

Taxonomic Studies on *Alternaria* in Korea (1)

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The taxonomy of the *Alternaria* spp. has been a subject of controversy because of their high variability in conidial morphology and polymorphism displayed even in pure cultures. The published Korean literature on the genus *Alternaria* is scattered and fragmentary, and pertains to about 25 species with special emphasis on occurrence and pathogenicity, but mycological studies on this group of fungi are insufficient. This is the first series of detailed and consolidated account of Korean species of *Alternaria*, which includes 11 species; viz., *Alternaria brassicae*, *A. brassicicola*, *A. cinerariae*, *A. dauci*, *A. dianthi*, *A. dianthicola*, *A. helianthi*, *A. helianthifaciens*, *A. iridicola*, *A. japonica* and *A. protenta*. Detailed diagnostic descriptions, specific characterizations, taxonomic discussions and illustrations for each species are presented.

KEYWORDS: *Alternaria*, Diagnostic description, Taxonomy

Alternaria is a dictyosporic genus of the family Dematiaceae, Hypomycetes, Fungi imperfecti. Species of *Alternaria* are frequent parasites on numerous agricultural crops, economic garden plants and weeds. They are also common components of the flora of seeds or saprophytes living on various substrates and constitute a group of fungi whose importance has been well known for a long time, in mycology as well as in plant pathology. The taxonomy of the *Alternaria* spp. has been a subject of controversy because of their high variability in conidial morphology and their polymorphy displayed even in pure cultures. Incomplete descriptions, mutations, secondary development or dwarfing of spores in culture and facultative parasitism resulting in large host range have caused great confusion in the classification of this genus and resulted in descriptions of numerous obscure species never verified by other researchers.

There are over 500 *Alternaria* taxons in the literature. In addition, approximately 400 species names in the old literature on *Macrosporium* Fries as well as around 200 names published in other genera have been or eventually must be considered as basionyms for *Alternaria* species names (Simmons, 1992). The mass of literature, specimens, and isolates immediately pertinent to a comprehensive *Alternaria* monograph has never been consolidated, appraised and presented for general use (Simmons, 1992). It is a tremendous task to elucidate which taxons actually exist and which are synonyms of others. Taxonomy and nomenclature of *Alternaria* spp. in their actual state need intensive work to reduce the significant number of confusing synonyms.

The genus *Alternaria* was first described by Nees in 1816, and *A. tenuis* was the sole species. The description is somewhat incomplete and inaccurate; however, it is suf-

ficiently definite to leave little doubt that Nees's description is now generally recognized as *Alternaria* (Elliot, 1917; Neergaard, 1945; Simmons, 1967). Fries in 1825 described the genus *Macrosporium*, and in 1832 he gave a more detailed description, differentiating it from *Cladosporium*, *Helminthosporium* and *Sporodesmium*. He did not recognize the genus *Alternaria* but described Nees's fungus under the name *Torula alternata*, citing *A. tenuis* Nees as a synonym. Chevallier (1836), however, recognized *Alternaria* and stated that it differed from *Torula* in having filiform connections between spores. Elliot (1917) considered *Alternaria* and *Macrosporium* to be distinct genera and suggested that the genus *Alternaria* can be divided into six groups of species based on conidial morphology such as size, shape, septation and beak. However, Angell (1929) considered *Alternaria* and *Macrosporium* synonymous and used the epithet *Macrosporium* to designate both genera. Wiltshire (1933) agreed that *Alternaria* and *Macrosporium* are congeneric, and stated that *Macrosporium* in the original description was used to designate fungi of the *Alternaria* type having non-filiform spores and one spore per conidiophore. He considered the term *Alternaria* to be illegal according to the International Rules of Botanical Nomenclature, since Fries did not recognize the genus in his *Systema*, but he concluded that the description given by Nees was sufficient enough to establish the current concept of the genus *Alternaria*. He suggested that since *Alternaria* is a universally known term, it should be used to designate both genera. Groves and Skolko (1944) subscribed to the classification proposed by Wiltshire. They made an extensive investigation of several *Alternaria* species and found many of them to be identical. They concluded that recognition of a large number of species is undesirable and should be avoided, but that it is more difficult to disentangle different species under the same name than to recognize species which

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may finally prove indistinguishable.

Neergaard (1945) completely revised the taxonomy of *Alternaria*, and eliminated some species and united others in one species with several formae speciales. Neergaard separated the species into three groups (which he called sections) according to catenulation (the number of spores in the chain). He distinguished 1) *Longicatenatae*, in which conidia appear in long chains of about 10 or more spores; 2) *Brevicatenatae*, in which conidia are formed in short chains of about 3-5 spores; and 3) *Noncatenatae*, in which conidia are usually formed singly, seldom producing a secondary spore. Species within each section were keyed by conidial morphology such as shape, septation, size, color, wall ornamentation, and beak. Neergaard paid particular attention to the difference between the true beak (eurostrum), as an integral part of the conidium, and the false beak (pseudorostrum), the structure that is in fact a secondary conidiophore essential to generation of conidial chains in *Alternaria*. Joly (1964) concluded, from a thorough study on 27 taxa, that evolution in *Alternaria* progressed in three lines (which he designated as sections) from a nucleus of a few saprophytic or weakly parasitic, polyphagous species. He based his sections on spore color and spore rigidity or lateral symmetry: *Claro-seminae*, with light colored spores; *Brunneoseminae*, with brown or brown-reddish colored spores; and *Rigidae*, in which spores appearing slightly rigid and with relatively few longitudinal septa. Later (1965), he supplied a detailed key to his sections and to the most common species of the genus known to him. Unfortunately, the key does not give descriptions of media, and give dimensions of spores not including the beak.

Simmons (1967), after examining an authenticated specimen of the type species of *Alternaria* Nees in Persoon's herbarium, redescribed the fungus and indicated that the correct name of the fungus should be *A. alternata* (Fries) Keissler according to the International Rules of Nomenclature. This specimen was presumed to represent Nees's opinion published as *A. tenuis* Nees (1816) and later compiled by Fries as *Torula alternata* Fries (1832) with *A. tenuis* Nees as a synonym. Ellis (1971, 1976) published precise descriptions and illustrations of 27 (1971) plus 17 (1976) taxa that he assigned to *Alternaria*. The taxa presented by him (1971, 1976) were not keyed out or grouped but arranged according to how abrupt the transition was from spore body to beak and how short or long the beak was relative to the length of the body. Simmons's continuing studies on *Alternaria* (Simmons, 1981-2000) redescribed numerous species and differentiated the genus into numerous species novae. In 1992, he also developed the species-group system within the genus after examining several thousand field specimens and isolates of *Alternaria*. Fourteen species groups were defined on the basis of conidial characteristics, the pattern of chain

formation, and the nature of the apical (sometimes lateral) extensions of conidial cells (true beaks as an integral part of the conidium; secondary conidiophores as a germination phenomenon leading to secondary conidiogenesis). For differentiation of species within a group, he emphasized any stable character, e.g., morphology and development of juvenile conidia; pattern of septum formation; shape, color, septation, ornamentation of the conidial body; nature of the conidial beak or of secondary conidiophores; unique cultural characters. Recently, numerous new species and varieties of *Alternaria* were also reported from China (Zhang, 1999; Zhang *et al.*, 1999; Zhang and Zhang, 1999). However, as Rotem (1994) indicated, the distinction between some morphologically similar species based on analysis of minute differences described by Simmons (1999) and Zhang *et al.* (1999) is somewhat confusing for non-taxonomic pathologists.

Molecular approaches have been used increasingly in taxonomy and systematics of filamentous fungi (Bruns *et al.*, 1991). Genetic analysis of small-spored *Alternaria* species by Adachi *et al.* (1993) and Kusaba and Tsuge (1994) examined variations in rDNA genes, either through RFLP analysis or sequence analysis of rDNA. RAPD analysis of *Alternaria* by Cooke *et al.* (1998), Weir *et al.* (1998) and Morris *et al.* (2000) evaluated the genetic diversity of several species but did not assess the congruence of morphological and genetic characteristics. Analysis of RAPD fragment patterns by Roberts *et al.* (2000) confirmed that when *Alternaria* isolates are cultured and observed under defined conditions, their phenotypic plasticity is minimized, and valid taxonomic separations can be made upon morphological characteristics. Future research with molecular means of identification may distinguish morphologically similar species and verify their taxa.

Alternaria of Korea is not well understood. The published Korean literature on this genus is scattered and fragmentary and pertains to about 25 species with special emphasis on occurrence and pathogenicity (Cho and Yu, 2000; Cho and Moon, 1980; Choi *et al.*, 1989; Kim and Yu, 1985; Kim *et al.*, 1994; Lee and Lee, 1972; Nakada and Takimoto, 1928; Park, 1958, 1961, 1967; Yu, 1992; Yu and Park, 1988; Yu and Lee, 1989; Yu *et al.*, 1981; Yu *et al.*, 1982; Yu *et al.*, 1984; Yu *et al.*, 1989; Yu *et al.*, 1989; Yu *et al.*, 1991; Yu *et al.*, 1992). There have been no comprehensive studies on this group of fungi in Korea. Therefore, it was considered desirable to undertake a consolidate compilation on this important genus featuring detailed diagnostic descriptions, specific characterization and taxonomic discussions with figures of the species of *Alternaria* found in Korea. In this paper, detailed diagnostic descriptions and illustrations of 11 species of *Alternaria* collected by the authors from Korea are presented.

