THE KOREAN JOURNAL OF MYCOLOGY
Vol. 22, No 4, p309-324 December 1994

Printed in S. KOREA

Anastomosis Groups and Cultural Characteristics of *Rhizoctonia solani* Isolates from Crops in Korea

Wan-Gyu Kim*, Won-Dae Cho and Young-Hee Lee
Department of Plant Pathology, Agricultural Sciences Institute, Suwon 441-707, Korea

國內 作物에서 분리한 *Rhizoctonia solani* 菌株들의 菌絲融合群과 培養的 特性

金完圭*·趙元大·李永熙
農村振興廳 農業技術研究所 病理科

ABSTRACT: A total of 2,276 isolates of *Rhizoctonia solani* obtained from diseased crops of 68 species was classified into anastomosis groups AG-1, AG-2-1, AG-2-2, AG-3, AG-4 and AG-5 by anastomosis test. Among the isolates, 1,091 isolates were identified as AG-1, 326 isolates as AG-2-1, 191 isolates as AG-2-2, 71 isolates as AG-3, 505 isolates as AG-4, and 92 isolates as AG-5. Among the isolates of AG-1, 791 isolates were grouped as cultural type IA, 280 isolates as cultural type IB, and the others as cultural type IC. Among the isolates of AG-2-2, 112 isolates were grouped as cultural type IIIB, and the others as cultural type IV. Cultural types IA, IB and IC of AG-1 were isolated from 7, 26 and 2 species of crops, respectively. AG-2-1 was isolated from 10 species of crops. Cultural types IIIB and IV of AG-2-2 were isolated from 7 and 3 species of crops, respectively. AG-3 was only isolated from *Solanum tuberosum*. AG-4 was isolated from 43 species of crops, and AG-5 from 13 species of crops. A single anastomosis group was isolated from each of 45 species of crops, but two or more than two anastomosis groups were isolated from each of the other crops. Cultural appearance of the isolates belonging to an anastomosis group or a cultural type was mostly distinct from that belonging to others, although cultural appearances of some anastomosis groups or cultural types were similar to one another. Optimum temperature for mycelial growth of AG-1, AG-2-2, AG-4 and AG-5 ranged from 26 to 30℃, and that of AG-2-1 and AG-3 from 22 to 26℃. Minimum temperature for mycelial growth of AG-2-1 was the lowest as 2~3℃, that of AG-1(IA) and AG-4 was the highest as 10~11℃, and that of the others ranged from 5 to 10℃. Maximum temperature for mycelial growth of AG-2-2(IIIB) was the highest as 36~37℃, that of AG-2-1 was the lowest as 29~30℃, and that of the others ranged from 31 to 36℃. When the mycelial growth rates at 26℃ were compared, AG-1(IC) grew most rapidly, followed by AG-1(IA) and AG-1(IB), and AG-2-1 grew most slowly.

KEYWORDS: *Rhizoctonia solani*, crop, anastomosis group, cultural characteristics.

Introduction

Rhizoctonia solani Kühn is a soilborne fungus, and attacks a variety of plants. Isolates of the fungus from crops were classified into four to six anastomosis groups which were different in cultural and pathological characteristics (Ogoshi, 1972a; Ogoshi, 1976; Parmeter *et al.*, 1969; Richter and Schneider, 1953; Schultz, 1937). More additional anastomosis groups have been found in the isolates from soil, wheat or barley (Carling *et al.*, 1987; Homma *et al.*, 1983; Kuninaga *et al.*, 1978; Neate and Warcup, 1985; Ogoshi *et al.*, 1990). There are some cultural types within the anastomosis group

*Corresponding author

AG-1 or AG-2-2 (Hyakumachi and Sumino, 1984; Watanabe and Matsuda, 1966). Cultural characteristics of the anastomosis groups or cultural types differ somewhat, although some of them are overlapped among the anastomosis groups or cultural types (Schultz, 1937; Ogoshi, 1976; Sneh *et al.*, 1991; Richter and Schneider, 1953; Sherwood, 1969). More precise information on the cultural characteristics is needed to elucidate ecological difference among the anastomosis groups or cultural types.

Disease caused by *R. solani* has commonly occurred on many kinds of crops in Korea. Anastomosis groups or cultural types of *R. solani* isolates from some kinds of the crops have been reported (Kim *et al.*, 1991, 1992a-d, 1993 and 1994). This study was conducted to reveal systematically anastomosis groups and cultural types of *R. solani* isolates from various crops in Korea. In addition, cultural characteristics of the anastomosis groups and cultural types were examined.

Materials and Methods

Collection

Crop fields were surveyed at geographic locations in Korea from 1988 to 1994. Diseased plants were collected from the fields surveyed.

Isolation and identification

Nine to 16 mm^2 lesion pieces cut from the diseased plants were plated on 2% water agar (WA) after surface-sterilizing with 1% sodium hypochlorite solution for 1 min. *Rhizoctonia* sp. was isolated from the lesion pieces after incubation at 25℃ for 1~2 days, and the isolates were transferred to potato dextrose agar (PDA) slants for identification. *R. solani* was identified based on the morphological and cultural characteristics according to the classification of Parmeter and Whitney (1970).

Anastomosis test

All isolates of *R. solani* from the diseased plants were tested for anastomosis grouping. Each isolate was paired with the tester isolates of *R. solani* representing AG-1 to AG-10 and AG-BI as listed in Table 1. Anastomosis test was accomplished by the procedure of previous workers (Ogoshi, 1976; Parmeter *et al.*, 1969). Mycelial disks taken from the edges of actively growing cultures of field and tester isolates on PDA were opposed 2~3 cm apart on 2% WA in 9 cm-petri dishes. The plates were incubated at 23~25℃ for 24~48 hr until hyphae from the opposite sides overlapped. The overlapped area of hyphae was stained with 0.05% toluidin blue O solution and examined

Table 1. Tester isolates used for anastomosis grouping of *Rhizoctonia solani* isolates

