and *P. kusanoi* or some other rust." Also, Kusano (1908) describes the variability he observed in the size and shape of teliospores according to the host plant.

Some variability also exists with regard to the ornamentation of the teliospore wall. Most authors (a.o. Sydow & Sydow 1904; Hiratsuka 1958; Reid 1978) describe it as smooth but Cummins (1971) says "minutely punctate-verrucose (especially the robust spores) or smooth". In our specimens, teliospore wall was smooth to finely punctate-verrucose.

Ito (1909) observed the presence of transitional forms between f. *azuma* and the typical form of *P. kusanoi*. He also notes that, with the exception of the shape of the thickened apex, the general form of the spore of f. *azuma* is closer to that of *P. longicornis* than to that of the typical form of *P. kusanoi*.

Basidiospores

It seems it is the first time that the basidiospores of this species are described and illustrated (Dr M. Scholler, in e-litt.).

Presence of paraphyses

All authors consider *P. deutziae*, comb. nov., as devoid of paraphyses, except Reid (1978), who describes and illustrates clavate or subcapitate paraphyses with heads up to 12 µm wide, subhyaline with thin but distinct walls and often 1-septate near the base. We observed clusters of cylindrical cells in our material, but we think they are constituted by the pedicels of the urediniospores. We never saw clavate or subcapitate paraphyses.

Host plants

A large number of bamboo species have been reported as hosts of *Puccinia deutziae*, comb. nov. (sub *P. kusanoi*) in the world. Farr & Rossman (2018) cite 71 bamboo species belonging to the following genera: *Arundinaria*, *Bambusa*, *Nipponobambusa*, *Phyllostachys*, *Pleioblastus*, *Pseudosasa*, *Sasa*, *Sasaella*, *Semiarundinaria*, *Sinobambusa* and *Yushania*, as well as ten *Deutzia* species (hosts of the aecial stage).

In Europe, the only host cited so far (United Kingdom) was *Semiarundinaria fastuosa* Makino. All the Belgian collections described above have been made on *Sasa ramosa*.

Hyperparasitic fungi and mycophagous insect

Sphaerellopsis filum (Biv.) B. Sutton.

Sphaerellopsis filum is the anamorphic state of *Eudarluca caricis* (Fr.) O.E. Eriksss., 1966 (Keener 1951). The teleomorph is rarely observed. Descriptions of the species are given by Keener (1934), Eriksson (1966, 1967), Scheuer (1988), Nag Raj (1993), Yuan *et al.* (1998), Płachecka (2005) and Trakunyingcharoen *et al.* (2014). It is hyperparasitic, leaving on many Uredinales (369 species in the list published by Kranz & Brandenburger 1981; none of our three *Puccinia* species being included in this list), even if it seems that a certain host-specificity does exist (Keener 1934; Nischwitz *et al.* 2005). The parasite is already mentioned by P. Sydow, in the description of *Uredo arundinariae* ("Sori saepe a *Darluca Filo* occupantur"). It has been recently shown that *S. filum* was a species complex (Liesebach & Zaspel 2004; Nischwitz *et al.* 2005; Trakunyingcharoen *et al.* 2014). After the descriptions (mostly conidia dimensions) given by these last authors, our material belongs to *S. filum* s. str.

Lecanicillium muscarium (Petch) Zare & W. Gams.

A few dozen species of conidial fungi grow on Uredinales (Hawksworth 1981). The genus *Lecanicillium* has been created to accommodate a majority of the species formerly classified in *Verticillium* sect. *Prostrata* (Gams & Zare 2001; Zare & Gams 2001, 2008). It contains almost thirty species mostly growing as parasites on scale insects, mites and fungi, a.o. Uredinales. Within that genus, our material can be placed in the group of *L. lecanii* (Zimm.) Zare & W.Gams, *L. longisporum* (Petch) Zare & W.Gams and *L. muscarium*, because of the ellipsoidal to cylindrical and straight conidia, produced in globose heads on mostly verticillate phialides. Finally, the dimensions of phialides and conidia in our material allow to determine it as *L. muscarium*. Descriptions of the species are given by Zare & Gams (2001, 2003). Leinhos & Buchenauer (1992) observed a pronounced chitinolytic activity in vitro of several hyperparasitic fungi (incl. *Verticillium lecanii*) growing on rust fungi. That study helps to understand why many of these fungi are also attacking scale insects.