Materials and Methods

The materials examined in this work were all collected by the authors from different localities and habitats in Korea during 1998-2000. All specimens have been preserved in CMH (Mycological Herbarium, Division of Applied Biology, Chemistry and Food Science, Chungnam National University). Each specimen was examined microscopically for the presence of *Alternaria* at the day of collection or after incubation in well moistened Petri dishes at 20°C in a 12 hr dark/12 hr light regime for one day. In some cases, seed samples infected by different species were tested by the blotter method (ISTA, 1976) and examined microscopically. For comparative study of the sporulation pattern and morphological characters of conidia and conidiophores, single spore isolations of each species were made and cultured on V-8 agar at 20°C in a 12 hr dark/12 hr light regime for 7 days. For producing macroscopic characters such as growth and color, etc., pure cultures of each species were grown on potato dextrose agar (sometimes on V-8 agar) at 25°C.

Slide preparations of conidia, conidiophores and mycelium from specimens and cultures were mounted in plain lactophenol, covered by a cover glass and sealed with glyceel. The mycological characteristics such as shape, size, color, surface ornamentation and number of septa, etc. were observed under a microscope. Measurements of conidia and conidiophores were made from 50 replicates for each species. Sporulation pattern, viz., arrangement of conidia on conidiophores, number of conidia in chain, and pattern of chain branching were observed under a binocular microscope at about 50× magnification. The morphology of each species was illustrated with the aid of a drawing tube.

Descriptions

1. *Alternaria brassicae* (Berkeley) Saccardo, *Michelia* 2: 172. 1880. Fig. 1

Macrosporium brassicae Berkeley, *Smith's Engl. Flora* 5 (2): 339. 1836.

Alternaria brassicae (Berk.) Bolle, *Meded. Phytopath. Lab. Willie Commelin Scholten* 7: 27. 1924.

Puccinia brassicae Montagne, *Ann. Sci. Nat., ser. 2, Bot.*, 6:30. 1836.

Rhopalidium brassicae (Mont.) Mont. & Fr., in *Montagne, Syll. Gen. Spec. Crypt.*, p. 297. 1856.

Sporidesmium exitiosum K hn, *Hedwigia* 1: 91. 1855.

Polydesmus exitiosus (Kühn) Rabenhorst, *Klotzschii Herb. Viv. Mycol.*, ed. Nova, no. 181. 1855.

Alternaria brassicae (Berk.) Sacc. var. *exitiosa* (Kühn) Ferraris, *Fl. Ital. Ryp. I* (8): 521. 1912.

Alternaria exitiosa (Kühn) Jorstad, *Meld. Stat. Plante-*



Fig. 1. *Alternaria brassicae*. (A) Conidia, conidiophores and habit sketch of conidia (opaque) and conidiophores (clear) from host. (B) Conidia from culture. All CMH-00550. Bar = 50 μ m.

patol. Inst. (Oslo), nr. 1. p. 94. 1945.

Macrosporium herculeum Ellis & Martin, *American Naturalist* 16: 1003. 1882. *Alternaria herculea* (Ell. & Mart.) Elliott, *Ame. J. Bot.* 4: 472. 1917.

Cercospora bloxami Berkeley & Broome, *Ann. Mag. Nat. Hist.*, ser. 5, 9: 183. 1882.

Cercospora lepidii Peck, *Annual Rept. New York State Mus.*, 35 th (1881), p. 140. 1884.

Alternaria brassicae (Berk.) Sacc. var. *macrospora* Sacc., *Syll. Fung.* 4: 546. 1886.

Alternaria macrospora (Sacc.) Sawada, *Rep. Dept. Agr. Gov. Res. Inst. Formosa* 51: 123. 1931.

Alternaria saccardoii Sawada, *Spec. Publ. Natl. Taiwan Univ. Coll. Agric.* 8: 208. 1959.

Macrosporium brassicae Berk. var. *macrospora* Eliasson, *Bih. Kongl. Svenska Vetensk. Akad. Handl. Bot.* 22 (III, 12): 18. 1897.

Macrosporium macrosporum (Eliasson) Sawada, *Bull. Gov. Forest Exp. Sta.* 105: 101. 1958.

Sporodesmium onnii Karsten, *Medd. Soc. Fauna et Flora Fennica* 18: 67. 1891.

Sporodesmium brassicae Masee, *Kew Bull.* 1901: 153. 1901.

Alternaria alliariae-officinalis Savul. & Sandu, in *Sa-*

vulescu, Herb. Mycol. Romanicum, fasc. 9, no. 447. 1932.

Cercospora moldavica Savul. & Bontea, in Savulescu, Herb. Mycol. Romanicum, fasc. 27, no. 1336. 1947.

(Synonymy, Simmons in Mycotaxon 55: 131-138. 1995).

Lesions on host leaves effuse, mostly marginal, pale olive gray to dark olive brown, variable in size from pinpoint to 7 cm across in old lesions, circular to zonate with a dark necrotic center surrounded by a chlorotic zone, shot holes may occur, sometimes coalescing and leading to death of the leaves; brown necrotic streaks and spots occurring on midribs and cotyledons. **Mycelium** immersed, partly superficial; hyphae hyaline to pale brown, septate, branched, smooth-walled, 3~10 μm wide. **Colonies** on agar effuse, loose cottony to velvety, white to pale gray with varying amounts of non-sporulating aerial mycelium, no pigment is released into the medium, 35~45 mm in diam. after 7 days. **Conidiophores** solitary or in fascicles of 2~5(-10), simple or occasionally branched, straight to slightly flexuous, more or less cylindrical, usually a single terminal conidiogenous site, sometimes proliferating sympodially and geniculate with 1 to several pigmented former conidium attachment sites, pale gray or olivaceous gray, often slightly swollen and almost hyaline at the apex of conidiogenous cell, smooth, several (up to 10) septate, 15~120 μm long, 6~10 μm wide; in culture the conidiophores produced as lateral extensions of the hyphae, up to ca. 150 μm long. **Conidia** mostly solitary, sometimes in short chains of 2~3 through the agency of secondary conidiophores, on agar media branched chains occurring more frequently than in nature; straight or slightly curved, obclavate or long ovoid, pale olivaceous brown on host tissue, dark olivaceous brown on agar media, smooth or minutely roughened, many have a long and sturdy beak, gradually tapering towards the beak, some others have a apical secondary conidiophore (false beak or pseudostrom), analogously to the beak; conidium body 50~220 (-300) \times 15~35 (-45) μm , with 5~18 transverse septa and usually only one (rarely 2) longitudinal septum in a few of the transverse segments, slightly or strongly constricted at the transverse septa; the beak almost cylindrical, simple and unbranched, never fragile or filamentous, commonly one-fourth to half of the length of the mature conidium body, sometimes the same length as the conidium body, pale, usually without transverse septa or sparsely septate, 3~8 μm wide; secondary conidiophores simple or geniculate, 5~9 μm wide, as short as 10 μm or as long as or longer than the conidium body; sometimes a beak enlarges terminally into a secondary conidiophore ca. 10~30 μm long, initiating a secondary conidium.

Hosts and records in Korea: *Armoracia lapathifolia* Gilib., (Lee et al., 1991); *Brassica campestris* subsp. *napus* var. *pekinensis* Makino, (Nakada and Takimoto, 1928); *Brassica campestris* subsp. *napus* var. *nippo-oleif-*

era Makino, (Chung et al., 1977); *Brassica juncea* var. *integrifolia* Sinsk, (Cho et al., 1997); *Brassica oleracea* var. *capitata* L., (Cho et al., 1997); *Lepidium apetalum* Wild., (Oh and Shin, 1999); *Raphanus sativus* var. *hortensis* for. *acanthiformis* Makino, (Yu et al., 1991); *Rorippa cantoniensis* Ohwi, (Oh and Shin, 1999); *Rorippa islandica* (Oed.) Borb., (Oh and Shin, 1999).

Materials examined: on *Brassica oleracea* var. *capitata* L., CMH-98013 (Okcheon, 19 May 1998), CMH-98037 (Daegwalryoung, 24 September 1998), CMH-99153 (Jangsu, 5 November 1999), CMH-00399 (Hongcheon, 29 August 2000), CMH-00400 (Seosan, 10 November 2000), CMH-00401 (Pyeongchang, 7 October 2000); on *Brassica campestris* subsp. *napus* var. *pekinensis* Makino, CMH-98112 (Daegwalryoung, 24 September 1998), CMH-98119 (Daegwalryoung, 24 September 1998), CMH-99078 (Pyeongchang, 14 August 1999), CMH-00549 (Hongcheon, 29 August 2000), CMH-00550 (Pyeongchang, 7 October 2000), CMH-00551; CMH-00549 (Hongcheon, 29 August 2000); CMH-00550 (Pyeongchang, 7 October 2000), (Pyeongchang, 7 October 2000); on *Raphanus sativus* var. *hortensis* for. *acanthiformis* Makino, CMH-99064 (Pyeongchang, 14 August 1999), CMH-00372 (Ulleung, 17 August 2000), CMH-00373 (Daejeon, 28 June 2000), CMH-00374 (Daejeon, 28 June 2000), CMH-00375 (Seosan, 10 November 2000), CMH-00376 (Mokpo, 2 September 2000), CMH-00377 (Dangjin, 4 July 2000); on *Armoracia lapathifolia* Gilib., CMH-99178 (Daejeon, 14 October 1999), CMH-00145 (Mokpo, 2 September 2000), CMH-00146 (Suwon, 25 September 2000), CMH-00147 (Bonghwa, 4 July 2000); on *B. juncea* var. *integrifolia* Sinsk., CMH-00129, (Bongpyeong, 7 October 2000).