Anastomosis group	Isolate No.	Source of isolates	Reference
AG-1	NIAES 5231	*Oryza sativa* L.	Ogoshi (1976)
AG-2-1	NIAES 5240	*Juncus effusus* L. var. *decipiens* Buch.	Ogoshi (1976)
AG-2-2	NIAES 5245	*Beta vulgaris* L. var. *saccharifera* Alef.	Ogoshi (1976)
AG-3	NIAES 5250	*Solanum tuberosum* L.	Ogoshi (1976)
AG-4	NIAES 5255	*Arachis hypogaea* L.	Ogoshi (1976)
AG-5	NIAES 5258	*Solanum tuberosum* L.	Ogoshi (1976)
AG-6	NIAES 5262	Soil	Kuninaga *et al.* (1978)
AG-7	1535	Soil	Homma *et al.* (1983)
AG-8	5762	*Triticum aestivum* L.	Neate and Warcup (1985)
AG-9	ATCC 62804	Soil	Carling *et al.* (1987)
AG-10	ATCC 76107	*Hordeum vulgare* L.	Ogoshi *et al.* (1990)
AG-BI	NIAES 5266	Soil	Kuninaga *et al.* (1978)

microscopically for hyphal anastomosis. More than twenty fusion sites were observed, and a cytoplasmic, non-cytoplasmic or semi-cytoplasmic fusion (Kim, *et al.*, 1989) was included in a positive reaction of anastomosis.

Classification of cultural types

Isolates belonging to anastomosis groups AG-1 and AG-2-2 of *R. solani* were typed based on the cultural characteristics according to the designation of previous workers (Hyakumachi and Sumino, 1984; Watanabe and Matsuda, 1966).

Investigation of cultural characteristics

Five isolates each of anastomosis groups or cultural types of *R. solani* were used for the investigation of cultural characteristics. Six-mm-diameter mycelial disks of the isolates were seeded on PDA in 9 cm-diameter petri dishes. Cultural appearance of the isolates was observed after 14 days of incubation at 26℃ in the dark.

Optimum temperature for mycelial growth of the isolates was examined in three replicate PDA cultures from 20 to 32℃ at 2℃ intervals, minimum temperature for that from 1 to 12℃ at 1℃ intervals, and maximum temperature for that from 28 to 38℃ at 1℃ intervals. The positive criterion for the mycelial growth at the minimum and maximum temperatures was above the linear growth rate of 1 mm per 24 hr during incubation for 5 days. Linear length of mycelial growth per 24 hr at 26℃ of the isolates was examined in three replicate PDA cultures to compare the mycelial growth rapidity among anastomosis groups or cultural types. Measurements were made after the mycelial growth length reached a constant rate.

Results

Anastomosis group, cultural type and isolation frequency

A total of 2,276 isolates of *R. solani* obtained from diseased crops of 68 species was classified into anastomosis groups AG-1, AG-2-1, AG-2-2, AG-3, AG-4 and AG-5 by anastomosis test (Table 2). Among the isolates, 1,091 isolates were identified as AG-1, 326 isolates as AG-2-1, 191 isolates as AG-2-2, 71 isolates as AG-3, 505 isolates as AG-4, and 92 isolates as AG-5. Among the isolates of AG-1, 791 isolates were grouped as cultural type IA, 280 isolates as cultural type IB, and the others as cultural type IC. Among the isolates of AG-2-2, 112 isolates were grouped as cultural type IIIB, and the others as cultural type IV.

Cultural types IA, IB and IC of AG-1 were isolated from 7, 26 and 2 species of crops, respectively. AG-2-1 was isolated from 10 species of crops. Cultural types IIIB and IV of AG-2-2 were isolated from 7 and 3 species of crops, respectively. AG-3 was only isolated from *Solanum tuberosum* L. AG-4 was isolated from 43 species of crops, and AG-5 from 13 species of crops.

Isolation frequency of each anastomosis group or cultural type from different plant parts of 68 species of crops is shown in Table 3. A single anastomosis group was isolated from each of 45 species of crops, but two or more than two anastomosis groups were isolated from each of the other crops. Same or different anastomosis groups and cultural types were isolated from different plant parts of a crop. Usually a single anastomosis group or cultural type was isolated from a plant part of a crop, but occasionally different anastomosis groups or cultural types were isolated from that.

Colony morphology

Cultural appearance of the isolates belonging to an anastomosis group or a cultural type of *R. solani* was mostly distinct from that belonging to others, although cultural appearances of some anastomosis groups or cultural types were similar to one another. Occasionally isolates within an anastomosis group or a cultural type varied in coloration and sclerotial formation. Typical appearances of representative cultures are shown in Fig. 1 through Fig. 12.

Cultural types IA, IB and IC of AG-1 could be differentiated by sclerotial formation in PDA culture. Mycelia of cultural type IA were very light brown to dark brown (Figs. 1 and 2). Sclerotia of the cultural type were scattered separately or sometimes joined laterally on PDA. They were

Table 2. Anastomosis groups and cultural types of *Rhizoctonia solani* isolates from diseased crops of 68 species

Anastomosis group (cultural type)	No. of isolates	Host	Isolated plant part
AG-1(IA)	791	*Arachis hypogaea* L.	Leaf, stem
		Cyperus exaltatus Retz. ssp. *iwasakii* Mak.	Leaf sheath
		Oryza sativa L.	Leaf sheath
		Platycodon grandiflorum A. Dc.	Stem
		Raphanus sativus L.	Leaf
		Solanum tuberosum L.	Stem, root
		Zea mays L.	Leaf sheath, stalk
AG-1(IB)	280	*Agrostis palustris* Huds.	Leaf, leaf sheath
		Allium fistulosum L.	Seedling
		Angelica jaluana Nakai	Stem
		Brassica campestris L. ssp. *pekinensis* (Lour.) Olss.	Leaf, root
		Brassica oleracea L. var. *capitata* L.	Root
		Bupleurum scorzoneraefolium Will. var. *stenophyllum* Nakai	Stem
		Capsicum annum L.	Stem
		Chrysanthemum morifolium Ram.	Leaf, root
		Citrullus lanatus (Thunb.) Matsum. et Nakai	Seedling
		Cnidium officinale Mak.	Stem
		Codonopsis lanceolata Traut.	Stem
		Cucumis sativus L.	Seedling
		Cucurbita moschata Duch.	Stem
		Daucus carota L. var. *sativa* Dc.	Leaf, petiole, root
		Lactuca sativa L.	Leaf, root
		Lactuca sativa L. var. *capitata* L.	Leaf
		Lithospermum erythrorhizon Sieb. et Zucc.	Leaf
		Monstera deliciosa Liebm.	Leaf
		Nicotiana tabacum L.	Seedling
		Ostericum koreanum (Max.) Kitag.	Leaf
		Panax ginseng Meyer	Stem
		Peucedanum japonicum Thunb.	Leaf
		Phlox subulata L.	Leaf
		P. grandiflorum	Leaf, stem, root
		R. sativus	Leaf
		Z. mays	Leaf sheath
AG-1(IC)	20	*B. campestris* ssp. *pekinensis*	Leaf, root
		Chaenomeles sinensis Koehne	Root

