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Occurrence of Colletotrichum Stem Rot Caused by *Glomerella cingulata* on Graft-Cactus in Korea

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In 1999 and 2000, a rot of graft-cacti including *Hylocereus trigonus* (three-angled cactus), *Gymnocalycium mihanovichii*, and *Chamaecereus silvestrii* occurred in several greenhouses in major cactus-growing areas of Korea. Typical symptoms included a moist, light brown rot or a watery rot of the stems. A *Colletotrichum* sp. was isolated from the lesions. The fungus formed dark gray, dense or floccose colonies on potato dextrose agar, frequently forming many light pink acervuli often surrounded with setae. The hyaline, cylindrical conidia were one-celled with round ends. Appressoria were mostly semicircular or clavate. Thin-walled asci contained eight, one-celled, hyaline ascospores (biseriate in ascus). Ascopspores were straight or curved, ellipsoidal or subcylindrical. Based on these characteristics, the fungus was identified as *Glomerella cingulata* (anamorph: *C. gloeosporioides*). Wound inoculation of basal stems of the cactus by the mycelial plugs or conidia produced symptoms identical to those described above. Various cactus species were compared in susceptibility using stem disc inoculation. *Cereus tetragonus, Eriocereus jusbertii, Myrtillocactus geomentrizans*, and three-angled cacti from Mexico and Taiwan were susceptible, but *C. peruvianus* (Peruvian apple cactus) and *Harrisia tortuosa* not. This is the first report of *G. cingulata* causing stem rot of graft-cactus in Korea.

Keywords : anthracnose, *Colletotrichum gloeosporioides, Glomerella cingulata*, graft-cactus, stem rot.

A graft-cactus comprising two different cactus species as a stock and a scion (like a flower bud) is a major commercial product in Korea. The most widely cultivating stock and scion cacti are three-angled (*Hylocereus trigonus*) and plain (*Gymnocalycium mihanovichii*) cacti, respectively. The graft-cactus, as its reputative quality in the world market, is one of the important exporting ornamental plants.

One of the limiting factors for cultivating graft-cacti in greenhouses is cactus diseases, especially stem rots caused by fungi. Various fungal diseases are known worldwide, however, only three fungal diseases of stem rots have been known to occur in graft-cactus in Korea. The major causal fungi are known to be *Fusarium oxysporum* and *Bipolaris cactivora* (old names: *Helminthosporium cactovorum* and *Drechslera cactivora*) (Chang et al., 1998; Hyun et al., 1998).

In 1999 and 2000, cactus stem diseases were surveyed in the areas of Suwon (National Horticulture Research Institute), Anseong, Eumseong, Cheonan, Daegu, and Goyang. A variety of stem rot symptoms have been frequently found in cactus greenhouses, from which *Alternaria* spp. and *Fusarium* spp. were most frequently isolated. *Bipolaris cactivora* was also often isolated from rotten stems of cactus, but in a lower frequency than the former two fungi.

A *Colletotrichum* species was isolated rarely, but invariably from typical symptoms showing a moist, light brown rot or a watery rot of cactus stems (Figs. 1A, 1B, 1C). In stock cacti such as three-angled cacti, acervuli were found on severely rotten stem areas. In *G. mihanovichii* and another popular scion cactus, *Chamaecereus silvestrii*, acervuli with pink tint or *Colletotrichum* conidiospores were observed readily in watery rots. Three *Colletotrichum* isolates obtained each from a three-angled cactus, *G. mihanovichii*, and *C. silvestrii* were examined for the mycological characteristics. The isolates were cultured on potato dextrose agar (PDA) at 23-25°C in a incubation chamber. The fungal colonies were dark gray, dense or floccose on PDA, frequently forming many light pink pustules (acervuli) on the agar surface composed of a great number of conidia and often setae (Fig. 1D). Morphology of the structures were examined with 50 replications. As shown in Table 1 and Figures 1E and 1F, the conidia were 1-celled, hyaline, straight and cylindrical with round ends, 3.5-6.7 (5.2 in average) μm × 12.9-19.3 (15.8) μm in size. Setae were 2.4-3.8 (3.0) μm × 61.6-107.2 (91.2) μm in size. Appressoria were mostly semicircular or clavate, 5.4-8.6 (7.4) μm × 4.6-7.5 (5.8) μm in size. Perithecia were obpyriform to subglobose, containing thin-walled, 8-spored asci containing ascospores 1-celled, hyaline, biseriate in ascus, straight or