Mycodiplosis sp.

Many insect species feed on fungi, but those eating Uredinales are just a few. A family of Diptera, Cecidomyiidae, includes many mycophagous species. Within this family, the genus *Mycodiplosis* contains several species feeding on rust fungi, a.o. on *Puccinia* species (Coutin 2005; Henk *et al.* 2011; Nelsen 2013; Nelsen & Aime 2013). One of them, *Mycodiplosis pucciniae* is present in Europe (Fauna Europaea) but we are not able to confirm that our collections correspond to this species. According to our observations, larvae mainly eat urediniospores.

2. ***Puccinia longicornis*** Pat. & Har.
(Figs 1A, B; 2C-E; 3D, G, H, J)

Puccinia longicornis Pat. & Har., Bulletin de la Société mycologique de France 7: 143 (1891). — *Dicaeoma longicorne* (Pat. & Har.) Kuntze, *in Revisio Generum Plantarum* 3 (2): 469 (1898).

Distribution. — *Puccinia longicornis* is mostly known from Japan (Hiratsuka 1958; Hiratsuka *et al.* 1992; Ito 1909; Kusano 1908; Morimoto 1973). It has also been mentioned from China (Reinking 1919; Tai 1979; Teng 1996; Wang & Zhuang 1998; Zhang *et al.* 1997; Zhuang 2001), Korea (Cho & Shin 2004), Russian Federation (far east, Azbukina 1984), United Kingdom (Reid 1978, 1984; Jones & Baker 2007; Lane *et al.* 2009; Henderson & Bennell 1979; Woods *et al.* 2015; Henderson 2000, 2004) and Belgium. These last two countries seem to be the only ones in Europe in which the species has been observed up to now (Termorshuizen & Swertz 2011; Klenke & Scholler 2015).

The British observations of *Puccinia longicornis* have been made during the period 1983-2015, in SE England and the Wales:

– Wakehurst Place, Ardingly, West Sussex (TQ33), 1.VI.1977 (Reid 1978);