Table 2. Continued

Anastomosis group (cultural type)	No. of isolates	Host	Isolated plant part
AG-2-1	326	*B. campestris* ssp. *pekinensis*	Leaf, root
		Brassica oleracea L. var. *botrytis* L.	Root
		Eutrema wasabi Maxim.	Crown
		Fragaria x *ananassa* Duch.	Leaf, petiole, crown, root
		L. sativa	Leaf
		Malva verticillata L.	Stem
		P. ginseng	Stem
		Ranunculus asiaticus L.	Root
		R. sativus	Root
		Tulipa gesneriana L.	Leaf
AG-2-2(IIIB)	112	*Angelica dahurica* Benth. et Hook.	Stem, root
		Angelica jaluana Nakai	Stem, root
		C. lanatus	Stem
		P. japonicum	Stem
		P. grandiflorum	Stem, root
		Schindapsus pictus Hassk. var. *argyraeus* Engl.	Petiole
		Z. mays	Leaf sheath
AG-2-2(IV)	79	*D. carota* var. *sativa*	Petiole, root
		Gypsophila elegans M. Bieb.	Stem
		Zoysia japonica Steud.	Leaf, leaf sheath, crown, stolon
AG-3	71	*S. tuberosum*	Root, tuber
AG-4	505	*Achyranthes japonica* Nakai	Stem
		Allium cepa L.	Seedling
		A. fistulosum	Seedling
		A. jaluana	Stem
		Antirrhinum majus L.	Seedling
		Arachis hypogaea L.	Stem
		Arctium lappa L.	Root
		Astragalus membranaceus Bunge	Stem, root
		B. campestris ssp. *pekinensis*	Leaf, root
		Brassica oleracea L. var. *capitata* L.	Root
		Calendula officinalis L.	Seedling
		Callistephus chinensis Nees.	Seedling
		Capsicum annum L.	Seedling, stem
		Chrysanthemum coronarium L.	Stem
		C. lanatus	Seedling, root

Table 2. Continued

Anastomosis group (cultural type)	No. of isolates	Host	Isolated plant part
		C. officinale	Stem
		Cucumis melo L.	Stem
		Cucumis sativus L.	Stem
		Cucurbita moschata Duch.	Root
		Dianthus caryophillus L.	Stem
		Dianthus japonicus Thunb.	Seedling
		Eustoma russellianum (Hook.) G. Don	Leaf
		Gerbera jamesonii Bolus.	Crown
		G. elegans	Stem
		L. sativa	Root
		L. sativa var. *capitata*	Leaf
		Lilium longiflorum Thunb.	Stem
		L. erythrorhizon	Stem
		Lupinus perennis L.	Seedling
		Lycopersicon esculentum Mill.	Seedling, stem
		P. ginseng	Stem
		Petunia hybrida Vilm.	Seedling
		Pinus densiflora Sieb. et Zucc.	Seedling
		P. grandiflorum	Stem
		R. sativus	Seedling, leaf, root
		Rehmannia glutinosa Libosch. var. *purpurea* Mak. et Nem.	Root
		Salvia splendens Sell. ex Nees.	Seedling
		S. pictus var. *argyraeus*	Petiole
		Sesamum indicum L.	Stem
		Solanum melongena L.	Seedling
		S. tuberosum	Leaf, stem, root, tuber
		Spinacia oleracea L.	Seedling, crown
		Z. mays	Leaf sheath, stalk
AG-5	92	*Allium fistulosum* L.	Seedling, leaf sheath
		Arachis hypogaea L.	Root
		B. oleracea var. *capitata*	Root
		C. officinale	Stem
		C. moschata	Root
		F. x *ananassa*	Crown, root
		Glycine max Merr.	Stem, root
		Godetia amoena Lilj.	Stem
		Iris hollandica Hort.	Bulb
		P. ginseng	Stem
		S. tuberosum	Stem, root
		Z. mays	Leaf sheath
		Zingiber officinale Rosc.	Stem, tuber

Table 3. Anastomosis groups and cultural types of *Rhizoctonia solani* isolates from different plant parts of crops at several locations in Korea

Host	Isolated plant part	Location	Anastomosis group (cultural type)	No. of isolates
Achyranthes japonica Nakai	Stem	Andong	AG-4	3
Agrostis palustris Huds.	Leaf	Anyang	AG-1(IB)	6
	Leaf sheath	Anyang	AG-1(IB)	3
Allium cepa L.	Seedling	Changnyeong	AG-4	20
Allium fistulosum L.	Seedling	Icheon, Nonsan	AG-1(IB)	2
			AG-4	4
			AG-5	5
	Leaf sheath	Gangreung	AG-5	5
Angelica dahurica Benth. et Hook.	Stem	Jangheung	AG-2-2(IIIB)	5
	Root	Jangheung	AG-2-2(IIIB)	4
Angelica jaluana Nakai	Stem	Hoengseong, Icheon,	AG-1(IB)	4
		Jangheung,	AG-2-2(IIIB)	23
		Pyeongchang, Yeoju	AG-4	2
	Root	Jangheung	AG-2-2(IIIB)	7
Antirrhinum majus L.	Seedling	Suwon	AG-4	2
Arachis hypogaea L.	Leaf	Suwon	AG-1(IA)	12
	Stem	Hwaseong, Nonsan,	AG-1(IA)	12
		Suwon	AG-4	7
	Root	Gochang	AG-5	1
Arctium lappa L.	Root	Jinyang	AG-4	7
Astragalus membranaceus Bunge	Stem	Euiseong	AG-4	2
	Root	Yeongweol	AG-4	1
Brassica campestris L. ssp. *pekinensis* (Lour.) Olss.	Leaf	Busan, Daejeon,	AG-1(IB)	5
		Gimhae, Jeongju,	AG-1(IC)	3
		Milyang, Naju,	AG-2-1	135
		Pyeongtaek, Suncheon, Suwon, Yeoncheon	AG-4	3
	Root	Daejeon, Jeongju,	AG-1(IB)	18
		Naju, Pyeongtaek,	AG-1(IC)	15
		Suwon, Yeoncheon	AG-2-1	15
			AG-4	12
Brassica oleracea L. var. *botrytis* L.	Root	Daejeon	AG-2-1	6
Brassica oleracea L. var. *capitata* L.	Root	Hoengseong, Jeju,	AG-1(IB)	2
		Jeongju, Pyeongchang,	AG-4	43
		Suwon	AG-5	1
Bupleurum scorzoneraefolium Will. var. *stenophyllum* Nakai	Stem	Inje	AG-1(IB)	3