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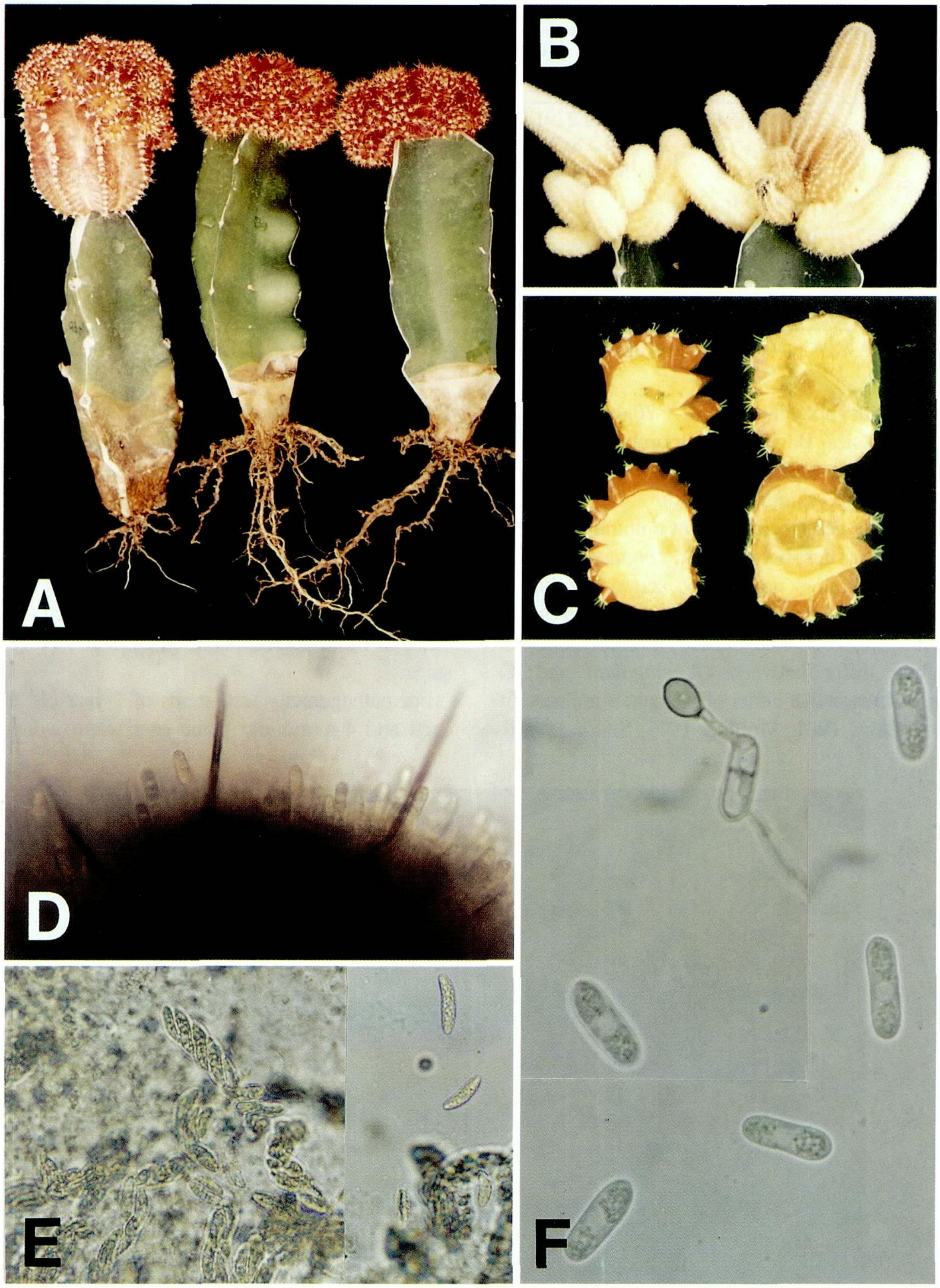

Fig. 1. Colletotrichum stem rot caused by *Glomerella cingulata* and the morphological characteristics of the fungus in sexual and asexual stages. (A) Symptoms in *Hylocereus trigonus* showing a moist, light-brown rot at the basal stem parts. (B) Watery brown rot in *Chamaecereus silvestrii*. (C) Watery rot of *Gymnocalycium mihanovichii* caused by wound inoculation of *G. cingulata* conidia (right), which is identical to the natural watery rot symptoms, and the uninoculated control (left). (D) Acervulus formed on potato dextrose agar showing conidia and setae (× 400). (E) Asci and ascospores (× 400). (F) Conidia and appressorium (× 1,000).

