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In Vivo Antifungal Activities of 57 Plant Extracts Against Six Plant Pathogenic Fungi

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Methanol extracts of fresh materials of 57 plants were screened for *in vivo* antifungal activity against *Magnaporthe grisea*, *Corticium sasaki*, *Botrytis cinerea*, *Phytophthora infestans*, *Puccinia recondita*, and *Blumeria graminis* f. sp. *hordei*. Among them, seven plant extracts showed disease-control efficacy of more than 90% against at least one of six plant diseases. None of the plant extracts was highly active against tomato gray mold. The methanol extracts of *Chloranthus japonicus* (roots) (CjR) and *Paulownia coreana* (stems) (PcS) displayed the highest antifungal activity; the CjR extract controlled the development of rice blast, rice sheath blight, and wheat leaf rust more than 90%, and tomato gray mold and tomato late blight more than 80%. The PcS extract displayed control values of more than 90% against rice blast, wheat leaf rust, and barley powdery mildew and more than 80% against tomato gray mold. The extract of PcS also had a curative activity against rice sheath blight and that of CjR had a little curative activity against rice blast. On the other hand, the extract of *Rumex acetocella* roots reduced specifically the development of barley powdery mildew. Further studies on the characterization of antifungal substances in antifungal plant extracts are underway and their disease-control efficacy should be examined under greenhouse and field conditions.

Keywords : Antifungal activity, *Chloranthus japonicus*, *Paulownia coreana*, Plant extract, *Rumex acetocella*

Natural products are possible sources of new agrochemicals, but they are unique in that, potentially, they can be exploited either as leads for further chemical synthesis, as commercial products in their own right following extraction directly from the producing organism, or as a source of inspiration to biochemists for the development of new bioassays capable of detecting other, structurally simpler, compounds with the same mode of action (Lange et al., 1993). Leads for chemical synthesis are undoubtedly the preferred route for a company with a synthesis base. Key examples are pyrethrins from *Chrysanthemum cinerariaefolium* (Elliott, 1989), nereistoxin from marine worm (*Lumbriconeresis heteropoda*) (Eldefrawi, 1976; Sakai, 1969), and antifungal oudemansin A and strobilurins from *Oudemansiella mucida* and *Strobilurus tenacellus*, respectively (Anke et al., 1977; Musilek et al., 1969). Using these compounds as lead molecules, cartap and thiocyclam (from nereistoxin), pyrethroid classs of insecticides (from pyrethrins), and strobilurin fungicides such as azoxystrobin, kresoxim-methyl, metominostrobin and trifloxystrobin (from strobilurins and oudemansin A) have been synthesized and commercialized. On the other hand, a number of commercial agrochemicals have been produced by fermentation. The examples are fungicides of polyoxins, blasticidin S, kasugamycin, mildiomycin and validamycin, insecticides of tetranactin and avermectins, and a herbicide of bilanaphos (Lange et al., 1993). Soraphen A is a complex natural product inhibiting strongly acetyl-CoA carboxylase in fungi. The chemical structure of soraphen A is complex, not suitable as leads for chemical synthesis. However, since its action site in fungi is novel, its discovery stimulates further research for novel fungicides that act on this enzyme (Pridzun et al., 1995).

Many of the earliest pesticides were extracts of plants, and several plants were exploited more widely as sources of commercial insecticides. But, from 1940s, synthetic agrochemicals largely replaced plant-derived products as the key commercial insecticides. Research on plant-derived natural products for the use in agriculture went into decline for a number of years, but this trend is now reversed as it becomes evident that plant natural products still have enormous potential to inspire and influence modern agrochemical research. It is estimated that there are at least 250,000 different species of plant in the worlds. But it was also estimated that only 10% of plant species have been examined chemically until 1993 (Benner, 1993), so there is enormous scope for further work.

Recently, many studies of the use of plant extracts,

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essential oils, and pure active principles against plant pathogenic fungi have been conducted. Kim et al. (2004) reported that two extracts *Achyranthes japonica* (whole plant) and *Rumex crispus* (roots) effectively control the development of cucumber powdery mildew caused by *Podosphaera xanthii* in glasshouse trials. They also isolated three antifungal substances from the roots of *R. crispus* and identified them as nepodin, chrysophanol, and parietin (Choi et al., 2004). Wilson et al. (1997) found that species of *Allium* and *Capsicum* and essential oils of palmarosa, red thyme, cinnamon leaf, and clove buds were highly active against *Botrytis cinerea*.