Notes: Three species of *Alternaria* have been recorded on Cruciferae (Neergaard, 1945; Wiltshire, 1947; Simmons, 1995), namely, *A. brassicae* (Berkeley) Saccardo, *A. brassicicola* (Schwein) Wiltshire and *A. japonica* Yoshii (syn. *A. raphani* Groves & Skolko). *A. brassicae* differs from the other *Alternaria* in its sturdy beaked and larger and longer conidia; smaller conidia of the other species have no true beak. *A. brassicae* also differs from the other species of *Alternaria* in conidial catenulation; the species forms a secondary conidium but seldom in nature, while *A. japonica* normally forms chains of 2~4 conidia and *A. brassicicola* forms long chains of more than 10 conidia. The disease symptoms caused by this fungus have been confused with those caused by *A. brassicicola*, which are known under various common names depending upon the host and the plant part attacked: gray leaf spot, black spot, alternaria leaf spot, alternaria black spot of leaves, pods and stems, alternaria black or gray spot (Corlett and MacLachy, 1996). *Alternaria* leaf spot of Chinese cabbage and other Brassicas may be caused by *A. brassicae* alone or in association with *A. brassicicola* and *A. japonica*.

2. *Alternaria brassicicola* (Schwein) Wiltshire, Mycol. Pap., 20:8. 1947. Fig. 2

Helminthosporium brassicicola Schweinitz, Trans. Am. Phil. Soc., ser. 2, 4:279, 1832, as *brassicola*.

Sporidesmium septorioides Westendorp, Bull. Acad. R. Sci. Belgique 21: 236, F. 4 (opp. P. 246). 1854.

Sporidesmium exitiosum Kühn f. *alternarioides* and f. *luxuriosum* Kühn, Hedwigia 1:91, Taf. XII-B, fig. 1-22. 1855.

Polydesmus exitiosus (Kühn) Rabenh. f. *alternarioides* and f. *luxuriosus* Kühn, Die Krankheiten der Kulturgewachse, p. 165. 1858.

Marosporium cheiranthi (Lib.) Fr. var. *circinans* (Berk. & Curt.) Berk., Grevillea, 3:105, 1875. nomen comb. illegit.

Alternaria circinans (Berk. & Curt.) Bolle, Meded. Phytopath. Lab. Willie Commelin Scholten, 7:26. 1924, nomen comb. illegit.

Macrosporium circinans Berk. & Curt., in M. A. Curtis, Geol. & Nat. Hist. Surv. North Carolina, Pt. III, Botany, p. 128. 1867, nomen nudum.

Macrosporium commune Rabenh. (1870, nomen nudum) var. *circinans* (Berk. & Curt.) Sacc., Syll. Fung. 4: 524.

1886. nomen comb. illegit.

Alternaria brassicae (Berk.) Sacc. f. *macrospora* Brunaud, Actes Soc. Linn. Bordeaux 52: 149. 1897.

Helminthosporium brassicae Hennings, Hedwigia 41: 117. 1902.

Alternaria oleracea Milbraith, Bot. Gaz., 74:320, 1922.

Alternaria brassicae (Berk.) Sacc. var. *minor* Sacc., Michelia 2: 172. 1880.

(Synonymy, Simmons in Mycotaxon 55: 131-138, 1995 and Corlett & MacLachy in Can. J. Plant Pathol. 18: 484-485, 1996).

Lesions on host tissue, effuse, dark olive gray to dark olive brown, variable in size from pinpoint to 7 cm, becoming black velvety with profuse sporulation. **Mycelium** immersed; hyphae hyaline to dark olivaceous brown, septate, branched, smooth-walled but minutely roughened in some areas subtending the conidiophores, 3-8 μm wide. **Colonies** on agar moderate yellowish brown to brownish black, velvety, sporulation (on V-8 agar) moderate to abundant, reaching about 50-60 mm in diam. after 7 days. **Conidiophores** solitary or in fascicles of 2-5, simple or occasionally branched on host, often multiple branching on agar media, straight or curved, more or less cylindrical, usually only one conidiogenous site at the apex, sometimes proliferating sympodially and geniculate with 1 to 2 pigmented former conidium attachment sites, pale yellow to pale brown, almost colourless and often slightly swollen at the apex, smooth, septate, 20-70 μm long, 3-8 μm wide; in culture the conidiophores produced terminally and laterally on the hyphae, up to 80 μm long. **Conidia** mostly in moderately long or long chains of 5-10 or more, occasionally short side branches or chains arising from a conidiophore or a secondary conidiophore, on agar media branching and side chains occurring more frequently and conidial side chains considerably longer than in nature; straight, narrowly to broadly ovoid or ellipsoid, usually first formed conidia larger and narrowly ovoid to nearly cylindrical, subsequent secondary conidia becoming progressively smaller and broader ovoid as the chain lengthens, often very regular and symmetrical as to their longitudinal axis, usually tapering slightly towards the apex, the basal cell rounded, pale to olive brown, smooth-walled or becoming minutely roughened with age, 20-120 \times 8-30 μm , with 1-10 transverse septa (mostly 4-6), often without longitudinal septum or a few longitudinal septa in a few of the transverse segments, often slightly to distinctly constricted at the transverse septa; true beak absent (erostrate), but having a pale apical conidiogenous structure which usually is a single celled secondary conidiophore and resembling a truncated cone, sometimes lateral secondary conidiophores also arising from intercalary conidium cells.

Hosts and records in Korea: *Armoracia lapathifolia*

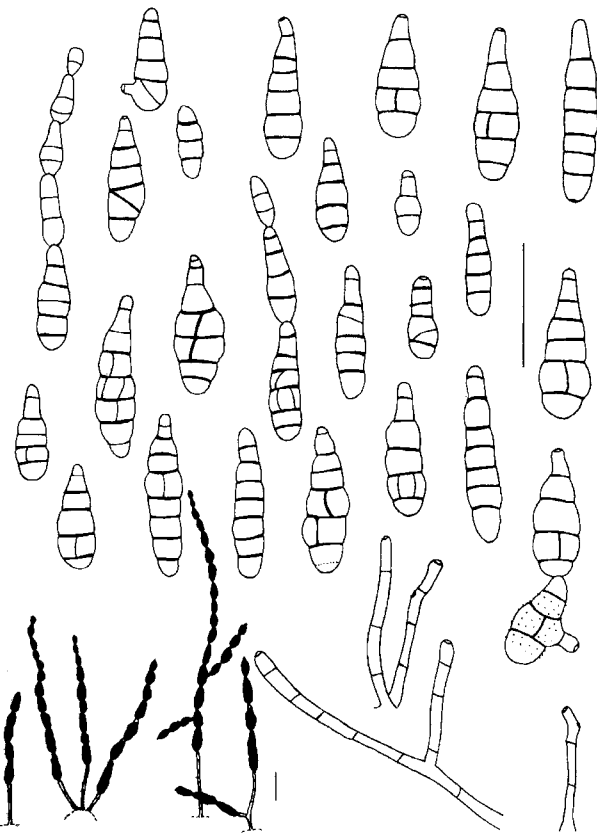


Fig. 2. *Alternaria brassicicola*. Conidia, conidiophores and habit sketch of conidia (opaque) and conidiophores (clear) from host. All CMH-00401. Bar = 50 μm .

Gilib., (new record to Korea); *Brassica campestris* subsp. *napus* var. *pekinensis* Makino, (Kang et al., 1985); *Brassica oleracea* var. *acephala* DC., (Cho et al., 1997); *Brassica oleracea* var. *capitata* L., (Yu and Park, 1982; Cho et al., 1997); *Raphanus sativus* var. *hortensis* for. *acanthiformis* Makino, (Yu and Park, 1982; Yu et al., 1991).

Materials examined: on *Armoracia lapathifolia* Gilib., CMH-99220 (Buyeo, 5 October 1999), CMH-00145 (Mokpo, 2 September 2000), CMH-00146 (Suwon, 25 September 2000), CMH-00147 (Bonghwa, 4 July 2000); on *Raphanus sativus* var. *hortensis* for. *acanthiformis* Makino, CMH-00372 (Ulleung, 17 August 2000), CMH-00373 (Daejeon, 28 June 2000), CMH-00374 (Daejeon, 28 June 2000), CMH-00375 (Seosan, 10 November 2000), CMH-00376 (Mokpo, 2 September 2000), CMH-00377 (Dangjin, 4 July 2000); on *B. oleracea* var. *capitata* L., CMH-00399 (Hongcheon, 29 August 2000), CMH-00400 (Seosan, 10 November 2000), CMH-00401 (Pyeongchang, 7 October 2000); on *B. campestris* subsp. *napus* var. *pekinensis*, CMH-00549 (Hongcheon, 29 August 2000), CMH-00550 (Pyeongchang, 7 October 2000), CMH-00551 (Pyeongchang, 7 October 2000).

Notes: *A. brassicicola* (Schwein.) Wiltshire is characterized by ovoid, beakless conidia produced in long linear and branching conidial chains (Simmons, 1992, 1995). The taxonomic confusion between *A. brassicae* (Berk.) Sacc. and *A. brassicicola* was disentangled by Wiltshire (1947) and Simmons (1995). The fungus differs from *A. brassicae* in its beakless and smaller conidia; the larger conidia of *A. brassicae* have the sturdy beak. Leaf lesion symptoms are usually darker than in *A. brassicae* and less clearly zonate. *A. brassicae*, *A. brassicicola* and *A. japonica* may occur together in the same crop, but *A. brassicicola* is more frequently associated with cabbage, *A. brassicae* with Chinese cabbage and *A. japonica* with radish.

3. *Alternaria cinerariae* Hori & Enjoji, J. Plant Prot. 18: 36. 1931. Fig. 3

Alternaria seneciensis Neergaard, Danish Species of *Alternaria* and *Stemphylium*. p. 201. 1945.