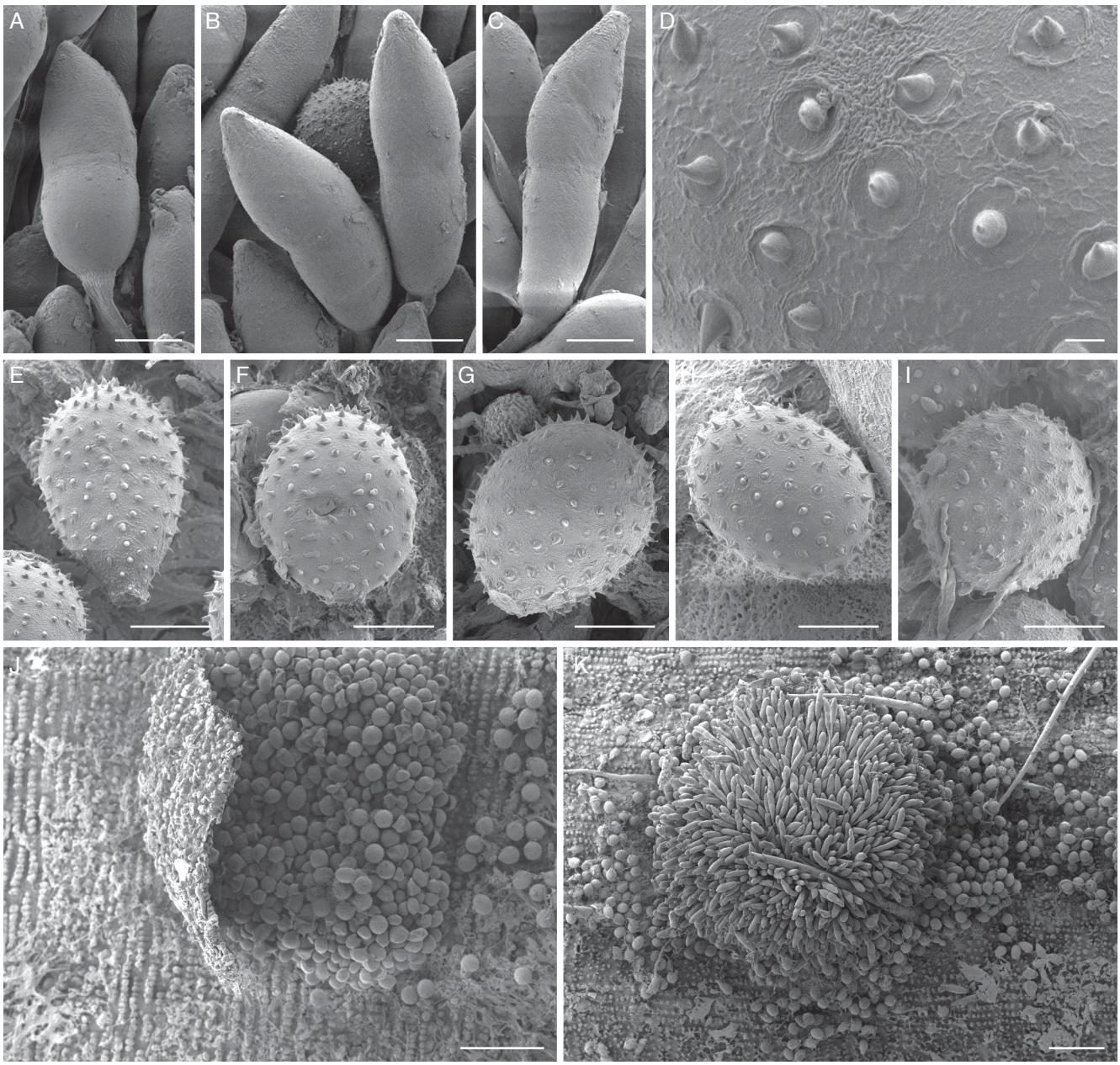

FIG. 3. — SEM pictures. *Puccinia deutziae* (Dietel) Fraiture & Vanderweyen, comb. nov. (AF 3738): **A**-**C**, teleutospores; **E**-**F**, uredospores; **K**, teleutosore surrounded by uredospores. – *Puccinia longicornis* Pat. & Har. (AF 3739): **D**, ornamentation of an uredospore; **G**-**H**, uredospores; **J**, uredosore with a fragment of epidermis. – *Puccinia phyllostachydis* Kusano (AF 3743): **I**, uredospore. Scale bars: A-C, E-I, 10 µm; D, 1 µm; J, K, 100 µm.

– Pondlands, Haslemere Museum, Haslemere, Surrey (SU93), 09.X.1983, 19.XI.1983, 10.III.1984 and 13.V.1984 (Reid 1984);
– Unspecified place, Surrey (TQ16), 05.V.1987, 29.V.1994, 08.VI.1997 and 04.VI.2000;
– "In a garden centre in southern England", V.2007 (Lane *et al.* 2009);
– Glamorgan (VC 41) (Woods *et al.* 2015);
– Carmarthenshire (VC 44) (Woods *et al.* 2015);
– Cardiganshire (VC 46) (Woods *et al.* 2015).
In Belgium, the species has been observed in nine places:
– Kalmthout, 15.V.2017 and 07.VII.2018 (FUNBEL and Observation.be);
– Kwaadmechelen, 01.IX.2017 (Observation.be);
– Oostmalle, Blommerschot, 31.X.2017 (Observation.be);
– Brussels (Ixelles), Parc Tenbosch, 19.V.2018 and 05.VI.2018 (our specimens);
– Meise, Domain of Bouchout (BR), outdoor bamboo collection, 20.VI.2018 and 05.II.2019 (our specimens);
– Brussels (Auderghem), 28.VII.2018 (our specimens);
– Brugelette, park of the Castle of Attre, 19.VIII.2018 (our specimens);
– Schilde, 13.XI.2018 (Observation.be);
– Ham, 22.XI.2018 (Observation.be).

MATERIAL EXAMINED. — **Belgium**, Brussels (Ixelles), Parc Tenbosch, 19.V.2018. On the underside of the leaves of *Sasa palmata*. Specimen *A. Fraiture 3739* (BR). – *Ibid.*, 05.VI.2018. On *Sasa palmata*. Specimens *A. Fraiture 3742* (BR) and *A. Vanderweyen F 1094* (KR-M-0006377). – Belgium, Meise, Domain of Bouchout (BR), outdoor bamboo collection, 20.VI.2018. On the underside of the leaves of *Sasa palmata* f. *nebulosa*. Specimens *A. Fraiture 3746* (BR) and *A. Vanderweyen F 1098* (KR-M-0006376). – *Ibid.*, 05.II.2019. On *Sasa*

palmata f. *nebulosa*. Specimen *A. Fraiture 3760* (BR). – Belgium, Brussels (Auderghem), 28.VII.2018. On *Sasa* cf. *tsuboiana*. Specimen *A. Vanderweyen F 1100*. – Belgium, Brugelette, park of the Castle of Attre, 19.VIII.2018. On *Sasa palmata*. Specimen *A. Fraiture 3751* (BR).