Table 3. Continued

Host	Isolated plant part	Location	Anastomosis group (cultural type)	No. of isolates
Calendula officinalis L.	Seedling	Suwon	AG-4	2
Callistephus chinensis Nees.	Seedling	Suwon	AG-4	2
Capsicum annum L.	Seedling	Icheon, Suwon	AG-4	10
	Stem	Changnyeong, Gimcheon,	AG-1(IB)	4
		Gochang, Naju, Suwon	AG-4	13
Chaenomeles sinensis Koehne	Root	Euiseong	AG-1(IC)	2
Chrysanthemum coronarium L.	Stem	Naju	AG-4	2
Chrysanthemum morifolium Ram.	Leaf	Yongin	AG-1(IB)	7
	Root	Suwon	AG-1(IB)	5
Citrullus lanatus (Thunb.) Matsum. et Nakai	Seedling	Buyeo, Yeongdong	AG-1(IB)	2
			AG-4	5
	Stem	Yeongdong	AG-2-2(IIIB)	3
	Root	Yeongdong	AG-4	9
Cnidium officinale Mak.	Stem	Bongwha, Yeoncheon	AG-1(IB)	15
			AG-4	2
			AG-5	5
Codonopsis lanceolata Traut.	Stem	Yeoncheon	AG-1(IB)	4
Cucumis melo L.	Stem	Gongju, Hwaseong,	AG-4	30
		Yeoju		
Cucumis sativus L.	Seedling	Pyeongtaek	AG-1(IB)	2
	Stem	Muan, Jungwon, Namhae	AG-4	9
Cucurbita moschata Duch.	Stem	Nonsan	AG-1(IB)	2
	Root	Boryeong, Pyeongtaek	AG-4	4
			AG-5	1
Cyperus exaltatus Retz. ssp. *iwasakii* Mak.	Leaf sheath	Naju	AG-1(IA)	6
Daucus carota L. var. *sativa* Dc.	Leaf	Pyeongchang	AG-1(IB)	4
	Petiole	Pyeongchang	AG-1(IB)	2
			AG-2-2(IV)	30
	Root	Pyeongchang	AG-1(IB)	6
			AG-2-2(IV)	4
Dianthus caryophillus L.	Stem	Busan, Gimhae,	AG-4	50
		Gokseong, Seongnam		
Dianthus japonicus Thunb.	Seedling	Suwon	AG-4	2
Eustoma russellianum (Hook.) G. Don	Leaf	Hampyeong, Icheon	AG-4	16
Eutrema wasabi Maxim.	Crown	Muju	AG-2-1	2

Table 3. Continued

Host	Isolated plant part	Location	Anastomosis group (cultural type)	No. of isolates
Fragaria x *ananassa* Duch.	Leaf	Nonsan	AG-2-1	4
	Petiole	Gyeongju, Nonsan, Milyang, Yeongdong	AG-2-1	43
	Crown	Gyeongju, Milyang,	AG-2-1	10
		Nonsan	AG-5	10
	Root	Gokseong, Gyeongju,	AG-2-1	34
		Milyang, Nonsan,	AG-5	3
		Okcheon, Suwon		
Gerbera jamesonii Bolus.	Crown	Gwangju, Jeju	AG-4	8
Glycine max Merr.	Stem	Suwon	AG-5	5
	Root	Suwon	AG-5	9
Godetia amoena Lilj.	Stem	Taean	AG-5	4
Gypsophila elegans M. Bieb.	Stem	Namwon	AG-2-2(IV)	2
			AG-4	5
Iris hollandica Hort.	Bulb	Jeju	AG-5	2
Lactuca sativa L.	Leaf	Migeum, Pyeongtaek	AG-1(IB)	3
			AG-2-1	2
	Root	Milyang, Anyang	AG-1(IB)	2
			AG-4	2
Lactuca sativa L. var. *capitata* L.	Leaf	Hwaseong,	AG-1(IB)	4
		Pyeongchang	AG-4	1
Lilium longiflorum Thunb.	Stem	Asan, Icheon	AG-4	5
Lithospermum erythrorhizon Sieb. et Zucc.	Leaf	Yeongweol	AG-1(IB)	9
	Stem	Yeongweol	AG-4	2
Lupinus perennis L.	Seedling	Suwon	AG-4	4
Lycopersicon esculentum Mill.	Seedling	Buyeo	AG-4	14
	Stem	Buyeo	AG-4	6
Malva verticillata L.	Stem	Yongin	AG-2-1	2
Monstera deliciosa Liebm.	Leaf	Yeoju	AG-1(IB)	4
Nicotiana tabacum L.	Seedling	Eumseong	AG-1(IB)	12
Oryza sativa L.	Leaf sheath	Cheolwon, Chuncheon,	AG-1(IA)	346
		Iri, Jinyang, Gimcheon,		
		Milyang, Naju, Suwon		
Ostericum koreanum (Max.) Kitag.	Leaf	Yeoncheon	AG-1(IB)	2
Panax ginseng Meyer	Stem	Gongju, Icheon,	AG-1(IB)	4
		Jinan	AG-2-1	11
			AG-4	7
			AG-5	17