Lesions on host irregularly scattered, reddish to olivaceous brown or olivaceous black, variable in size, 1~10 mm in diam., often with a gray central area. **Mycelium** immersed; hyphae hyaline to pale olivaceous brown, septate, branched, smooth-walled, 3~10 μm wide. **Colonies** on agar, effuse, cottony, aerial mycelium fluffy, olivaceous gray to dark gray, sporulation (on V-8 agar) moderate to abundant, 55~65 mm in diam. after 7 days. **Conidiophores** usually solitary, simple and unbranched on host, branching occurred frequently in culture, straight to slightly curved, more or less cylindrical, pale to olivaceous brown, smooth, often slightly swollen at the apex with a pig-

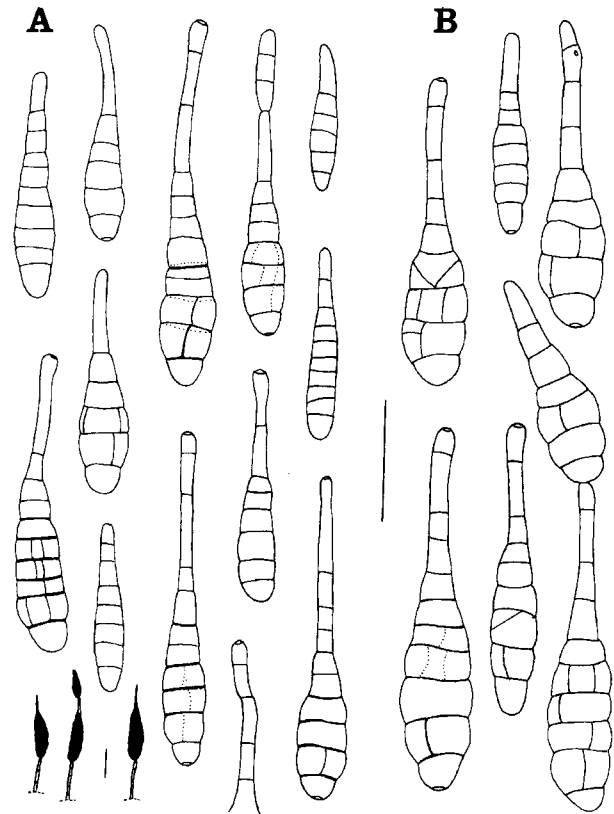


Fig. 3. *Alternaria cinerariae*. (A) Conidia, conidiophores and habit sketch of conidia (opaque) and conidiophores (clear) from host. (B) Conidia from culture. All CMH-00104. Bar = 50 μm .

mented zone at the site of former conidium attachment, several (-5) septate, 50~150 μm long, 5~8 μm wide; in culture the conidiophores produced terminally and laterally on the hyphae. **Conidia** solitary or in short chains of 2~3 through the agency of the secondary conidiophore; straight to slightly curved, narrowly to broadly ovoid or ellipsoid on host, obclavate to obpyriform in culture, mostly erostrate with a short broadly tapered apical cell when juvenile, pseudorostrate with a relatively broad secondary conidiophore at maturity, some have a relatively short beak, medium yellow brown, smooth, some conidium cells becoming swollen and inflated with age in culture; conidium body (excluding any secondary conidiophore) 40~100 (-140) \times 15~30 (-50) μm , with 5~10 transverse septa and 1~2 longitudinal septa in 1~4 of the transverse segments, slightly or sharply constricted at the transverse septa; beaks, when present, ca. 20~30 \times 3~5 μm ; secondary conidiophores (false beaks or pseudorostra) at the apical cell of the conidium relatively broad, paler or the same colour as the conidium body, simple, sometime geniculate (in culture), slightly swollen at the apex, up to 90 μm long, 5~9 μm wide, initiating a secondary conidium.

Hosts and records in Korea: *Senecio flammeus* Turcz.,

(new record to Korea), *Senecio vulgaris* L., (Oh & Shin, 1999).

Materials examined: on *Senecio flammeus* Turcz., CMH-00104 (Cheongyang, 29 July 2000).

Notes: *Alternaria cinerariae* Hori & Enjoji as initially described by Enjoji (1931) in Japan and later by Neergaard (1945) under the name of *A. seneciensis* Neergaard is now considered a morphologically distinctive species restricted to the *Senecio* spp. *A. cinerariae*, a member of the *Alternaria sonchi* species group (Simmons, 1997), is characterized by ovoid to ellipsoid, or obclavate, and apically pseudorostrate, catenate spores. Korean materials of the present authors were in good agreement with the previous records of *A. cinerariae* (Enjoji, 1931; Neergaard, 1945; Simmons, 1997).

4. *Alternaria dauci* (Kühn) Groves & Skolko, Can. J. Res., Sec. C., 22:222, 1944. Fig. 4

Sporidesmium exitiosum Kühn var. *dauci* Kühn, Hedwigia, 1:91, 1855.

Polydesmus exitiosus (Kühn) Rabenh. var. *dauci* Kühn, in Rabenhorst, Klotzschii Herb. Viv. Mycol., ed. Nov. Cent. II, no. 182. 1855.

Macrosporium dauci (Kühn) Rostrup, Tidsskr. Lando-

konomi, ser. 5, 7:385. 1888.

Alternaria brassicae (Berk.) Sacc. var. *dauci* (Kühn) Lindau, in Rabenhorsts Kryptogamen-Flora, Pilze, Abt. IX, p. 260. 1908.

Alternaria brassicae (Berk.) Sacc. var. *dauci* (Kühn) Bolle, Meded. Phytopath. Lab. Willie Commelin Scholten 7: 42. 1924.

Alternaria porri (Ellis) Ciferri f. sp. *dauci* (Kühn) Neergaard, Danish Species of *Alternaria* and *Stemphylium*, p. 252. 1945.

Macrosporium carotae Ellis & Langlois, J. Mycol., 6:36, 1890.

Alternaria carotae (Ellis & Langlois) Stevenson & Wellman, J. Wash. Acad. Sci., 34: 263, 1944.

Alternaria carotae (Ellis & Langlois) Ciferri, Atti Ist. Bot. Lab. Critt. Pavia, ser. 5, 19:86. 1962.

(Synonymy, Simmons in Mycotaxon 55: 151-154).

Lesions on host effuse, dark brown to grayish black, sometimes surrounded by a chlorotic halo, mostly marginal or occurring along veins or on the petioles; the leaflets become shrivelled and convoluted at the edges, the whole top may be killed when infection is severe. **Mycelium** mostly immersed; hyphae hyaline to pale or dark brown, septate, branched, smooth-walled. **Colonies** on agar olive gray or grayish green, cottony to woolly with abundant development of aerial mycelium, sometimes producing a red pigment which diffuses into the medium, reaching about 55~65 mm in diam. after 7 days. **Conidiophores** mostly solitary, rarely in fascicles of 2~3, usually unbranched, straight or curved, stout and rigid, pale to dark brown, smooth, usually only one conidiogenous site at the apex, sometimes proliferating sympodially and geniculate with 1~2 pigmented former conidium attachment sites, often slightly swollen at the apex, 2~7 septate, up to 120 μm long, 5~10 μm wide; in culture conidiophores arise as side branches on the main hyphae. **Conidia** mostly solitary or occasionally in chains of 2~3 through the agency of secondary conidiophores; obclavate or long ellipsoid on host, broadly ellipsoid or obpyriform on agar, straight or curved, pale olivaceous brown when juvenile, becoming dark brown at maturity, smooth or rarely minutely roughened, rostrate and tapering gradually towards a narrow beak; conidium body 50~120 \times 15~25 μm , with 5~11 transverse septa and usually 1 rarely 2 longitudinal or oblique septa in a few of the transverse segments, often slightly (on host) or strongly (on agar) constricted at the transverse septa; the beak long, filiform, narrows gradually from its site of origin in the body apex, colourless or pale, septate, often branched once (bifurcate), rarely branched twice (trifurcate), up to 3 times the length of the spore body, 50~250 μm long, 5 μm wide at the base tapering to 2~3 μm ; occasionally (uncommonly) a relatively broad secondary conidiophore (pseudorostrum), up

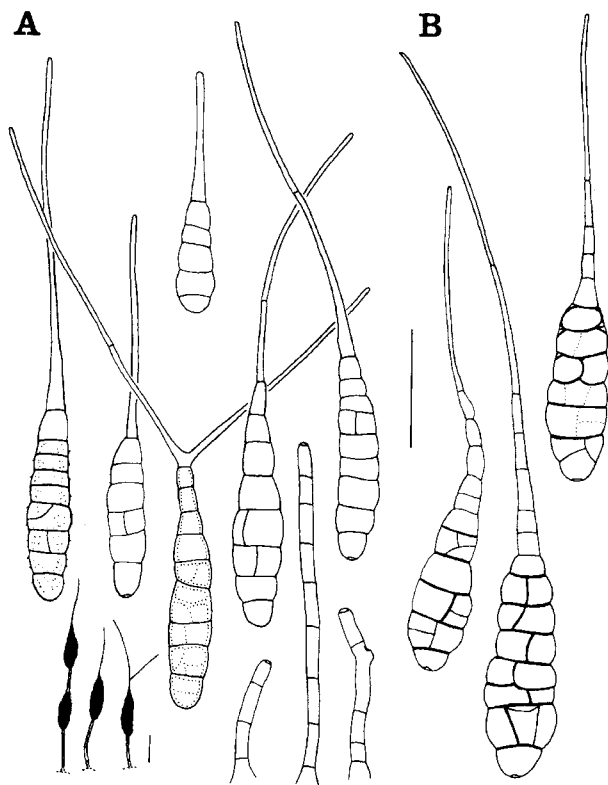


Fig. 4. *Alternaria dauci*. (A) Conidia, conidiophores and habit sketch of conidia (opaque) and conidiophores (clear) from host. (B) Conidia from culture. All CMH-00285. Bar = 50 μm .

to ca. $50 \times 6 \mu\text{m}$, develops from the apical conidium cell, generates a secondary conidium with the filiform beak.

Hosts and records in Korea: *Daucus carota* var. *sativa* DC., (Park, 1958; Yu & Park, 1982).