Description

Aecia

Not seen.

Uredinia

Hypophyllous, erumpent, 0.2-0.7 × 0.2-0.5 mm, cinnamon, rupturing the epidermis of the leaf and initially surrounded by a thin whitish collar of epidermis fragments and by an ochraceous halo on the tissues of the host, each sore producing on the upper surface of the leaf a small spot, 0.3-1.5 mm diam., which is dark brown with a yellowish border.

Urediniospores

(27-)29-33.5-38(-41) × (20-)23-26.1-31(-32) µm, subglobose, obovoid or ellipsoid, with a pale brownish wall 1.5-3.0 µm thick looking two layered, provided with acute spines 1.0-1.5 µm long and with 4(-5) approximately equatorial germpores; inserted on a 4-5 µm wide pedicel which is almost always detached from the spore.

Paraphyses

Non-septate, hyaline, capitate, with a head (8-)19-23(-28) µm wide and a 1.0-2.0(-3.0) µm thick wall.

Telia

Hypophyllous 0.25-1.2 mm diam., isolated, erumpent, appearing in winter, dark brown then (in May) covered by a whitish layer of basidia and basidiospores, producing on the upper surface of the leaf rather inconspicuous pale brownish round spots, about 0.4-1.0 mm diam.

Teliospores

(60-)70-79.8-89(-95) × (12-)15-17.1-21 µm, 2-celled, pale brownish, with a 1-2 µm thick wall appearing sometimes finely punctate; fusoid, most of them bearing an elongated thickened rostrate apex which is often destroyed or partly dissolved during germination of basidia; inserted on an up to 250 µm long and 2-4 µm wide pedicel which is hyaline and usually very thick walled (1-1.5 µm) [but rather thin walled(0.3-0.5 µm) and often collapsed in the specimen AF 3746]. A small proportion of the teliospores are shorter and broader, 37-50 × 19-22 µm (dimorphism), with somewhat darker and thicker wall (up to 2 µm).

Basidiospores

10-12.2-14.5 × 7.0-8.6-10.0 µm, Q = 1.24-1.42-1.71, ellipsoid to ovoid or phaseoliform, with a hyaline, smooth and thin wall.

Host plants

Sasa palmata E.G.Camus and *S. palmata f. nebulosa* (Makino) Suzuki.

Culms not caespitose, up to 3 m high, with cylindrical internodes and single branch-complement on the nodes. Culm-sheaths shorter than the corresponding internodes. Five leaves on each branch. Leaf-blades 26-34 (-38) × 6,0-8,5 cm, glabrous on both sides, with 11-13 pairs of secondary veins.

Sasa cf. *tsuboiana* Makino.

Culms not caespitose, up to 3 m high, with cylindrical internodes and single branch-complement on the nodes. Culm-sheaths pubescent. Leaves 3-5 on each branch. Leaf-blades up to 3,5 cm wide, glabrous on both sides, with eight pairs of secondary veins.

Hyperparasitic fungus and mycophagous insect

On some of our specimens of *Puccinia longicornis* we observed numerous pycnidia of *Sphaerellopsis filum* as well as a development of *Lecanicillium muscarium* and larvae of *Mycodiplosis* sp. feeding on the uredinia (see more details about these three species in the notes under *P. deutziae*, comb. nov.).

Discussion and notes

Descriptions

Descriptions of *Puccinia longicornis* are given by Cummins (1971: 138), Henderson & Bennell (1979), Hiratsuka (1958), Hiratsuka *et al.* (1992), Kusano (1908), Reid (1978, 1984), Sydow & Sydow (1904), Teng (1996), Wang & Zhuang (1998, in Chinese).

Spermogonial and aecial stages

These stages have been studied by Sato & Horie (1975), who also demonstrated heteroecism of the species by reciprocal inoculation with *Deutzia crenata* Sieb. & Zucc.