Table 3. Continued

Host	Isolated plant part	Location	Anastomosis group (cultural type)	No. of isolates
Petunia hybrida Vilm.	Seedling	Suwon	AG-4	2
Peucedanum japonicum Thunb.	Leaf	Andong	AG-1(IB)	25
	Stem	Jangheung	AG-2-2(IIIB)	14
Phlox subulata L.	Leaf	Anyang	AG-1(IB)	8
Pinus densiflora Sieb. et Zucc.	Seedling	Suwon	AG-4	10
Platycodon grandiflorum A. Dc.	Leaf	Cheongyang, Jeongseon, Jinan	AG-1(IB)	14
	Stem	Bongwha, Cheongyang,	AG-1(IA)	4
		Daejeon, Hoengseong,	AG-1(IB)	63
		Jangsu, Jeongseon,	AG-2-2(IIIB)	27
		Jinan, Suwon,	AG-4	16
		Yeoncheon		
	Root	Cheongyang	AG-1(IB)	3
			AG-2-2(IIIB)	7
Ranunculus asiaticus L.	Root	Seongnam	AG-2-1	2
Raphanus sativus L.	Seedling	Suwon	AG-4	9
	Leaf	Hwaseong	AG-1(IA)	26
			AG-1(IB)	30
			AG-4	4
	Root	Hwaseong, Naju,	AG-2-1	37
		Suwon, Yeoncheon	AG-4	27
Rehmannia glutinosa Libosch. var. *purpurea* Mak. ex Nem.	Root	Andong	AG-4	11
Salvia splendens Sell. ex Nees.	Seedling	Suwon	AG-4	4
Schindapsus pictus Hassk. var. *argyraeus* Engl.	Petiole	Goyang	AG-2-2(IIIB)	12
			AG-4	5
Sesamum indicum L.	Stem	Damyang, Gochang, Suwon	AG-4	14
Solanum melongena L.	Seedling	Daejeon	AG-4	7
Solanum tuberosum L.	Leaf	Suwon	AG-4	2
	Stem	Jeju, Namhae,	AG-1(IA)	3
		Pyeongchang	AG-4	43
			AG-5	1
	Root	Pyeongchang	AG-1(IA)	1
			AG-3	4
			AG-4	2
			AG-5	1

Table 3. Continued

Host	Isolated plant part	Location	Anastomosis group (cultural type)	No. of isolates
	Tuber	Geumreung, Gochang,	AG-3	67
		Jeju, Namhae,	AG-4	8
		Pyeongchang, Suwon		
Spinacia oleracea L.	Seedling	Naju	AG-4	10
	Crown	Hwaseong	AG-4	2
Tulipa gesneriana L.	Leaf	Anyang, Suwon	AG-2-1	23
Zea mays L.	Leaf sheath	Bonghwa, Hwaseong,	AG-1(IA)	327
		Pyeongchang,	AG-1(IB)	1
		Pyeongtaek, Yeongweol	AG-2-2(IIIB)	10
			AG-4	7
			AG-5	16
	Stalk	Pyeongtaek, Yeongweol	AG-1(IA)	54
			AG-4	6
Zingiber officinale Rosc.	Stem	Wanju	AG-5	2
	Tuber	Wanju	AG-5	4
Zoysia japonica Steud.	Leaf	Suwon	AG-2-2(IV)	5
	Leaf sheath	Suwon	AG-2-2(IV)	8
	Crown	Suwon	AG-2-2(IV)	10
	Stolon	Anyang, Suwon	AG-2-2(IV)	20

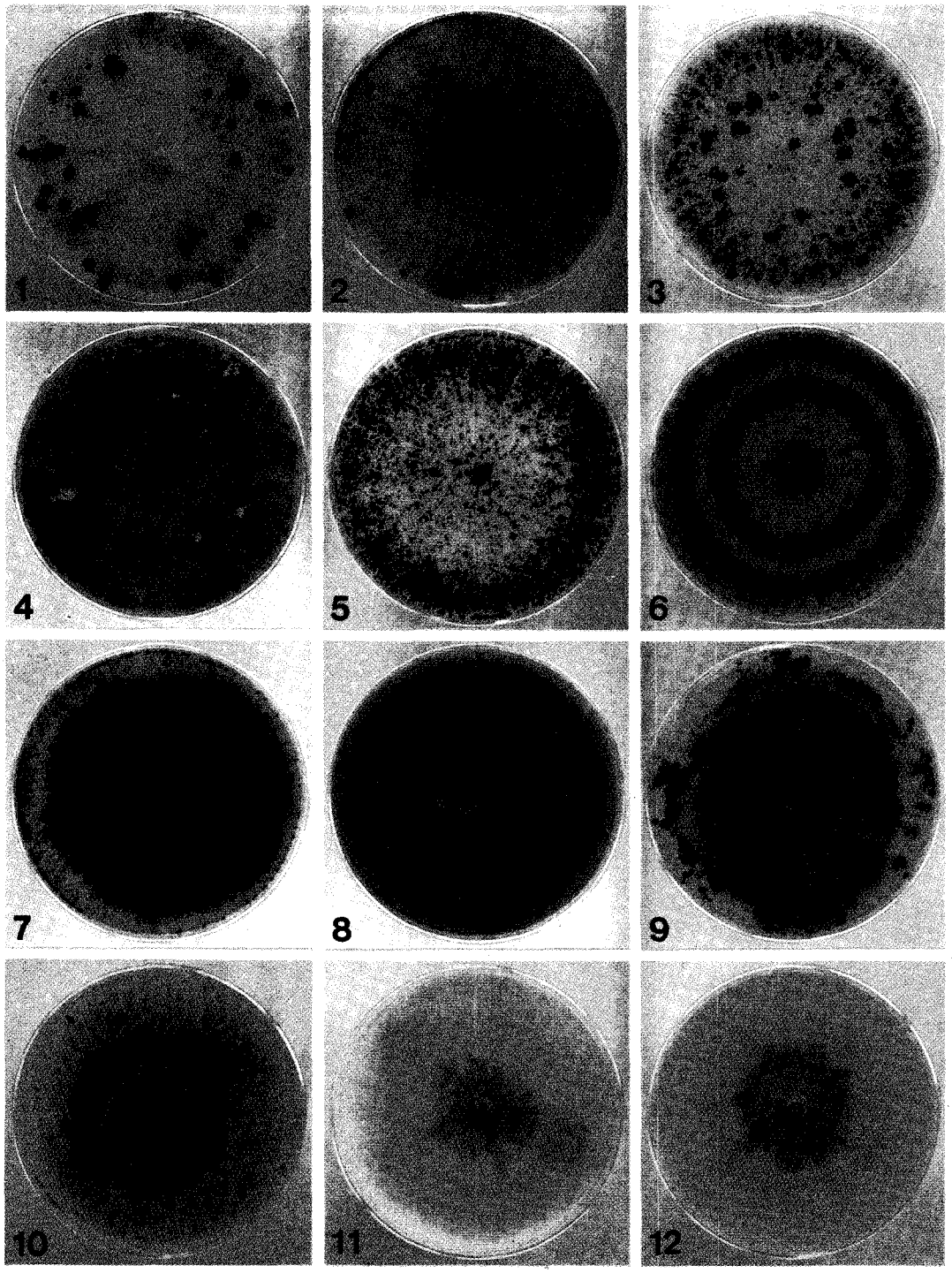
dark brown to black, subspherical to irregular, and 0.6~6.0 mm in diameter. Mycelia of cultural type IB were light brown to grayish brown (Figs. 3 and 4). Sclerotia of the cultural type were scattered separately or aggregately on the medium. They were grayish brown, subspherical to irregular, and 0.6~5.8 mm in diameter. Their surface usually mycelioid or wooly, occasionally becoming solid and pitted. Mycelia of cultural type IC were white to very light brown (Fig. 5). Sclerotia of the cultural type were very abundantly scattered on the medium. They were dark brown to black, solid, spherical to subspherical, and 0.3~1.5 mm in diameter.