Materials examined: on *Daucus carota* var. *sativa* DC., CMH-99060 (Pyeongchang, 14 August 1999), CMH-00285 (Pyeongchang, 31 August 2000), CMH-00664 (Bongpyeong, 7 October 2000), CMH00665 (Bongpyeong, 7 October 2000).

Notes: Two species of *Alternaria*; *A. dauci* (Kühn) Groves & Skolko and *A. radicina* Meier have been recorded on *Daucus carota* var. *sativa* DC. for a long time (Neergaard, 1945; Ellis, 1971). Recently, Simmons (1995) added two more species of *Alternaria*; *A. atrocariis* Simmons and *A. carotiincultae* Simmons on *D. carota* var. *sativa*. *A. dauci* differs from the other *Alternaria* in its filiform beaked and larger conidia; the smaller conidia of the other species have no true beak.

5. *Alternaria dianthi* Stevens & Hall, Bot. Gaz., 47: 409, 1909.

Fig. 5

Alternaria brassicae (Berk.) Sacc. v. *dianthi* Zimmermann, Ochrana Rostrin 4: 8. 1924.

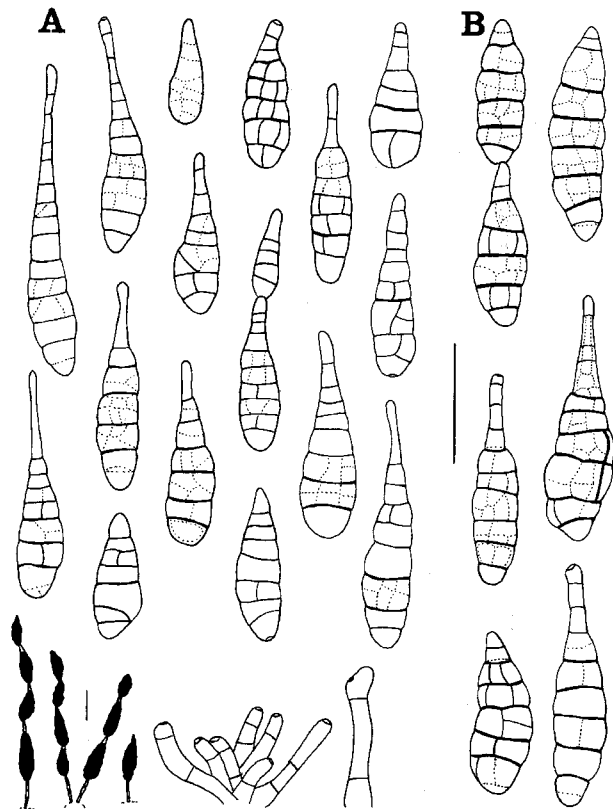


Fig. 5. *Alternaria dianthi*. (A) Conidia, conidiophores and habit sketch of conidia (opaque) and conidiophores (clear) from host. (B) Conidia from culture. All CMH-00761. Bar = $50 \mu\text{m}$.

Macrosporium dianthi (St. & Hall) Bewley, Disease of Glasshouse Plants, p. 208. 1923.

Lesions on host leaves scattered, circular to slightly oval or irregular, dark purple to dark brown with a greenish border, becoming pale in the center as they increase in size; necrosis lesions also formed on stems and petioles adjacent to the leaves. **Mycelium** usually immersed or partly superficial; hyphae subhyaline to olivaceous brown, branched, septate, smooth-walled, $3\text{--}10 \mu\text{m}$ wide, occasionally constricted at the older septa. **Colonies** on agar densely cottony, olive gray to smoky gray with varying amount of aerial mycelium, sporulation abundant (on V-8 agar) held in a 12/12 hr NUV light/dark cycle, $30\text{--}35 \text{mm}$ in diam. after 7 days. **Conidiophores** solitary or in fascicles of $2\text{--}10$, usually unbranched, straight or curved, more or less cylindrical, pale brown to mid-olivaceous brown, smooth, with a single pigmented conidiogenous site at the apex, sometimes proliferating sympodially and geniculate with $1\text{--}3$ pigmented conidiogenous sites, septate, up to $90 \mu\text{m}$ long, $5\text{--}9 \mu\text{m}$ wide; in culture conidiophores arise as side branches on the main hyphae, up to $130 \mu\text{m}$ long. **Conidia** solitary or in chains of $3\text{--}5$ through the agency of secondary conidiophores (pseudorostra); conical to obclavate, tapering towards the apex, sometimes broadly ovoid or ellipsoid in culture, brown to dark-olivaceous brown, smooth-walled, many are beakless (erostrate) or have a secondary conidiophore (pseudorostrum) from apical conidium cell, some others have a relatively short beak; conidium body $20\text{--}80 \times 10\text{--}25 \mu\text{m}$, with $3\text{--}10$ transverse septa and 1 to several longitudinal or oblique septa in a few to most of the transverse segments, often constricted (strongly constricted in culture) at the transverse septa; beaks, when present, subhyaline and ca. $20\text{--}30 \times 2\text{--}3 \mu\text{m}$ or usually shorter, occasionally the tip of the beak converted into a slightly enlarged functional conidiophore; secondary conidiophores relatively broad, paler or the same colour as the conidium body, mostly simple sometimes geniculate (in culture), variable in length, as short as a few or up to $60 \mu\text{m}$ long, $5\text{--}7 \mu\text{m}$ wide.

Hosts and records in Korea: *Dianthus caryophyllus* L., (Yu et al., 1989a; Lee et al., 1989); *Dianthus littorsus* Makino, (new record to Korea); *Dianthus sinensis* L., (new record to Korea).

Materials examined: on *Dianthus caryophyllus* L., CMH-98009 (Gimhae, 3 May 1998); on *D. littorsus* Makino, CMH-00504 (Ulleung, 17 August); on *D. sinensis* L., CMH-00755 (Hongcheon, 30 August 2000), CMH-00756 (Namwon, 23 August 2000), CMH-00757 (Cheongyang, 29 July 2000), CMH-00758 (Suwon, 25 September 2000), CMH-00759 (Mokpo, 2 September 2000), CMH-00760 (Gongju, 24 September 2000), CMH-00761 (Daejeon, 20 June 2000).

Notes: This species is referred to as the *Brevicatenate* of

Neergaard (1945) and overall is most similar to *A. japonica* Yoshii. However, conidia of *A. dianthi* are smaller and more regular and are conical, whereas conidia of *A. japonica* are oval, and *A. dianthi* does not produce chlamydo-spores. The present species is also closely related to *A. dianthicola* Neergaard. Refer to the notes under *A. dianthicola*.

6. *Alternaria dianthicola* Neergaard, Danish Species of *Alternaria* and *Stemphylium*. p. 190. 1945. Fig. 6

Lesions occur on leaves, buds and stems of the host, whitish yellow or pale brown, oval or irregular spots with dark margins, becoming black following sporulation in the middle of the spot. **Mycelium** immersed or partly superficial; hyphae hyaline to pale olive-brown, septate, branched, smooth-walled, 3–10 μm wide. **Colonies** on agar velvety, sometimes fluffy or loose cottony, white to pale gray in colour, 30–40 mm in diam. after 7 days. **Conidiophores** solitary or in fascicles of 2–8, mostly unbranched, sometimes branched, straight to curved, more or less cylindrical, pale olive to olive brown, smooth, usually with a single terminal pigmented conidiogenous site, occasionally geniculate with 1–2 pigmented conidiogenous sites, up to 150 μm long, 3–9 μm wide; in culture the conidio-

phores are produced as lateral extensions of the hyphae. **Conidia** solitary or in chains of 2–3 on host, in culture usually in chains of 3–5; obclavate to almost cylindrical, straight or slightly curved, pale olivaceous brown, smooth-walled, some have a long beak (rostrate), some others have a apical secondary conidiophore (psedorostrate), analogously to the beak, gradual transition from spore body to the beak or to the secondary conidiophore; conidium body 20–85 \times 10–21 μm , with 3–10 transverse septa and occasionally (uncommonly) only one rarely two longitudinal or oblique septum in 1–2 of the transverse divisions, often slightly constricted at the transverse septa; beaks, when present, sturdy and almost cylindrical, simple and unbranched, subhyaline or the same colour as the body 10–70 (–90) μm long, 3–5 μm wide; secondary conidiophores usually simple, occasionally geniculate, as short as 10 μm or up to 90 μm long, 3–7 μm wide; sometimes a beak enlarges terminally into a secondary conidiophore ca. 10–20 μm long.

Hosts and records in Korea: *Dianthus superbus* var. *longicalycinus* (Max.) Williams, (new record to Korea).

Materials examined: on *Dianthus superbus* var. *longicalycinus* (Max.) Williams, CMH-00200 (Euseong, 4 July 2000), CMH-00757 (Cheongyang, 29 June 2000).

Notes: Two species of *Alternaria*, *A. dianthi* Stevens & Hall and *A. dianthicola* Neergaard, have been described on *Dianthus* spp. (Ellis, 1971). *A. dianthicola* can be distinguished from *A. dianthi* in that *A. dianthi* has many more longitudinal septa, the beak or the secondary conidiophore is shorter, and the conidia are broader and darker.

7. *Alternaria helianthi* (Hansford) Tubaki & Nishihara, Trans. Br. mycol. Soc., 53: 147, 1969. Fig. 7

Helminthosporium helianthi Hansford, Proc. Linn. Soc. London 155:49, 1943.

Helminthosporium helianthi Pavgi, Mycopath. Mycol. appl. 24:352, 1964.