Table 1. Morphological characteristics of *Colletotrichum gloeosporioides* and *Glomerella cingulata*

Species or isolate	Measurements (μm)[a]				Reference
	Conidia	Setae	Ascospores	Appressoria	
Present isolates	12.9-19.3 (15.8) × 3.5-6.7 (5.2)	61.6-107.2 (91.2) × 2.4-3.8 (3.0)	12.1-20.4 (15.9) × 2.7-6.7 (5.1)	5.4-8.6 (7.4) × 4.6-7.5 (5.8)	
G. cingulata	12.5-17.5 × 5	50-110 × 5	17.5-22.5 × 4.5	–	Nam et al., 1998
G. cingulata	9-24 × 3-6	–	–	6-20 × 4-12	Mordue, 1971
C. gloeosporioides (*G. cingulata*)	10-21 × 4-6	–	9-30 × 3-8	–	Arx, 1957
C. gloeosporioides	7.5-17.5 × 3.8-5.0	50-110 × 5	–	–	Nam et al., 1998
C. gloeosporioides	9-24 × 3-4.5	–	–	6-20 × 4-12	Sutton, 1980

[a] Cultures of the present isolates on potato dextrose agar were used for measurements.

curved, ellipsoidal or subcylindrical, 12.1-20.4 (15.9) μm × 2.7-6.7 (5.1) μm in size. Based on the morphological characters, this fungus was identified as *Glomerella cingulata* (anamorph: *C. gloeosporioides*) (Table 1).

Nam et al. (1998) described different cultural and morphological characteristics between *G. cingulata* and *G. gloeosporioides* (forming no perfect stage). Width of conidia was slightly larger in *G. cingulata* than in *C. gloeosporioides* in their study. Also measurements of conidia slightly differ between *G. cingulata* and *C. gloeosporioides* in case that either of the names are specifically indicated (Arx, 1981; Mordue, 1971; Sutton, 1980). The *Colletotrichum* isolates in our study are very similar in conidial morphology to *C. gloeosporioides* isolates from strawberry plants that form sexual spores (Nam et al., 1998). Strawberry plants are usually grown in greenhouses like cacti. Therefore, the causal fungus of the rot of graft-cactus may be more appropriate to be called *G. cingulata*, although *C. gloeosporioides* is handled as a group that is extremely variable and the term *C. gloeosporioides* is more commonly used even if having the sexual stage.

For pathogenicity test, stems of 1-year-old three-angled cacti and 4-month-old plane cacti were wounded with a