Mycelia of AG-2-1 were brown to reddish brown, and the colony showed clear concentric zones (Fig. 6). Sclerotia were mostly formed in concentric zones. They were sometimes confluent, reddish to dark brown, wooly, spherical to irregular, and 0.4~1.6 mm in diameter.

Mycelia of AG-2-2(IIIB) were brown to dark brown, and the colony showed concentric zones (Fig. 7). Sclerotia were absent or rarely formed on the medium. They were dark brown, wooly, spherical to irregular, and 0.6~2.2 mm in diameter.

Mycelia of AG-2-2(IV) were light to dark brown, and the colony showed concentric zones (Fig. 8) or no concentric zone (Fig. 9). Sclerotia were absent or rarely formed in some isolates. They were dark brown, wooly, spherical to irregular, and 0.6~4.8 mm in diameter. Cultural appearance of the isolates which produced concentric zones was similar to that of AG-2-2(IIIB) isolates, but cultural appearance of the isolates which did not produce concentric zones was not.

Mycelia of AG-3 were light to dark brown (Fig. 10). Sclerotia were rarely formed on the medium.



Figs. 1-12. Colony morphology of the anastomosis groups and cultural types of *Rhizoctonia solani* cultured on PDA.
1 and 2, AG-1(IA); 3 and 4, AG-1(IB); 5, AG-1(IC); 6, AG-2-1; 7, AG-2-2(IIIB); 8 and 9, AG-2-2(IV); 10, AG-3; 11, AG-4; 12, AG-5.

Table 4. Temperature range for mycelial growth and mycelial growth rapidity of *Rhizoctonia solani* isolates belonging to different anastomosis groups and cultural types in PDA culture

Anastomosis group (cultural type)	Temperature(℃) for mycelial growth[a]			Linear length(mm) of mycelial growth per 24 hr at 26℃[a]	
	Minimum	Optimum	Maximum	Range	Mean[b]
AG-1(IA)	10~11	26~30	34~35	21.0~28.5	23.7b
AG-1(IB)	6~7	26~30	33~34	21.0~25.0	22.5b
AG-1(IC)	6~7	26~30	34~35	25.5~31.5	27.6a
AG-2-1	2~3	22~24	29~30	8.0~11.0	9.9e
AG-2-2(IIIB)	9~10	28~30	36~37	14.0~15.5	14.7d
AG-2-2(IV)	8~9	26~30	33~34	9.5~16.5	13.5d
AG-3	5~6	22~26	31~32	11.5~13.3	12.6d
AG-4	10~11	26~30	35~36	16.5~21.5	19.7c
AG-5	6~7	26~28	33~34	16.5~18.5	17.3c

[a] Five isolates per anastomsis group or cultural type were examined in three replicates. [b] In a column, means followed by a common letter are not significantly different by Duncan's multiple range test at the 0.05 level.

They were sometimes confluent, brown to dark brown, wooly, irregular, and 0.6~4.8 mm in diameter. Cultural appearance of the anastomosis group was similar to that of AG-2-2(IV) isolates which did not produce concentric zones.

Mycelia of AG-4 were whitish light brown with a powdery gray or purple tint, and grew adhensively on the medium (Fig. 11). Sclerotia were absent or rarely formed on the medium. They were gray brown to dark brown, wooly or solid, subspherical tc irregular, and 0.5~3.5 mm in diameter.

Mycelia of AG-5 were yellowish light brown with dark brown tint at the center of colony (Fig. 12). Sclerotia were absent or rarely formed on the medium. They were light to dark brown, wooly, irregular, and 0.6~1.3 mm in diameter.

Temperature range for mycelial growth and mycelial growth rapidity

Optimum temperature for mycelial growth of AG-1, AG-2-2, AG-4 and AG-5 ranged from 26 to 30℃, and that of AG-2-1 and AG-3 from 22 to 26℃ (Table 4). Minimum tremperature for mycelial growth of AG-2-1 was the lowest as 2~3℃, that of AG-1(IA) and AG-4 was the highest as 10~11℃, and that of the others ranged from 5 to 10℃. Maximum temperature for mycelial growth of AG-2-2(IIIB) was the highest as 36~37℃, that of AG-2-1 was the lowest as 29~30℃, and that of the others ranged from 31 to 36℃. When the mycelial growth rates at 26℃ were compared, AG-1(IC) grew most rapidly, followed by AG-1(IA) and AG-1(IB), and AG-2-1 grew most slowly.

Discussion

Isolates of *R. solani* have been classified into anastomosis groups AG-1, AG-2-1, AG-2-2, AG-3 to AG-10 and AG-BI (Carling *et al.*, 1987; Homma *et al.*, 1983; Kuninaga *et al.*, 1978; Neate and Warcup, 1985; Ogoshi, 1976; Ogoshi *et al.*, 1990; Parmeter *et al.*, 1969). The isolates of *R. solani* from 68 species of crops were classified into AG-1, AG-2-1, AG-2-2, AG-3, AG-4 and AG-5. Cultural types IA, IB and IC were identified in the isolates of AG-1, and cultural types IIIB and IV in the isolates of AG-2-2. This is the first report on the anastomosis groups and cultural types of the isolates from the crops in Korea except 7 species of crops reported previously (Kim *et al.*, 1991, 1992a-d, 1993 and 1994). This report also reveals many new hosts of *R. solani.*

AG-6 to 10 and AG-BI were not isolated from the crops in Korea. The isolates belonging to AG-

2-1 and AG-2-2 mostly anastomosed with the tester isolate of AG-BI but not with any other anastomosis groups, suggesting that there is no AG-BI in the isolates. It has been reported that AG-6, AG-7, AG-9 and AG-BI are isolated from soil (Carling *et al.*, 1987; Homma *et al.*, 1983; Kuninaga *et al.*, 1978), and AG-8 and AG-10 from cereals (Neate and Warcup, 1985; Ogoshi *et al.*, 1990). The anastomosis groups except AG-8 are nonpathogenic or mildly pathogenic (Sneh *et al.*, 1991). In the present study, *R. solani* isolates from soil were not examined for the anastomosis grouping. It is needed to examine anastomosis groups of the isolates from soil and other crops in Korea.