Lesions on host leaves effuse, scattered, variable in size, begin as light brown to brown flecks and oval to circular spots, becoming larger and dark brown in colour, surrounded by a yellow halo, often coalescing to form bigger irregular or circular spots, up to 2–3 cm in diam.; brown elongated spots or streaks occurring on petioles and stems. **Mycelium** immersed or partly superficial; hyphae hyaline to olive brown, septate, branched, smooth-walled. **Colonies** on agar light brown to olive brown, velvety, slowly growing, 15–25 mm in diam. after 20 days; sporulation abundant on both PDA and V-8 agar. **Conidiophores** solitary, rarely in fascicles of 2 or more, simple, straight or curved, cylindrical, pale gray to pale brown, almost hyaline at the apex, smooth, up to 5-septate, usually with a single terminal conidiogenous site, sometimes

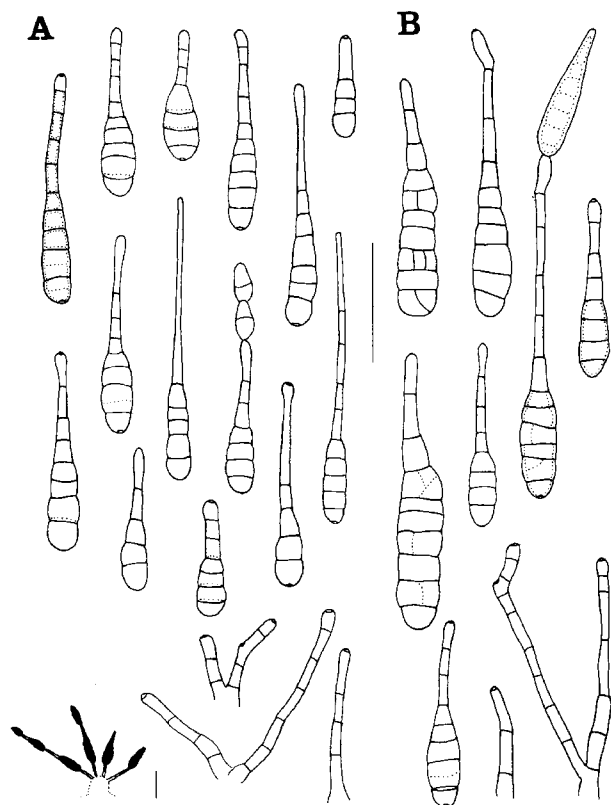


Fig. 6. *Alternaria dianthicola*. (A and B) Conidia, conidiophores and habit sketch of conidia (opaque) and conidiophores (clear) from host. (A) CMH-00200. (B) CMH-00757. Bar = 50 μm .

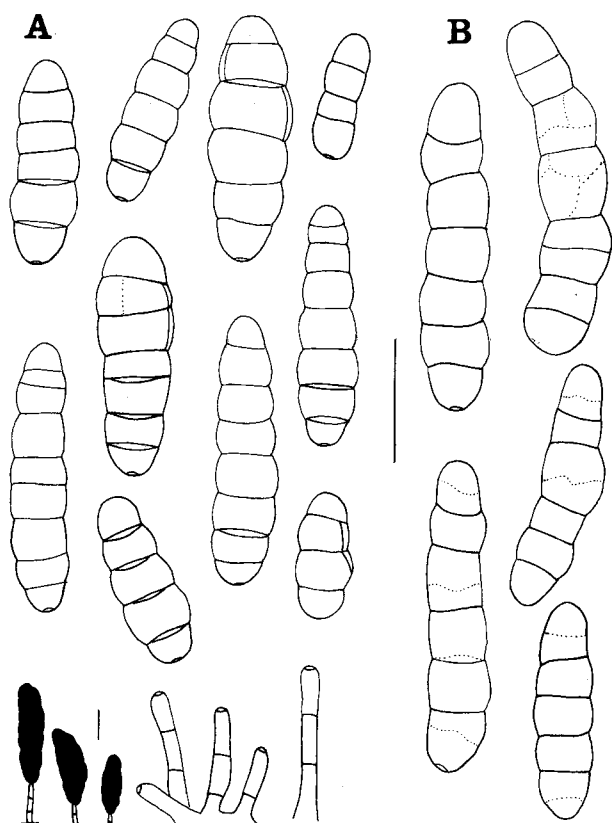


Fig. 7. *Alternaria helianthi*. (A) Conidia, conidiophores and habit sketch of conidia (opaque) and conidiophores (clear) from host. (B) Conidia from culture. All CMH-98062. Bar = 50 μ m.

proliferating sympodially and geniculate with 1~2 pigmented former conidium attachment sites, simple or branched, up to 130 μ m long, 6~12 μ m thick; in culture (on V-8 agar) the conidiophores are produced terminally or laterally on the hyphae. **Conidia** mostly solitary, rarely in chains of 2 with age through the agency of secondary conidiophores; straight or slightly curved, long cylindrical to long ellipsoid on host tissue, long cylindrical to obclavate on agar media, rounded at both ends, subhyaline to light yellow or golden brown, smooth-walled, erostrate (beakless), 40~140 \times 15~35 μ m, with 2~12 (mostly 5~8) transverse septa and 1 (rarely 2) longitudinal or oblique septum in 1~3 of the transverse compartments, constricted at the transverse septa; sometimes a relatively broad secondary conidiophore (pseudorostrum or false beak) produced from the apical or intercalary conidium cell, initiating a secondary conidium.

Hosts and records in Korea: *Helianthus annuus* L., (Chung et al., 1977; Yu et al., 1989); *Rudbeckia bicolor* Nvtt., (Oh & Shin, 1999; Cho et al., 1999).

Materials examined: on *Helianthus annuus* L., CMH-98027 (Cheongyang, 12 September 1998), CMH-98062 (Daegwalyoung, 24 September 1998), CMH-99035 (Buyeo, 7 July 1999), CMH-99133 (Geumsan, 11 September 1999),

CMH-00767 (Yeongi, 15 September 2000), CMH-00768 (Bongpyeong, 7 October 2000), CMH-00769 (Mokpo, 2 September 2000), CMH-00770 (Hongcheon, 29 August 2000), CMH-00771 (Daejeon, 20 June 2000); on *Rudbeckia bicolor* Nvtt., CMH-00336 (Pyeongchang, 31 August 2000), CMH-00337 (Namwon, 23 August 2000), CMH-00338 (Hoengseong, 30 August 2000), CMH-0039 (Mokpo, 2 September 2000), CMH-00340 (Cheongyang, 4 June 2000), CMH-00341 (Bonghwa, 4 July 2000), CMH-00342 (Euseong, 4 July 2000).

Notes: Four species of *Alternaria* have been recorded on *Helianthus* (Simmons, 1986b). They are *A. helianthi* (Hansford) Tubaki & Nishihara, *A. helianthinfiens* Simmons, *A. helianthicola* G. N. Rao & Rajagopalan and *A. protenta* Simmons. *A. helianthi* can be readily differentiated from other species of *Alternaria* on the host genus by the morphology of its long cylindrical, larger and non-beaked conidia; *A. helianthinfiens* and *A. protenta* having a narrow, filiform-beaked conidia and *A. helianthicola* having comparatively small conidia produced in chains (Simmons, 1986b).

8. *Alternaria helianthinfiens* Simmons, Walcz & Roberts, Mycotaxon 25 (1): 204. 1986. Fig. 8

Lesions on host leaves, effuse, scattered, variable in size, starting as small brown flecks, becoming larger and dark brown in color, oval to circular, surrounded by a yellow halo, often coalescing to form large irregular spots. **Mycelium** immersed; hyphae hyaline to pale brown, septate, branched, smooth-walled. **Colonies** on agar effuse, cottony, with little surface mycelium and moderate amount of submerged mycelium, somewhat slowly growing, usually secreting a yellowish red pigment into the medium, 35~45 mm in diam. after 7 days. **Conidiophores** solitary, rarely in small fascicles of 2~3, unbranched, straight or flexuous, more or less cylindrical, pale or olivaceous gray, smooth, septate, usually with a single conidiogenous site at the apex, sometimes proliferating sympodially and geniculate with 1~2 pigmented former conidium attachment sites, often slightly swollen at the apex, up to 150~200 μ m long, 4~7 μ m wide; in culture the long conidiophores with short lateral branches produced terminally and laterally on the main hyphae. **Conidia** mostly solitary, rarely in chains of 2; ellipsoid or ovoid, pale to medium brown, smooth to minutely rough, sometimes conspicuously verrucose, commonly beakless with a conoid apical cell when juvenile, have a filiform beak at maturity, the point of transition from spore body to beak is definite and conspicuous; conidium body 25~90 \times 10~30 μ m 4~10 transverse septa and 1~2 longitudinal or oblique septa in 3~7 of the transverse divisions, giving a surface view of 10~20 bubble-like compartments; the beak, when present, long and flexuous, hyaline or pale brown, sparsely septate, simple

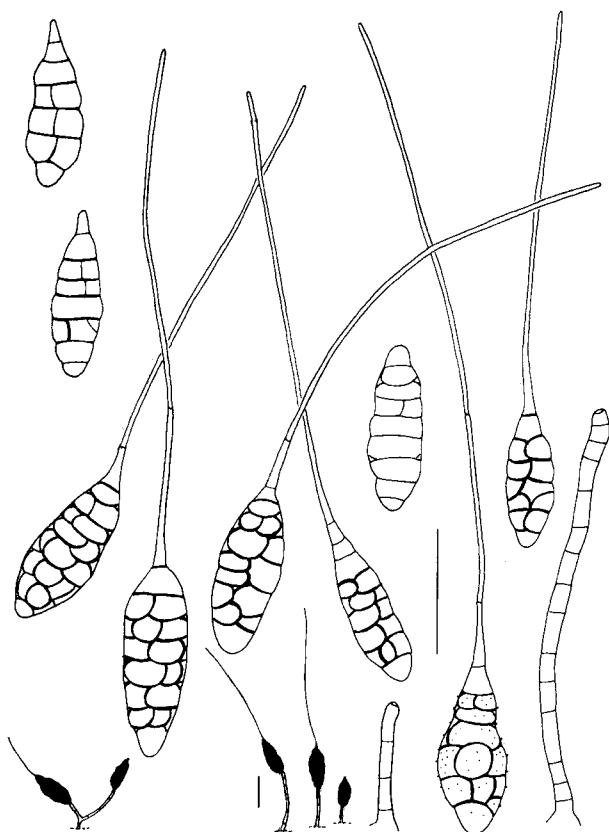


Fig. 8. *Alternaria helianthificiens*. Conidia, conidiophores and habit sketch of conidia (opaque) and conidiophores (clear) from host. All CMH-98027. Bar = 50 μ m.

and not branched, 100–280 μ m long, 2–3 μ m wide along most of its length; on agar media erostrate (beakless) conidia abundant, beaks often shorter (50–150 μ m) than those in nature.