Uredinia and urediniospores

According to Reid (1984), uredinia are surrounded by a very conspicuous whitish halo of paraphyses. In the same publication, Reid reports that "a very few urediniospores were observed, along with normal urediniospores, which were obpyriform or subclavate measuring 39.6-40.0 × 25.0 µm with 2-4 equatorial germ-pores, but in which the ornament, barely visible in profile, was found, using the oil-immersion objective, to be much more crowded and irregularly disposed, sometimes consisting of tiny groups of densely arranged spines. In such sori, the urediniospores appeared to be dimorphic". We sometimes did observe urediniospores with a rather elongate, obpyriform shape but did not notice a particular ornamentation of their wall.

Teliospores

Teliospores can be very variable (see the notes under *P. deutziae*, comb. nov., hereabove).

The specimen AF 3746 differs in some respects from our other specimens of *P. longicornis*:

– Urediniospores are somewhat bigger (32-36.3-40 × 26-28.7-31 vs 29-33.6-38 × 23-26.1-31 µm);

– Teliospore pedicels have a wall which is thinner (0.3-0.5 µm vs 1-1.5 µm) and rather often collapsed (due to age or to the action of parasitic *Lecanicillium* ?);

– Many very small black spots are scattered on the surface of the leaf, between the sores; they entirely consist of spores

which, under the microscope, appear dark bistre, ellipsoid to ovoid, and measure 6-8 × 3.5-4.0 µm. These spores do not belong to the *Puccinia* but we could not identify the species concerned.

Host plants
Many bamboo species have been reported as hosts of *Puccinia longicornis*. Farr & Rossman (2018) cite 40 bamboo species belonging to the following genera: *Arundinaria*, *Bambusa*, *Indocalamus*, *Ischurochloa*, *Nipponobambusa*, *Phyllostachys*, *Pleioblastus*, *Pseudosasa*, *Sasa*, *Sasaella* and *Sasamorpha*, as well as two *Deutzia* species (hosts of the aecial stage).

Almost all our observations have been made on *Sasa palmata*, one of them on *Sasa* cf. *tsuboiana*. With regard to Europe, the rust fungus had already been mentioned on *Phyllostachys aurea*, *Pseudosasa japonica*, *Sasa veitchii*, *S. palmata* and *Semiarundinaria fastuosa* in United Kingdom, while in Belgium the species had been mentioned on *Pseudosasa japonica*.

3. ***Puccinia phyllostachydis*** Kusano
(Figs 1D; 2F, G; 3I)

Puccinia phyllostachydis Kusano, *Bulletin of the College of Agriculture, Tokyo Imperial University* 8 (1): 38 (1908). — *Dicaeoma phyllostachydis* (Kusano) Syd., *Annales Mycologici* 20 (3/4): 118 (1922).

Anamorph:

Uredo phyllostachydis Pardo-Cardona, *Revista Facultad nacional de Agronomía Medellín* 52 (2): 768 (1999).

Misapplied:

Puccinia melanocephala ss. auct. plur. (southeastern United States).

Lectotype. — Designated by Cummins (1971: 125).

Distribution. — *Puccinia phyllostachydis* is mostly known from Japan (Hiratsuka 1958; Hiratsuka *et al.* 1992; Ito 1909; Kusano 1908; Morimoto 1973). It has also been observed in China (Tai 1979; Teng 1996; Wang & Zhuang 1998; Zhuang 2005), Taiwan (Hiratsuka & Chen 1991), India (Boa 1985), United States: South (Cummins 1962; McCain *et al.* 1990; repeatedly mentioned under the wrong name *P. melanocephala*) and Hawaii (Gardner & Hodges 1989), Costa Rica (Berndt 2004), Colombia (Pardo-Cardona 1999; Salazar-Yepes & Buriticá 2002), Switzerland (Brodtbeck 2011; Senn-Irlet *et al.* 2016; Beenken & Senn-Irlet 2016) and Belgium (this study). The mention from Germany (Kruse *et al.* 2018) is a misidentification and corresponds rather to *P. deutziae*, comb. nov., as J.Kruse (comm. pers.) has confirmed to us.
The only European country in which *P. phyllostachydis* has been reported is Switzerland. Fourteen observations have been made, all of them by T. Brodtbeck or L. Beenken, on *Phyllostachys* sp. in the canton Ticino (Switzerland), at an altitude of 240-570 m: Curio, Pura and Morcote in 2007, Caslano and Melano in 2009, Gordola in 2010, Vira in 2011, Tegna in 2012, Aurigeno and Lamone in 2013, Cresciano in 2014, Locarno and Lugano in 2015 (Senn-Irlet *et al.* 2016).
The species is new for the Belgian mycoflora (our specimens):
– Brussels (Ixelles), Parc Tenbosch, 05.VI.2018 and 11.VII.2018;
– Braine-l'Alleud, Golf Club des 7 Fontaines, 21.II.2019;
– Brussels (Auderghem), 28.II.2019.