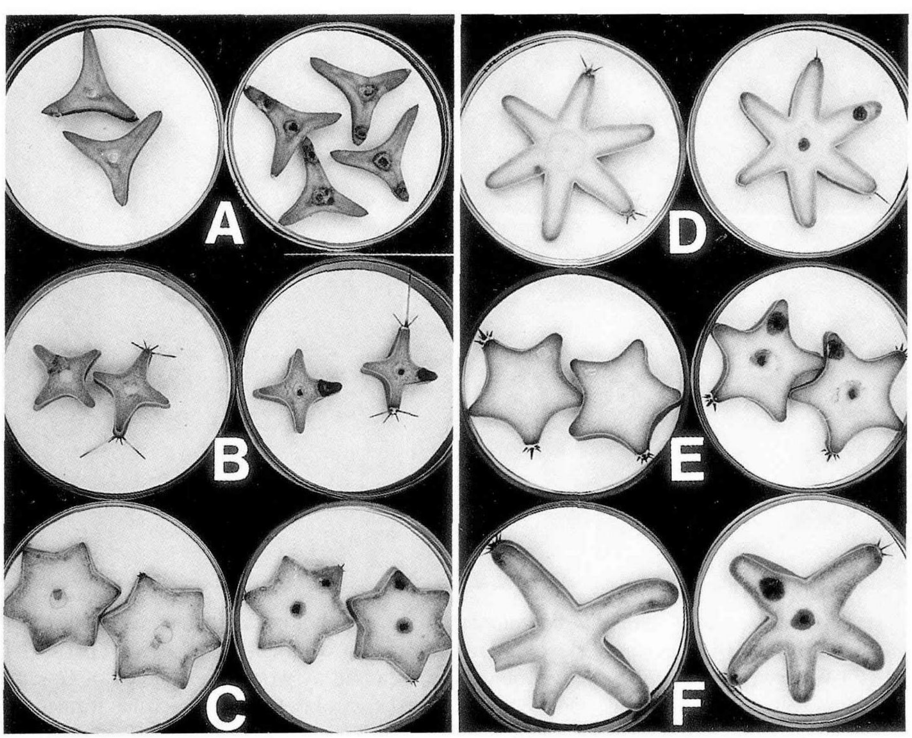

Fig. 2. Rots formed on stem discs of various cactus species 4 days after inoculation with agar pieces containing spores and mycelia of *Glomerella cingulata*. (A) *Hylocereus trigonus*. (B) *Myrtillocactus geomentrizans*. (C) *Harrisia tortuosa*. (D) *Cereus peruvianus*. (E) *Eriocereus jusbertii*. (F) *Cereus tetragonus*. Controls (left) were inoculated with fresh potato dextrose agar pieces.

suspension (ca. 10^6 spores/ml), and placed in plastic bags containing moistened paper towel at room temperature. In three-angled cacti, symptom development began 4 days after inoculation with black spots at inoculated areas and later advanced to moist, light brown rot symptoms around 10-15 days after inoculation. In plane cacti, a watery rot symptoms were produced, which were identical to the natural watery symptoms (Fig. 1C). In both cacti, no symptom was developed without wounding. The same fungi were reisolated from the diseased stems, confirming Koch's postulates for that *G. cingulata* is the causal agent of the stem rot disease.

The isolate from the three-angled cactus rotted both the stems of the stock cactus and scion cacti (plane cacti). The other two isolates from the scion cacti (*G. mihanovichii* and *C. silvestrii*) also showed pathogenicity to the stock cactus, suggesting that both stock and scion cactus species may be susceptible to the anthracnose fungus. When grafting, stock and scion cacti are cut and bound together. Therefore, sanitation is required to prevent the anthracnose disease and other stem rots caused by fungi as well.

Several cactus species used as stocks were tested to compare their susceptibility and resistance to the anthracnose pathogen. Cactus stem discs with 0.5-1.0 cm in thickness were prepared and inoculated on the center and edges with small pieces of agar cultures containing spores and mycelium. The inoculated stem discs were placed on wetted filter paper in Petri-dishes at 25°C. Five replications were used for each cactus species. In this experiment, rot symptoms were readily developed on *Cereus tetragonus, Eriocereus jusbertii, Myrtillocactus geomentirizans* and three-angled cacti from Mexico and Taiwan, while only minimal and small portions of inoculated areas were rotten in *C. peruvianus* (Peruvian apple cactus) and *Harrrisia tortuosa* (Fig. 2, Table 2). This suggests that the latters may be resistant to the anthracnose disease.

Colletotrichum gloeosporioides accounts for the majority of anthracnose diseases of ornamental foliage plants and host specificity on foliage plants is unlikely (Chase, 1988). In Cactaceae also no resistant genetic sources have been reported yet. However, the two cactus species, especially *C. peruvianus* appeared to be highly resistant to the anthracnose fungus, which can be used as a source for the development of resistant cactus plants.

Table 2. Degree of rotting in cactus species inoculated with *Glomerella cingulata*

Cactus species	Degree of rotting
Hylocereus trigonus	+++
H. trigonus (Mexico)	+++
H. trigonus (Taiwan)	++
Harrisia tortuosa	+
Myrtillocactus geomentrizans	++
Cereus peruvianus	+
Cereus tetragonus	+++
Eriocereus jusbertii	++

[a] Stem discs were inoculated with small pieces of agar cultures containing spores and mycelium, and examined 4 days later. Degree of rotting: +++; rotten area diameter more than 5 mm, ++; 2-5 mm, and +; less than 2mm

Aknowldegement

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