Hosts and records in Korea: *Helianthus annuus* L., (Cho & Yu, 2000).

Materials examined: on *Helianthus annuus* L., CMH-98027 (Cheongyang, 12 September 1998), CMH-99241 (Namwon, 10 September 1999).

Notes: This species can be distinguished from other species described on the same plant genus by its ovoid to ellipsoid conidia with filamentous and not-branched beaks. The Korean materials of the present author were in good agreement with the previous records of *A. helianthificiens* (Simmons, 1986b, 1997).

9. *Alternaria iridicola* (Ellis & Everh.) J.A. Elliott, Amer. Jour. of Bot. 4(8): 439, 1917. Fig. 9

Macrosporium iridicolum Ellis & Everh., Pro. Acad. Nat. Sci. Philad., 1895.

Lesions on host, elliptical to irregular, sometimes concentrically zonnate, forming parallel to the longitudinal veins of the leaf, yellow brown to dark brown in colour and sur-

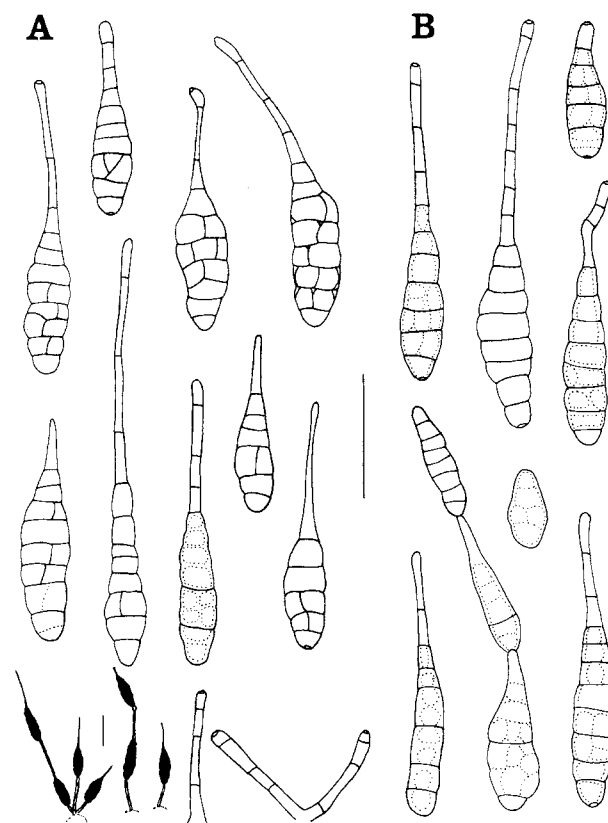


Fig. 9. *Alternaria iridicola*. (A) Conidia, conidiophores and habit sketch of conidia (opaque) and conidiophores (clear) from host. (B) Conidia from culture. All CMH-99233. Bar = 50 μ m.

rounded by a yellow or chlorotic halo, lesions often enlarged and coalescing, resulting in blighting of the leaves. **Mycelium** immersed or partly superficial; hyphae hyaline or colourless, septate, branched, smooth-walled but minutely roughened in some areas, 2.5–7.5 μ m wide. **Colonies** on agar cottony, white to pale gray, slowly growing, reaching about 35–50 mm in diam. after 7 days. **Conidiophores** solitary or in fascicles of 2–5, simple, straight or flexuous, more or less cylindrical, septate, pale yellow to pale brown, almost colourless at the tip, smooth, usually with a single conidiogenous site at the apex, sometimes elongating sympodially and geniculate with 1 to several pigmented former conidium attachment sites, slightly swollen at the apex, up to 120 μ m long, 5–7.5 μ m wide; in culture the conidiophores are produced as lateral extensions of the hyphae, simple, erect, sometimes geniculate. **Conidia** solitary or in chains of 2–3 through the agency of secondary conidiophores, on agar media chains occurring more frequently than in nature; straight or slightly curved, obclavate or long ovoid, pale olive or pale brown in colour, smooth, slightly or sharply constricted at the transverse septa, many are beakless (erostrate) with a conoid apical cell when juvenile, or have a beak (rostrate) at maturity, some others (often in culture) have a apical secondary

conidiophore (pseudorostrate), analogously to the beak; conidium body $20\text{--}95 \times 15\text{--}35 \mu\text{m}$, with 3–10 transverse septa and 1 to 2 longitudinal or oblique septa in a few of the transverse segments; beaks almost cylindrical, sturdy, simple and unbranched, shorter or the same length as spore bodies, sometimes 2 times the length of the spore bodies, sparsely septate, lighter in colour than the body, some of the cells become thicker, $10\text{--}90$ ($\times 200$) long, $3\text{--}5 \mu\text{m}$ wide; the secondary conidiophores simple or geniculate, $4\text{--}8 \mu\text{m}$ wide, as short as $10 \mu\text{m}$ or as long as or longer than the spore body; sometimes a beak enlarges terminally into a secondary conidiophore ca. $10 \mu\text{m}$ long.

Hosts and records in Korea: *Belamcanda chinensis* (L.) DC., (Yu et al., 2001); *Gladiolus gandavensis* Van Houtte, (new record to Korea).

Materials examined: on *Belamcanda chinensis* (L.) DC., CMH-99233 (Goyang, 5 October 1999), CMH-00417 (Geumsan, 30 August 2000), CMH-00418 (Cheongyang, 29 July 2000), CMH-00419 (Jinan, 23 August 2000), CMH-00420 (Suwon, 25 September 2000), CMH-00421 (Daejeon, 24 September 2000), CMH-00422 (Seonghwan, 28 June 2000), CMH-00423 (Daejeon, 20 June 2000), CMH-00424 (Bongpyeong, 7 October 2000); on *Gladiolus gandavensis* Van Houtte, CMH-00222 (Namwon, 23 August 2000).

Notes: This fungus is characterized by obclavate to long ovoid, and long and sturdy beaked or apically pseudorostrate conidia produced singly or in short chains of 2–4. The Korean collections were in good agreement with the previous records of *A. iridicola* (Ellis & Everh.) J.A. Elliott (Elliott, 1917; Shimasaki, 1930). *A. iridicola* was reported on *Iris* species in the central United States (Elliott, 1917; Anonymous, 1960) and Japan (Shimasaki, 1930), and recently on *Belamcanda* in Korea (Yu et al., 2001).

10. *Alternaria japonica* Yoshii, Jour. Plant Prot. (Tokyo) 28:14, 1941. Fig. 10

Alternaria brassicae var. *macrospora* sensu Yoshii, Bull. Sci. Fac. Terkultura, Kyushu Univ. 5(3): 221. 1933.

Alternaria raphani Groves & Skolko, Can. J. Res., c, 22:227. 1944.

Alternaria matthiolae Neergaard, Danish Species of *Alternaria* and *Stemphylium*, p. 184. 1945.

Lesions on host leaves effuse, small (5–10 mm in diam.), chlorotic or grayish, circular to ellipsoid with a thin papery center showing dark sporulation, sometimes surrounded by a yellow halo, shot holes may occur on some host tissue. **Mycelium** immersed or partly superficial; hyphae hyaline to pale brown, septate, branched, smooth-walled, $2\text{--}10 \mu\text{m}$ wide. **Colonies** on agar cottony, pale brown or greenish gray with scanty sporulation, reaching

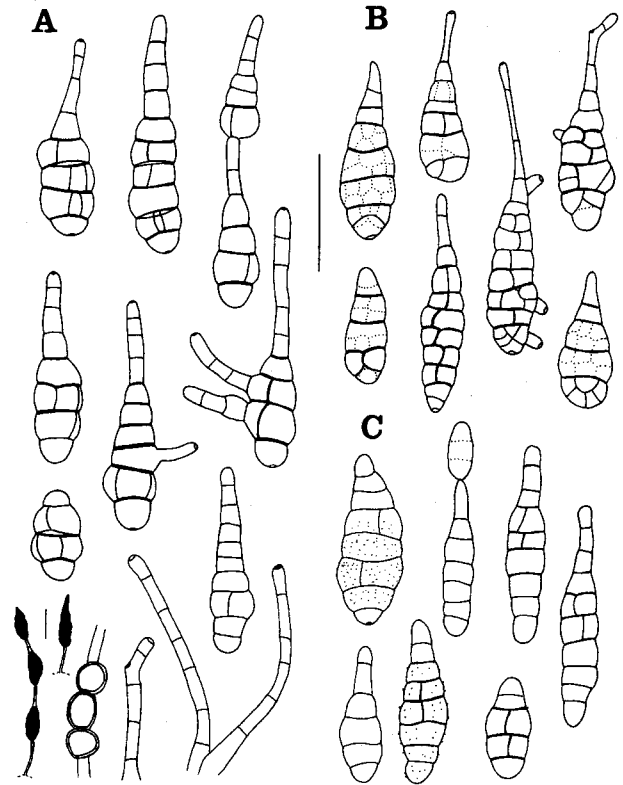


Fig. 10. *Alternaria japonica*. (A) Conidia, conidiophores, chlamydospores and habit sketch of conidia (opaque) and conidiophores (clear) from host. (B) Conidia from host. (C) Conidia from culture. (A) CMH-00803. (B and C) CMH-98040. Bar = $50 \mu\text{m}$.