Material examined. — **Belgium**, Brussels (Ixelles), Parc Tenbosch, 05.VI.2018. On the underside of the leaves of *Phyllostachys nuda*, Specimens *A. Fraiture 3743* (BR) and *A. Vanderweyen F 1093* (KR-M-0006374). – *Ibid.*, 11.VII.2018. On *Phyllostachys nuda*. Specimen *A. Fraiture 3749* (BR). – Belgium, Braine-l'Alleud, Golf Club des 7 Fontaines, 21.II.2019. On the underside of the leaves of *Phyllostachys* sp. Specimen *A. Fraiture 3761* (BR). – Belgium, Auderghem, 28.II.2019. On the underside of the leaves of *Phyllostachys* cf. *nuda*. Specimen *A. Vanderweyen F 1108* (BR).

Description
Aecia
Not seen.

Uredinia
Hypophyllous, 0.2-1.0 mm × 0.2-0.4, cinnamon, each sore producing on the upper surface of the leaf a small round to elongate spot, 0.2-1.0 × 0.2-0.4 mm, which is dark brown with a yellowish to orange border.

Urediniospores
(26-)28-31.6-36(-43) × (19)21-25.1-29(-30) µm, Q = 1.11-1.29-1.52, subglobose, obovoid or ellipsoid, with a pale brownish wall 2.0-2.5(3.0) µm thick looking two layered, provided with acute spines 0.5-1.0 µm long and with 4-5 approximately equatorial germ-pores.

Paraphyses
Hyaline, capitate, with head (13-)21-24(-27) µm wide and a 2.03.5(-5.0) µm thick wall; pedicel with a septum within 20(-30) µm from the head.

Telia
Hypophyllous, similar to the uredinia but darker, erumpent or starting their development in the center of uredinia, producing on the upper surface of the leaf small dark brown to blackish rectangular spot, 0.1-0.5 mm long, extending between two venules.

Teliospores
(32-)38-42.2-48(-53) × (16.0)18-20.4-24 µm, Q = (1.58-)1.74-2.05-2.56(-2.68) [we saw one much elongated spore: 54 × 19 µm], 2-celled, brownish, with a rounded top and a finely punctate (1.5-)2.0(-3.0) µm thick wall, inserted on an up to 130 µm long and 3-6 µm wide pedicel which is hyaline and very thick walled(1.0-1.5 µm). Rare mesospores also present (M. Scholler, comm. pers.).

Basidiospores
Not seen.

Host plants
Phyllostachys nuda McClure.

Culms not caespitose, up to 3 m high, green with prominent blackish nodes, surmounting a whitish pruinose 1 cm high zone on the culm, internodes grooved on one side, 1-2 branch-complements on the nodes. Leaf-blades (5-)6-14 × 0.8-1.4 cm, glabrous on both sides or the underside slightly pubescent, with five pairs of secondary veins.

Phyllostachys sp.

Culms not caespitose, up to 3 m high, green, Sheath-scars with two prominent ridges, internodes grooved on one side, 1-2 branch-complements on the nodes. Leaf-blades 8-14 × 0.7-1.4 cm, glabrous on both sides, with five pairs of secondary veins.

Hyperparasitic fungus and mycophagous insect

On two of our specimens of *Puccinia phyllostachydis* we observed numerous pycnidia of *Sphaerellopsis filum*. On one specimen, we saw larvae of *Mycodiplosis* sp. feeding on the uredinia (see more information about these two species in the notes under *P. deutziae*, comb. nov.).

Discussion and notes

Descriptions

Descriptions of the parasite are given by Cummins (1971: 125), Hiratsuka (1958), Hiratsuka *et al.* (1992), Kusano (1908), Teng (1996), Wang & Zhuang (1998, in Chinese).

Aecial stage

It seems that the aecial stage of this species has never been observed.