A number of antifungal compounds of diverse skeletal patterns have been found in plants. These compounds belong mainly to six broad chemical groups, such as phenolics and phenolic acids, coumarins and pyrones, flavonoids, isoflavonoids, steroids and steroidal alkaloids, and miscellaneous compounds (Mitra et al., 1984). However, only a few commercial products from plant are used in practical plant protection. Lechitin from soybean is registered as a plant protecting agent (Klingauf and Herger, 1990). Milsana, a plant extract of *Reynoutria sachalinensis* is commercialized for the control of cucumber powdery mildew (Dik and Van Der Staay, 1995). Neemazal, a product made from neem (*Azadirachta indica*), a neem extract containing 5% azadirachtin, was found to induce resistance against powdery mildew in pea (Prithiviraj et al., 1998).

In this study, we examined *in vivo* antifungal efficacy of 57 plant extracts against six plant pathogenic fungi on plant seedlings under growth-chamber conditions to develop environmental-friendly fungicides using plant resources. We also evaluated protective and curative activities of the active extracts showing control values of more than 90% in the primary screening.

Materials and Methods

Collection of Plant Samples and Methanol Extraction. A total of 57 fresh samples of plants were collected in various locations in Korea. All samples were identified and authenticated by Dr. Kyu Young Chung, Division of Bioresource and Environmental Science, College of Natural Sciences, Andong National University, Andong, Kyoungsangbuk-do 760-749, Korea and voucher specimens were deposited in the herbarium of the College of Natural Sciences, Andong University. The botanical name, family,

Table 1. Disease control efficacy of plant extracts collected in Korea against six plant pathogens[a]

Family	Scientific Name	Plant part[b]	Control Value (%)					
			RCB[c]	RSB	TGM	TLB	WLR	BPM
Betulaceae	*Alnus hirsuta*	S	10	0	0	0	53	0
	"	L	40	0	0	0	73	0
Campanulaceae	*Adenophora triphylla* var. *japonica*	R	10	0	6	0	53	0
	"	S,L	0	0	0	0	0	0
Chenopodiaceae	*Chenopodium album* var. *centrorubrum*	L,S,Fr	0	0	6	0	0	0
Chloranthaceae	*Chloranthus japonicus*	R	99	100	81	84	100	33
Compositae	*Artemisia keiskeana*	Fl,S,L	30	0	13	25	20	0
	Aster scaber	S,L,Fl	50	0	13	56	0	0
	Helianthus tuberosus	L	20	0	36	0	0	50
	"	S	0	0	0	0	73	0
	Saussurea pulchella	Sd	10	0	7	0	83	0
	"	S,L	0	0	0	0	73	0
	Youngia chelidoniifolia	S,L	78	0	13	13	57	50
Cornaceae	*Cornus officinalis*	Fr	0	0	0	0	67	0
Crassulaceae	*Sedum sarmentosum*	W	0	0	6	31	0	0
Curcurbitaceae	*Schizopepon bryoniaefolius*	W	10	0	0	0	80	0
Fumariaceae	*Corydalis ochotensis* var. *raddeana*	S,L	75	0	36	0	3	50
Labiatae	*Clinopodium micranthum*	S,L	0	0	13	38	0	0
	Elsholtzia ciliata	W	10	0	0	31	0	0
	Isodon inflexus	S,L,Fl	10	0	69	44	60	8
	Isodon japonicus	S,L,Fl	10	5	19	56	3	0

Table 1. Continued.