Among the anastomosis groups AG-1 to AG-5, AG-4 was isolated from the most number of crops, suggesting that the anastomosis group has the widest host range. Among the cultural types IA, IB, IC of AG-1, AG-1(IB) has the widest host range. AG-1(IC), AG-2-2(IV) and AG-3 were isolated from 2, 3 and 1 species of crops, respectively. It has been reported that the anastomosis groups are isolated from very fewer species of crops than the other anastomosis groups (Ogoshi, 1976; Parmeter *et al.*, 1969; Sneh *et al.*, 1991; Tu and Chang, 1978). Accordingly it is likely that AG-1 (IC), AG-2-2(IV) and AG-3 have very narrow host range.

R. solani attacks various parts of plants. Anastomosis groups and cultural types of the fungus are somewhat to very specific in pathogenicity to the plant parts. Watanabe and Matsuda (1966) reported that cultural types IA and IB belonging to AG-1 were mostly isolated from aerial parts of crops, AG-2-1, AG-2-2(IIIB) and AG-4 from ground surface of crops, and AG-2-2(IV) and AG-3 from subterranean parts of crops. However, the present study showed that the anastomosis groups except AG-1(IA) and AG-3 were isolated various parts of crops. AG-1(IA) was mostly isolated from aerial parts of the crops, and AG-3 was isolated from subterranean parts of *Solanum tuberosum* as reported by the previous workers (Watanabe and Matsuda, 1966). It is required to ascertain pathogenicity of the anastomosis groups and cultural types to the plant parts of the hosts.

The list of anastomosis groups and cultural types of *R. solani* isolated from the crops could be used to plan an agronomic control by crop rotation for the disease caused the fungus. It also should be referred in pathogenicity test for screening of resistant cultivars of the crops to the disease. Two or more than two anastomosis groups and cultural types as well as a single anastomosis group are isolated from each crop. The anastomosis groups and cultural types differ in pathogenicity to a crop (Sneh *et al.*, 1991). Kim *et al.* (1991, 1992a-d, 1993 and 1994) have reported on pathogenicity of the anastomosis groups and cultural types from some crops. It needs further study on pathogenicity of the anastomosis groups and cultural types from the other crops.

Cultural characteristics of some anastomosis groups or cultural types of *R. solani* have been studied (Ogoshi, 1972b; Ogoshi, 1976; Sherwood, 1969; Watanabe and Matsuda, 1966). The present study reveals that there is a little to much difference in cultural characteristics among anastomosis groups AG-1 to AG-5 or cultural types within the anastomosis groups. Compared with other anastomosis groups, AG-2-1 and AG-3 grow well at the low temperatures, and AG-2-2(IIIB) grows well at the high temperatures.

It is very difficult to distinguish cultural types IA, IB and IC of AG-1 with some cultural characteristics. The data on the sclerotial size and the minimum temperature for mycelial growth could be used to distinguish the three cultural types. It is also very difficult to distinguish cultural types IIIB and IV of AG-2-2 with the cultural appearances. Watanabe and Matsuda (1966) reported that the cultural type IIIB grew well at 35℃ but the cultural type IV did not. The present study shows that the two cultural types could be distinguished by the maximum temperature for mycelial growth.

摘 要

68종의 병든 作物에서 분리한 총 2,276균주의 *Rhizoctonia solani*를 菌絲融合群 檢定結果, 菌絲融合群 AG-1, AG-2-1, AG-2-2, AG-3, AG-4, AG-5로 분류되었다. 이들 균주중 1,091균주는 AG-1으로 同

定되고, 326균주는 AG-2-1, 191균주는 AG-2-2, 71균주는 AG-3, 505균주는 AG-4, 92균주는 AG-5로 同定되었다. AG-1의 균주들중에서 791균주는 배양형 IA로 분류되고, 280균주는 배양형 IB, 나머지 균주들은 배양형 IC로 분류되었다. AG-2-2의 균주들중에서 112균주는 배양형 IIIB로 분류되고, 나머지 균주들은 배양형 IV로 분류되었다. AG-1의 배양형 IA, IB, IC는 각각 7종, 26종, 2종의 作物에서 분리되었다. AG-2-1은 10종의 作物에서 분리되었다. AG-2-2의 배양형 IIIB와 IV는 각각 7종 및 3종의 作物에서 분리되었다. AG-3은 감자에서만 분리되었다. AG-4는 43종의 作物에서 분리되었으며, AG-5는 13종의 作物에서 분리되었다. 45종의 作物에서는 단일한 菌絲融合群이 분리되었으나, 나머지 作物에서는 둘 혹은 둘 이상의 菌絲融合群이 분리되었다. 일부 菌絲融合群 혹은 배양형의 배양적인 모습은 서로 비슷하였으나, 하나의 菌絲融合群 혹은 배양형에 속하는 균주들의 배양적인 모습은 다른 菌絲融合群 혹은 배양형에 속하는 균주들의 배양적인 모습과 대부분 달랐다. AG-1, AG-2-2, AG-4, AG-5의 균사생장 最適溫度 범위는 26～30℃ 이고, AG-2-1과 AG-3의 균사생장 最適溫度 범위는 22～26℃ 였다. AG-2-1의 균사생장 最低溫度는 2～3℃ 로서 가장 낮았고, AG-1(IA)와 AG-4의 균사생장 最低溫度는 10～11℃ 로서 가장 높았으며, 이외 다른 菌絲融合群의 균사생장 最低溫度 범위는 5～10℃ 였다. AG-2-2(IIIB)의 균사생장 最高溫度는 36～37℃ 로서 가장 높았고, AG-2-1의 균사생장 最高溫度는 29～30℃ 로서 가장 낮았으며, 이외 다른 菌絲融合群의 균사생장 最高溫度 범위는 31～36℃ 였다. 26℃ 에서의 菌絲生長率을 비교한 결과, AG-1(IC)가 가장 빨리 자랐으며, AG-1(IA)와 AG-1(IB)가 다음으로 빨리 자라고, AG-2-1이 가장 느리게 자랐다.