Teliospores

There is an astonishing variability in the figures given by the authors for the length of *P. phyllostachydis* teliospores. Cummins (1971) gives (35-) 40-50 (-55) µm, which is in perfect accordance with our observations. Hiratsuka (1958) gives 38-66 µm, Kusano (1908) 45-70 µm and Teng (1996) even 50-70 µm. A possible explanation can perhaps be dimorphism. The pl. VI fig. 1 of the original description of *P. phyllostachydis* (Kusano 1908) shows four small spores ("typical spores") and a more elongated one ("longer spore"). It probably means that dimorphism in teliospores, a phenomenon which is well known in *P. deutziae*, comb. nov., and *P. longicornis*, also exists in *P. phyllostachydis*, with a small proportion of longer spores, which have not been observed by Cummins (1971) nor by us.

Host plants

Several bamboo species have been reported as hosts of *Puccinia phyllostachydis*. Farr & Rossman (2018) cite 23 bamboo species belonging to the following genera: *Arundinaria*, *Bambusa*, *Chusquea*, *Phyllostachys*, *Pleioblastus*, *Pseudosasa* and *Sinarundinaria*.

Host plants mentioned for the Swiss collections are *Phyllostachys viridiglaucescens* (Klenke & Scholler 2015) and *Phyllostachys* sp. (Senn-Irlet *et al.* 2016). The Belgian specimens have been collected on *Phyllostachys nuda*.

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Nicolas Legros, gardener in charge of the Parc Tenbosch, guided us on a visit to the park. Camille Mertens indicated us a locality of *P. phyllostachydis*. Damien Ertz (BR) took pictures of our material with the Keyence microscope and Myriam De Haan (BR) did the same with the SEM. Cyrille Gerstmans (BR) helped us to prepare the illustrations for publication. Markus Scholler (KR) kindly sent us the results of observations he made on our material, concerning the number and position of pores in the urediniospores as well as the presence of mesospores. M. Scholler (KR) and Y. Tikhonenko (KW) sent us several useful remarks and suggestions. Beatrice Senn-Irlet and Simon Egli sent us information concerning a bibliographic reference about *P. phyllostachydis* in Switzerland. Nicole Hankar (BR), Judith Warnement (HUH) and Karin Oehme (B) helped us to obtain a copy of some bibliographic references. J. Kruse spoked with us by e-mail about a specimen collected in Bochum. We thank them all for their useful help and kindness.

Identification key to *Puccinia* Pers. nom. sanct. species growing on bamboos in Europe

1. Teliospores mostly 35-50 µm long, with a rounded top, not dimorphic. Uredinia with capitate paraphyses, whose pedicel is septate within 20(-30) µm from the head ..... *Puccinia phyllostachydis* Kusano
   Hosts (Europe): *Phyllostachys nuda* McClure, *Phyllostachys viridiglaucescens* Rivière & C.Rivière, and *Phyllostachys* sp. Distribution in Europe: Belgium (Brussels), Switzerland (Ticino)

— Teliospores mostly 55-90 µm long, most of them ending with a short to long rostrum ; dimorphic: a very small proportion of spores are much smaller (37-50 µm long) than the others. Uredinia without paraphyses or with capitate non-septate paraphyses 2

2. Uredinia without capitate paraphyses. Teliospores mostly 55-77 µm long, most of them with a conical top or a short rostrum ..... *Puccinia deutziae* (Dietel) Fraiture & Vanderweyen comb. nov.
   Hosts (Europe): *Sasa ramosa* (Makino) Makino & Shibata, *Semiarundinaria fastuosa* Makino. Distribution in Europe: Belgium (Brussels and Meise), United Kingdom (SE England and Cornwall), Germany (Bochum)

— Uredinia with capitate non-septate paraphyses. Teliospores mostly 70-90 µm long, many of them bearing a long rostrum (often destroyed or partly dissolved during germination of basidia) .... *Puccinia longicornis* Pat. & Har.
   Hosts (Europe): *Phyllostachys aurea* Carrière ex Rivière & C.Rivière, *Pseudosasa japonica* Makino, *Sasa palmata* E.G.Camus, *S. veitchii* Rehder, *S.* cf. *tsuboiana* Makino and *Semiarundinaria fastuosa* Makino. Distribution in Europe: Belgium, United Kingdom (SE England and the Wales)

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