Family	Scientific Name	Plant Part[b]	Control Value (%)					
			RCB[c]	RSB	TGM	TLB	WLR	BPM
Leguminosae	*Amorpha fruticosa*	S,L	0	0	0	31	53	0
	Asparagus oligoclonos	W	10	0	6	0	33	0
	Disporum sessile	S,L	20	0	19	50	3	0
	Lespedeza cuneata	S,L	20	0	13	38	0	0
	Polygonatum inflatum	S,L,Fr	40	0	0	6	80	58
	"	R	40	0	0	6	80	58
	Rhynchosia volubilis	S,L	10	0	0	0	3	0
	Tricyrtis dilatata	S,L,Fr	0	0	0	0	0	0
Osmundaceae	*Osmunda cinnamomea* var. *japonica*	S,L	0	5	13	0	3	0
Polygonaceae	*Bistorta manshuriensis*	S,L	75	5	29	6	60	8
	Persicaria sieboldi	S,L	65	0	13	56	43	0
	Persicaria filiforme var. *neofiliforme*	S,L,Fl	10	0	7	0	20	50
	Rumex acetocella	R	93	0	6	50	67	90
	"	S,L	75	0	6	13	3	42
Primulaceae	*Lysimachia clethroides*	W	97	0	44	78	53	0
Ranunculaceae	*Clematis apiifolia*	S,L	0	0	7	0	60	0
	Clematis trichotoma	S,L,Fl	65	0	44	56	3	0
	Thalictrum aquilegifolium	S,L,Fl	20	0	19	0	83	0
	"	R	0	5	0	25	33	0
Rosaceae	*Malus sieboldii*	S,L	86	0	19	38	53	42
Rutaceae	*Zanthoxylum schinifolium*	Fl	10	0	13	44	27	0
	"	Fr	10	0	13	13	3	0
Saxifragaceae	*Rodgersia podophylla*	R	96	0	19	13	53	0
	"	S,L	97	0	19	63	3	0
Scrophulariaceae	*Paulownia coreana*	S	98	0	82	69	100	100
Solanaceae	*Solanum japonense*	W	20	0	0	6	67	0
Sterculiaceae	*Corchoropsis psilocarpa*	L	92	0	71	94	80	58
Umbelliferae	*AIngelica decursiva*	S,Fr	50	0	19	6	60	50
Urticaceae	*Boehmeria spicata*	S,L	88	0	21	6	67	0
	Laportea bulbifera	W	20	0	7	0	0	0
Valerianaceae	*Patrinia scabiosaefolia*	Fl	10	0	14	44	3	42
	"	R	75	0	82	88	20	0
	"	S,L	10	0	0	50	0	33
	Patrinia villosa	S,L,Fl	80	0	64	75	13	58
Verbenaceae	*Clerodendron trichotomum*	S,L	86	0	19	38	53	42
Vitaceae	*Ampelopsis brevipedunculata*	S,L	20	0	6	44	13	0

[a]The plant seedlings were inoculated with spores or mycelial suspensions of the organisms 1day after the plant extracts were sprayed to run-off the leaves.

[b]S, stems; L, leaves; W, whole plant; R, roots, Fr, fruits; Fl, flowers; Sd, seeds.

[c]RCB, rice blast (caused by *Magnaporthe grisea*); RSB, rice sheath blight (caused by *Corticium sasaki*); TGM, tomato gray mold (caused by *Botrytis cinerea*); TLB, tomato late blight (caused by *Phytophthora infestans*); WLR, wheat leaf rust (caused by *Puccinia recondita*); BPM, barley powdery mildew (caused by *Blumeria graminis* f. sp. *hordei*).

and parts of plant samples are summarized in Table 1. The 57 plant samples belong to 42 genera and 27 families.

Preparation of extracts. Preparation of the plant extracts for the antifungal screening against six plant pathogenic fungi was conducted as previously described by Kim et al. (2004). In brief, fresh plant material (300 g) was macerated using a Waring blender (Dynamics Corporation of America, New Hartford, Connecticut, USA) for 1 min and extracted with 600 ml of methanol (MeOH) for 2 hr. The suspension was filtered through Whatman No. 2 filter paper and the marc was rinsed with 200 ml of MeOH followed by filtration. The filtrate was concentrated *in vacuo* using a rotary evaporator to obtain approximately 25 ml of a wet residue. After decanting the aqueous solution, the residue was dissolved in 10 ml of dimethyl sulfoxide (DMSO). The aqueous and DMSO solutions were recombined. Distilled water was added to this solution to obtain a 50-ml volume, of which 1.5 ml (corresponding to 9 g fresh plant material) was used for *in vivo* antifungal assay against the six plant pathogenic fungi.