about $50\text{--}60 \text{ mm}$ in diam. after 9 days. **Conidiophores** mostly solitary, unbranched or occasionally branched; straight or curved, pale to medium brown, smooth, $1\text{--}5$ septate, usually with a single terminal conidiogenous site, sometimes geniculate with 1–2 pigmented former conidium attachment sites, slightly swollen at the apex, up to $130 \mu\text{m}$ long, $4\text{--}7 \mu\text{m}$ wide; in culture the conidiophores produced as lateral extension of main hyphae, not proliferating sympodially, more or less cylindrical, with a pigmented conidiogenous locus. **Conidia** mostly solitary or in short chains of 2–3 on host, in culture commonly 2–4 through the agency of secondary conidiophores (pseudorostrate); broadly ovoid or ellipsoid to obclavate, tapering towards the apex, light brown to dark olivaceous brown, some conidium cells becoming swollen and irregular due to bulging of individual cells, erostrate (beakless) but most often producing secondary conidiophores from apical or lateral cells of the conidium, smooth when juvenile becoming roughened with age; conidium body $50\text{--}100 \times 20\text{--}40 \mu\text{m}$ on host, smaller in culture $30\text{--}80 \times 18\text{--}25 \mu\text{m}$, with 2–9 transverse septa and 1–2 longitudinal or oblique septa in a few to most of the transverse divisions, strongly constricted at the transverse septa; second conidiophores variable in length, as short as a few or up to $70 \mu\text{m}$ long

and 5–6 μm wide, pale or light yellow brown. **Chlamydospores** formed both in culture and on host, yellow brown to dark olivaceous brown, initially may be one-celled, intercalary on a hyphae, becoming multicelled and irregular in shape with a thickened wall, often strongly ornamented, secondary conidiophores often develop from them.

Hosts and records in Korea: *Brassica campestris* subsp. *napus* var. *pekinensis* Makino, (Kang *et al.*, 1985); *B. campestris* subsp. *napus* var. *nippo-oleifera* Makino, (new record to Korea); *Raphanus sativus* var. *hortensis* for. *acanthiformis* Makino, (Park, 1967; Yu *et al.*, 1991).

Materials examined: on *Raphanus sativus* var. *hortensis* for. *acanthiformis* Makino CMH-98040 (Daegwalryoung, 24 September 1998), CMH-98068 (Boryeong, 19 May 1998), CMH-98077 (Cheongyang, 12 September 1998); from seeds of *Brassica campestris* subsp. *napus* var. *pekinensis* Makino, CMH-99242 (Daejeon, 20 September 1999); on *B. campestris* subsp. *napus* var. *nippo-oleifera* Makino, CMH-00803 (Daejeon, 30 April 2000).

Notes: *Alternaria japonica* Yoshii, a member of the *Alternaria cheiranthi* species group (Simmons, 1995) can be readily differentiated from two described species of *Alternaria* on plants of Cruciferae by its beakless conidia produced solitary or in short chains of 2–4 through the agency of paler, slender, secondary conidiophores. The presence of intercalary mycelial chlamydospores, occurring as distinctive chains or knots of dark, thick-walled, often strongly ornamented cells, is another important distinguishing character of *A. japonica*. Wiltshire (1947) considered *A. japonica* (syn. *A. rapani*) and *A. brassicae* to be closely related but these results do not agree with those of Jasalavich *et al.* (1995) who found *A. japonica* to be more closely related to *A. brassicicola* based on rDNA sequence data. However, the taxonomic data based on RAPDs revealed that *A. brassicae* and *A. brassicicola* are closely related species because the isolates of *A. brassicae* and *A. brassicicola* are grouped on the same branch of the tree despite their very different morphology. However, *A. japonica* does not group with *A. brassicae* and *A. brassicicola* in the phylogenetic tree (Cooke *et al.*, 1998).

In the early 1940s, researchers in Canada, Denmark, and Japan, independently published three epithets (*japonica*, *raphani*, and *matthiola*) for the same fungus occurring on various brassicas. *A. japonica* was described by Yoshii in 1941 on the basis of the fungus pathogenic to *Raphanus sativus*, *Brassica oleracea*, *B. campestris* and other related species for which he had already reported under the name of *A. brassicae* var. *macrospora* in 1931. Groves and Skolko established *A. raphani* Groves & Skolko based on *Alternaria* species on seeds and pods of *R. sativus* collected from North America in 1944. *A. matthiolae* was set up by Neergaard in 1945 based on *Alternaria* species on *Matthiola*. *A. raphani* and *A. matthiolae*

are now considered as synonymous with *A. japonica*.

11. *Alternaria protenta* Simmons, Mycotaxon 25(1): 207, 1986. Fig. 11

Lesions on host leaves, scattered, variable in size, starting as small brown flecks, becoming larger and dark brown, oval to circular, surrounded by a yellow halo, often coalescing to form large irregular patches. **Mycelium** immersed; hyphae hyaline to pale brown, septate, branched, smooth-walled. **Colonies** on agar cottony, white to pale gray, reaching about 60–70 mm in diam. after 7 days. **Conidiophores** solitary or in fascicles, simple or occasionally branched, straight or slightly flexuous, more or less cylindrical, usually only a single terminal conidiogenous site, sometimes elongating sympodially and geniculate with 1 to 2 pigmented former conidium attachment sites, septate, pale gray or pale brown, smooth, often slightly swollen at the apex, 50–130 μm long, 3–7 μm wide; in culture the conidiophores produced terminally or laterally on the hyphae, erect, simple or branched, 100–200 μm long, 4–8 μm wide. **Conidia** mostly solitary, occasionally in chains of 2 through the agency of secondary conidiophores; long-ellipsoid, straight or slightly curved,

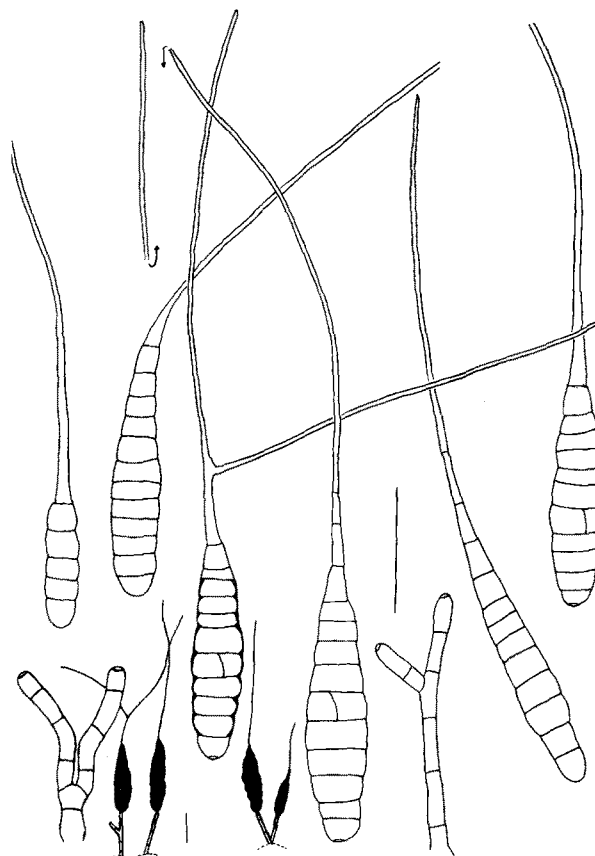


Fig. 11. *Alternaria protenta*. Conidia, conidiophores and habit sketch of conidia (opaque) and conidiophores (clear) from host. All CMH-98062. Bar = 50 μm .

light brown to medium brown in colour, smooth or minutely rough, sometimes verruculose, beakless and apically bluntly conical when juvenile, many have a long beak at maturity, the transition from spore body to beak is gradually tapering; conidium body 40–120 × 12–20 μm on host, 50–140 × 17–25 μm on agar media, with 5–14 transverse septa and several longitudinal or oblique septa; the beak filiform, colourless or pale, septate, often once branched (bifurcate), 80–150 μm long, 3–5 μm wide at the base, 2 μm at the tip.

Hosts and records in Korea: *Helianthus annuus* L., (Cho and Yu, 2000); *Rudbeckia bicolor* Nvtt., (new record to Korea).

Materials examined: on *Helianthus annuus* L., CMH-98027 (Cheongyang, 12 September 1998), CMH-98062 (Daegwalryoung, 24 September 1998), CMH-99035 (Buyeo, 7 July 1999), CMH-99133 (Geumsan, 11 September 1999), CMH-00767 (Yeongi, 15 September 2000), CMH-00768 (Bongpyeong, 7 October 2000), CMH-00769 (Mokpo, 2 September 2000), CMH-00770 (Hongcheon, 29 August 2000); CMH-00771 (Daejeon, 20 June 2000); on *Rudbeckia bicolor* Nvtt., CMH-00336 (Pyeongchang, 31 August 2000), CMH-00337 (Namwon, 23 August 2000), CMH-00338 (Hoengseong, 30 August 2000), CMH-00339 (Mokpo, 2 September 2000), CMH-00340 (Cheongyang, 4 June 2000), CMH-00341 (Bonghwa, 4 July 2000), CMH-00342 (Euseong, 4 July 2000).

Notes: *Alternaria protenta* Simmons differs from all the species of *Alternaria* described on plants of *Helianthus* and *Rudbeckia* by its longer conidia with long and often once branched beaks. Refer to the notes under *A. helianthi* and *A. helianthinifcience*.

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