Outbreak of Rust Caused by *Coleosporium asterum* on *Solidago virgaurea* var. *gigantea* in Ulleung-do

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Abstract From June to October 2012, severe outbreaks of rust disease on *Solidago virgaurea* var. *gigantea* were observed in 5 different regions of Ulleung-do, Korea. Typical rust symptoms appeared as yellow spots, uredinia on leaves, and massive urediniospores covering the entire plant. Severely infected plants became discolored and died. On the basis of its morphological and molecular characteristics, the causal agent was identified as *Coleosporium asterum*. This pathogen has been reported as rust disease on *S. virgaurea* in the Canada and United States. In Korea, rust disease on *S. virgaurea* var. *gigantea* was reported as *Uromyces rudbeckia* in 1992. To the best of our knowledge, *C. asterum* is a novel rust pathogen on *S. virgaurea* var. *gigantea* in Korea.

Keywords *Coleosporium asterum*, Korean goldenrod, Phylogenetic analysis, Rust disease, 28S rDNA

Solidago virgaurea var. *gigantea* (Nakai, kitam; English name: Korean goldenrod) is a perennial herb belonging to the Asteraceae [1]. This plant is cultivated as a culinary vegetable in Ulleung-do and is used commonly in Korean folk medicine [2]. Accordingly, this plant has been cultivated widely on 72.3 ha out of 385 ha, making it the third most cultivated crop with an estimated value of 2.7 billion won in Ulleung-do. From June to October of 2012, outbreaks of rust disease with yellow spots and uredinia were observed consistently in all cultivation areas in Ulleung-do. Indeed, it is estimated that the production of *S. virgaurea* var. *gigantea* was reduced by over 10% due to rust disease on leaves. The leaves infected by rust fungi showed massive urediniospores on the stem and lower leaf

surface with corresponding small yellowish to chlorotic lesions on the upper surface (Fig. 1A and 1B). No symptoms were observed on flowers. Severe infections often resulted in leaf distortion, drying, and premature senescence (Fig. 1C). In February 2013, rust disease was observed on the leaves of overwintered *S. virgaurea* var. *gigantea*. Even though these plants were covered with snow, diseased brown leaves were observed with uredinia and urediniospores on the lower leaves (Fig. 1D). *Coleosporium asterum* infected by *Aster pilosus* has been reported to overwinter in the uredinial state in Korea [3].

The morphological characteristics of uredinia and urediniospores were observed by light microscopy and electron microscopy as described by Back *et al.* [4], and yellow-orange and rounded uredinia with a diameter of 340~360 µm were observed on the surfaces of lower leaves (Fig. 1E). The urediniospores were subglobose to ellipsoid, but somewhat irregular and variable in shape, yellow-orange, verrucose, and 31.0~36.5 × 26.5~29.0 µm in size (Fig. 1F and 1G). Orange-red and flat rounded telia were observed in late July. Teliospores were one-celled, obovoid, yellowish, and 73.0~86.5 × 22.0~37.0 µm in size (Fig. 1H). On the basis of the morphological characteristics of urediniospores and teliospores, this pathogen was identified as *Coleosporium asterum* (Dietel) Syd. & P. Syd. [5]. Total genomic DNA was extracted from urediniospores on the lower surface of diseased leaves collected from 5 different areas. A portion of the 28S rDNA gene was amplified using the primers NL1 and NL4 (5'-GCA TAT CAA TAA GCG GAG GAA

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Fig. 1. Symptoms of rust disease on Korean goldenrod leaves and morphological characteristics of urediniospores and teliospores; yellow spots on the upper side of leaves (A) and lower side of leaves (B), severely infected and defoliated symptoms of leaves (C), rust symptoms still observed on overwintered leaves in February (D), globose-shaped urediniospores (E), yellow-orange color ellipsoid-shaped teliospores (F) as observed by light microscopy. Scanning electron micrograph of uredinia (G) and urediniospores (H) of *Coleosporium asterum* (scale bars: E = 20 μ m, F, G = 100 μ m, H = 5 μ m).

AAG-3' and 5'-GGT CCG TGT TTC AAG ACG G-3', respectively) and directly sequenced [6]. The resulting sequences of the 5 isolates had an identity of 100%. All sequences of these isolates were deposited in the DDBJ/GenBank database with the accession number (AB847106, AB847107). An NCBI BLAST search showed that the present sequences had an identity of 99% with those of *C. asterum* on *Aster* sp. and *Solidago* sp. The partial 28S rDNA sequences were compared with other sequences deposited in the NCBI GenBank database using the GENETYX-WIN ver. 3.2 program (GENETYX Co., Tokyo, Japan) and found to have an identity of 99.8–100% with *C. asterum* infected by *Solidago* sp. in Canada and the United States and 98.8–99.0% identity with *C. asterum* caused by *A. pilosus* in Korea. The sequences were aligned using DNASTAR programs (DNASTAR Inc., Madison, WI, USA) and a phylogenetic tree of 28S rDNA was obtained using the

Fig. 2. Phylogenetic trees constructed by the neighbor-joining method based on partial 28S rDNA sequences of *Coleosporium asterum* on *Solidago virgaurea* var. *gigantea* and other *Coleosporium* species from GenBank. *Chrysomyxa arctostaphyli* (AF522163) was used as the outgroup. Numbers above the branches represent the bootstrap values obtained for 100 replicates (only 80% values were shown). The bar represents a phylogenetic distance of 0.01%.

neighbor-joining method in CLUSTALW [7]. The phylogenetic tree was visualized using the TreeView program (Win32, ver. 1.6.1). Bootstrap analysis with 100 replications was performed to determine support for various clades. The results revealed that the Korean goldenrod rust isolates were *C. asterum* (Fig. 2). The rust fungi *C. asterum* has been reported on *Solidago* sp. from Canada and the United States [8], and *A. pilosus* rust caused by *C. asterum* has been reported in Korea [3]. However, these isolates had different morphologies and 28S rDNA sequences than those observed in the present study. The causal agent of the rust disease of *S. virgaurea* var. *gigantea* was reported to be *Uromyces rudbeckia* in Ulleung-do in 1992 [9]. Since our study started in 2011, no rust pathogens of *U. rudbeckia* have been observed on *S. virgaurea* var. *gigantea*. Recently, the pathogen responsible for outbreaks of rust disease on *S. virgaurea* var. *gigantea* was identified as *C. asterum*. This rust pathogen is dominant in cultivated areas in Ulleung-do and was first reported on *S. virgaurea* var. *gigantea* in Korea. Rust disease on *S. virgaurea* var. *gigantea* occurs annually and leads to considerable economic losses in Ulleung-do. Thus, additional investigations of the ecological and mycological characteristics of rust pathogens to enable the prevention and control of rust disease are warranted.

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