***In vivo* Antifungal Activity.** In order to select samples showing a potent antifungal activity, the MeOH extracts of 57 plants, at a concentration of 0.3 g fresh weight of plant tissue per ml, were tested *in vivo* for antifungal activity against the following six plant diseases: rice blast (*Magnaporthe grisea*); rice sheath blight (*Corticium sasaki*); tomato gray mold (*Botrytis cinerea*); tomato late blight (*Phytophthora infestans*); wheat leaf rust (*Puccinia recondita*) and barley powdery mildew (*Blumeria graminis* f. sp. *hordei*) (Kim et al., 2001 and 2004). Rice (*Oryza sativa* L., cv. Nakdong), tomato (*Lycopersicon esculentum* Mill., cv. Seokwang), barley (*Hordeum sativum* Jessen, cv. Dongbori), and wheat (*Triticum aestivum* L., cv. Chokwang) plants were grown in the plastic pots (4.5-cm diameter) in a greenhouse at 25 ± 5°C for 1 to 4 weeks. The plant seedlings were sprayed with a mixture of the plant extract (1.5 ml) and aqueous Tween 20 solution (250 μg/ml) (28.5 ml) until run-off and allowed to stand for 24 hr. Control plants were treated with Tween 20 solution containing 1% DMSO.

For the development of rice blast, the rice seedlings of the 2nd leaf stage were inoculated with *M. grisea* by spraying a spore suspension (5×10^5 spores/ml) of the fungus. Following the incubation of the seedlings in the dark for 1 day at 25 ± 2°C and 100% RH, they were transferred to a growth chamber maintained at 25 ± 2°C and 70-80% RH with 12 hr daylight per day. Disease severity was determined as the percentage of infected leaf area 5 days after inoculation. For the rice sheath blight assay, the rice seedlings of the 3rd leaf stage were inoculated by adding 7-days old wheat-rice bran (200 ml of wheat bran, 100 ml of rice bran, and 100 ml of distilled water in 1 L Erlenmeyer flask) cultures of *C. sasaki* to soil. After incubation for 4 days in the dark at 25 ± 2°C and 100% RH, the inoculated plants were kept in a growth chamber for 4 days at 25 ± 2°C and 100% RH with 12 hr daylight per day and then disease severity was assessed.

For tomato late blight, the treated tomato seedlings of the 2nd leaf stage were inoculated with *P. infestans* by spraying a zoospore suspension released from sporangial suspension (5×10^4 sporangia/ml) of the fungus. For the tomato gray mold assay, the tomato seedlings of the 2nd leaf stage were inoculated by spraying a spore suspension (10^6 spores/ml) of *B. cinerea*. The inoculated tomato plants were kept in the dark at 25 ± 2°C and 100% RH. Disease severity was assessed 3 to 4 days after inoculation.

For wheat leaf rust, the wheat seedlings of 1st leaf stage were inoculated with *P. recondita* by spraying a spore suspension (0.67 mg urediospores/ml, containing 250 μg/ml Tween 20) of the fungus. They were incubated in a moist chamber for 1 day at 20°C and then transferred to a growth chamber. The disease severity was determined by rating the infected leaf area 7 days after inoculation. For the development of barley powdery mildew, the barley seedlings of the 1st leaf stage were inoculated with *B. graminis* f. sp. *hordei* by dusting dry inoculum from diseased plants. The inoculated barley seedlings were incubated for 7 days at 20°C in a growth chamber, and then the disease severity was determined.

Pots were arranged as a randomized complete block with three replicates per treatment. Each pot was assayed for extent of infection by visual estimation of the percentage area of leaves covered by sporulating lesions or the percent chlorotic and necrotic symptoms on the inoculated foliage or sheaths. Three estimates for each treatment were converted into percentage fungal control as compared to the control plants.

Protective activity of the active plant extracts. To further investigate a protective activity of seven plant extracts showing potent disease-control efficacy against at least one of the six plant pathogenic fungi, a series of three fold dilutions of the extracts were applied protectively (1 day prior to inoculation). Solvent-(1% aqueous DMSO) treated plants were used as controls. Pots were arranged as a randomized complete block with three replicates per treatment. The three estimates for each extract were converted into percentage fungal control as compared to the control plants.

Curative activity of the active plant extracts. The seven plant extracts being highly active were applied onto foliage of plant seedlings at a concentration of 0.3 g fresh weight of plant tissue per ml 1 day after inoculation in order to evaluate their curative activities against the six plant pathogenic fungi. Pots were arranged as a randomized complete block with three replicates per treatment. The three estimates for each extract were converted into percentage fungal control as compared to the control plants.