References

Carling, D. E., Leiner, R. H. and Kebler, K. M. 1987. Characterization of a new anastomosis group (AG-9) of *Rhizoctonia solani*. *Phytopathology* **77**: 1609-1612.

Homma, Y., Yamashita, Y. and Masayoshi, I. 1983. A new anastomosis group (AG-7) of *Rhizoctonia solani* Kühn from Japanese radish fields. *Ann. Phytopath. Soc. Japan* **49**: 184-190.

Hyakumachi, M. and Sumino, A. 1984. New morphological type (IC) in *Rhizoctonia solani* AG-1 isolated from the sugar beet-manufactory-waste-soils and some of its characteristics. *Ann. Phytopath. Soc. Japan* **50**: 507-514.

Kim, W. G., Shim, G. Y., Cho, W. D. and Lee, Y. H. 1991. Anastomosis groups and pathogenicity of *Rhizoctonia solani* isolates causing Rhizoctonia blight of turfgrasses. *Korean J. Plant Pathol.* **7**: 257-259.

Kim, W. G., Cho, W. D. and Lee, Y. H. 1992a. Anastomosis groups and pathogenicity of *Rhizoctonia solani* isolates from strawberry (*Fragaria* x *ananassa* Duch.). *Korean J. Plant Pathol.* **8**: 91-95.

Kim, W. G., Cho, W. D. and Lee, Y. H. 1992b. Anastomosis groups and pathogenicity of *Rhizoctonia solani* isolates from balloon flower. *Korean J. Plant Pathol.* **8**: 159-163.

Kim, W. G., Cho, W. D. and Lee, Y. H. 1992c. Anastomosis groups and pathogenicity of *Rhizoctonia solani* isolates from potato. *Korean J. Plant Pathol.* **8**: 223-229.

Kim, W. G., Cho, W. D. and Lee, Y. H. 1992d. Anastomosis groups and pathogenicity of isolates of *Rhizoctonia solani* and *R. zeae* from corn. *Proc. Asian Mycol. Symp. Seoul, Korea.* p. 147-159.

Kim, W. G., Cho, W. D. and Lee, Y. H. 1993. Anastomosis groups and pathogenicity of *Rhizoctonia solani* isolates from Chinese cabbage. *Korean J. Plant Pathol.* **9**: 200-205.

Kim, W. G., Cho, W. D. and Lee, Y. H. 1994. Anastomosis groups and pathogenicity of *Rhizoctonia solani* isolates from radish. *Korean J. Plant Pathol.* **10**: 7-12.

Kim, W. G., Yamaguchi, T. and Yoshino, R. 1989. Process of hyphal anastomosis and hyphal interactions among different isolates of *Rhizoctonia solani* AG-1(IA). *Trans. Mycol. Soc. Japan* **30**: 265-275.

Kuninaga, S., Yokosawa, R. and Ogoshi, A. 1978. Anastomosis grouping of *Rhizoctonia solani* Kühn isolated from non-cultivated soils. *Ann. Phytopath. Soc. Japan* **44**: 591-598.

Neate, S. M. and Warcup, J. H. 1985. Anastomosis grouping of some isolates of *Thanatephorus cucumeris* from agricultural soils in south Australia. *Trans. Brit. Mycol. Soc.* **85**: 615-620.

Ogoshi, A. 1972a. Grouping of *Rhizoctonia solani* Kühn with hyphal anastomosis. *Ann. Phytopath. Soc. Japan* **38**: 117-122.

Ogoshi, A. 1972b. Some characters of hyphal anastomosis groups in *Rhizoctonia solani* Kühn. *Ann. Phytopath. Soc. Japan* **38**: 123-129.

Ogoshi, A. 1976. Studies on the grouping of *Rhizoctonia solani* Kühn with hyphal anastomosis and on the perfect stage of groups. *Bull. Natl. Inst. Agric. Sci. C* **30**: 1-63.

Ogoshi, A., Cook, R. J. and Bassett, E. N. 1990. *Rhizoctonia* species and anastomosis groups causing root rot of wheat and barley in the Pacific Northwest. *Phytopathology* **80**: 784-788.

Parmeter, Jr., J. R., Sherwood, R. T. and Platt, W. D. 1969. Anastomosis grouping among isolates of *Thanatephorus cucumeris*. *Phytopathology* **59**: 12 70-1278.

Parmeter, Jr., J. R. and Whitney, H. S. 1970. Taxonomy and nomenclature of the imperfect state. In: *Rhizoctonia solani, Biology and Pathology*. ed. by J. R. Parmeter, Jr. p. 7-19. Univ. of California Press, Berkeley, Los Angeles and London.

Richter, H. and Schneider, R. 1953. Untersuchungen zur morphologischen und biologischen Differenzierung von *Rhizoctonia solani* K. *Phytopath. Z.* **20**: 167-226.

Schultz, H. 1937. Vergleichende Untersuchungen zur Ökologie, Morphologie und Systematik des "Vermehrungspilzes." *Arb. Biol. Reichsanst. für Land und Forstwirtsch.* **22**: 1-41.

Sneh, B., Burpee, L. and Ogoshi, A. 1991. Identification of *Rhizoctonia* species. APS Press, The American Phytopath. Soc., St. Paul, Minnesota, USA. 133 pp.

Sherwood, R. T. 1969. Morphology and physiology in four anastomosis groups of *Thanatephorus cucumeris*. *Phytopathology* **59**: 1924-1929.

Tu, C. C. and Chang, Y. C. 1978. Studies on the anastomosis groups of *Rhizoctonia solani* Kühn in Taiwan. *J. Agric. Res. China* **27**: 325-343.

Watanabe, B. and Matsuda, A. 1966. Studies on the grouping of *Rhizoctonia solani* Kühn pathogenic to upland crops. Appointed Experiment (Plant diseases and insect pests). Bull. No. 7, Agric. For. Fish. Res. Counc. and Ibaraki Agric. Exp. Stn. Japan. 137 pp.