Results and Discussion

Screening of plant extracts for *in vivo* antifungal activity. Seven (12%) out of 57 plant extracts displayed disease control activity of more than 90% against at least one of six plant diseases (Table 1). None of the plant extracts was active against tomato gray mold. The extract of *C. japonicus* roots (CjR) exhibited control values of more than 90% against rice blast, rice sheath blight, and wheat leaf rust. In addition, the extract effectively controlled the development of tomato gray mold and tomato late blight over 80%. The extract of *Paulownia coreana* (stems) (PcS) displayed control values of more than 90% against rice blast, wheat leaf rust and barley powdery mildew and more

Table 2. Plant extracts with *in vivo* antifungal activity of more than 90% against at least one of six plant pathogenic fungi

Family	No. of samples tested	No. of active plant samples against[a]						No. of active plant extracts[b]
		RCB	RSB	TGM	TLB	WLR	BPM	
Betulaceae	2	0	0	0	0	0	0	0
Campanulaceae	2	0	0	0	0	0	0	0
Chenopodiaceae	1	0	0	0	0	0	0	0
Chloranthaceae	1	1	1	0	0	1	0	1
Compositae	7	0	0	0	0	0	0	0
Cornaceae	1	0	0	0	0	0	0	0
Crassulaceae	1	0	0	0	0	0	0	0
Curcurbitaceae	1	0	0	0	0	0	0	0
Fumariaceae	1	0	0	0	0	0	0	0
Labiatae	4	0	0	0	0	0	0	0
Leguminosae	3	0	0	0	0	0	0	0
Liliaceae	5	0	0	0	0	0	0	0
Osmundaceae	1	0	0	0	0	0	0	0
Polygonaceae	5	1	0	0	0	0	1	1
Primulaceae	1	1	0	0	0	0	0	1
Ranunculaceae	4	0	0	0	0	0	0	0
Rosaceae	1	0	0	0	0	0	0	0
Rutaceae	2	0	0	0	0	0	0	0
Saxifragaceae	2	2	0	0	0	0	0	2
Scrophulariaceae	1	1	0	0	0	1	1	1
Solanaceae	1	0	0	0	0	0	0	0
Sterculiaceae	1	1	0	0	1	0	0	1
Umbelliferae	1	0	0	0	0	0	0	0
Urticaceae	2	0	0	0	0	0	0	0
Valerianaceae	4	0	0	0	0	0	0	0
Verbenaceae	1	0	0	0	0	0	0	0
Vitaceae	1	0	0	0	0	0	0	0
Total	57	7	1	0	1	2	2	7

[a] RCB, rice blast (caused by *Magnaporthe grisea*); RSB, rice sheath blight (caused by *Corticium sasaki*); TGM, tomato gray mold (caused by *Botrytis cinerea*); TLB, tomato late blight (caused by *Phytophthora infestans*); WLR, wheat leaf rust (caused by *Puccinia recondita*); BPM, barley powdery mildew (caused by *Blumeria graminis* f. sp. *hordei*).

[b] Plants showing *in vivo* antifungal activity of more than 90% against at least one of six plant pathogenic fungi.

than 80% against tomato gray mold. Of the seven active extracts, two exhibited control values of more than 90% against two of the six plant diseases: the extract of *Corchoropsis psilocarpa* (leaves) (CpL) effectively controlled both rice blast and tomato late blight, and the extract of *Rumex acetocella* (roots) (RaR) did both rice blast and barley powdery mildew. The three extracts of *Lysimachia clethroides* (whole plant) (LcW), *Rodgersia podophylla* (roots) (RpR) and *R. podophylla* (stems and leaves) (RpSL) were highly active only against rice blast of the six plant diseases tested. For each plant family tested, Table 2 exhibits the number of plant extracts displaying potent *in vivo* antifungal activity against one of the six plant diseases. Among 27 families, the extracts of plant species belonging to 6 families displayed potent *in vivo* antifungal activity.

Kim et al. (2004) reported that 33 (18%) out of 183 plant extracts exhibited strong *in vivo* antifungal activity against at least one of six plant pathogenic fungi. In the previous report, the methanol extract of *C. japonicus* stems and leaves (CjSL) also displayed high *in vivo* antifungal activities against rice blast, tomato late blight, and wheat leaf rust. However, it had little activities against rice sheath blight and tomato gray mold. Compared to the methanol extract of CjSL, that of CjR showed higher antifungal activities against plant pathogenic fungi tested.

As for the extract of RaR, it showed strong antifungal activity against *B. graminis* f. sp. *hordei* on barley seedlings as well as *M. grisea* on rice seedlings. Kim et al. (2004) found that the extract of *R. crispus* roots effectively suppressed the development of barley powdery mildew in a

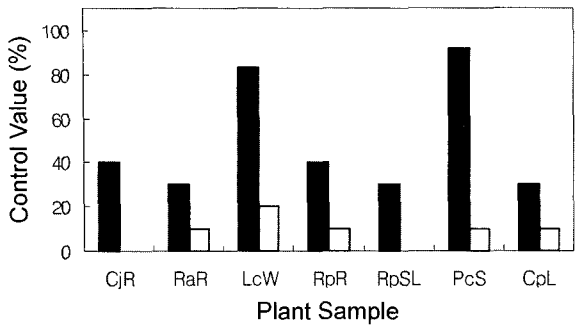

Fig. 1. Protective efficacy of several plant extracts at concentrations of 0.1 g (■) and 0.03 g (□) fresh weight of plant tissue per ml against rice blast (CjR, *Chloranthus jaoinicus* roots; RaR, *Rumex acetocella* roots; LcW, *Lysimachia clethroides* whole plant; RpR, *Rodgersia podophylla* roots; RpSL, *Rodgersia podophylla* stems & leaves; PcS, *Paulowinia coreana* stems; CpL, *Corchoropsis psilocarpa* leaves).

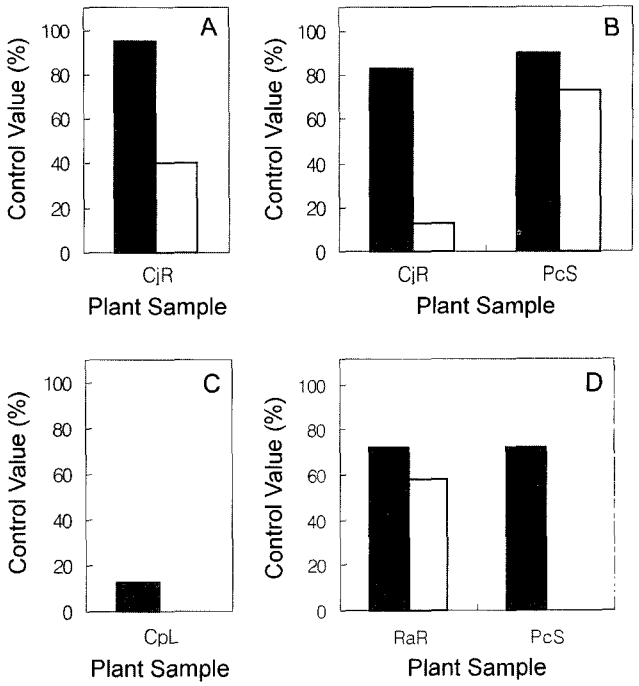

Fig. 2. Protective efficacy of several extracts at concentrations of 0.1 g (■) and 0.03 g (□) fresh weight of plant tissue per ml against rice sheath blight (A), wheat leaf rust (B), tomato late blight (C), and barley powdery mildew (D) (CjR, *Chloranthus jaoinicus* roots; PcS, *Paulowinia coreana* stems; CpL, *Corchoropsis psilocarpa* leaves; RaR, *Rumex acetocella* roots).

growth chamber and cucumber powdery mildew caused by *P. xanthii* under glasshouse conditions. In addition, they isolated three antifungal substances showing strong antifungal activity against powdery mildew fungi and identified their structures as nepodin, parietin, and chrysophanol, respectively (Choi et al., 2004). The two plants of *R. acetocella* and *R. crispus* belong to the same genus, suggesting that their roots might contain the same antifungal substances.

Protective efficacy of the active plant extracts at lower concentrations. The seven active plant extracts were evaluated for their 1-day protective activity against each of plant diseases. Two extracts of LcW and PcS, at 0.1 g fresh weight of plant tissues per ml, controlled development of rice blast more than 80% in 1-day protective application (Fig. 1). The extract of CjR also showed potent antifungal activity against *C. sasaki* on rice seedlings; it almost completely controlled the plant disease at the concentration of 0.1 g fresh weight of plant tissue per ml and 40% at the concentration of 0.03 g fresh weight of plant tissue per ml (Fig. 2A). Both extracts of CjR and PcS effectively controlled the development of *P. recondita* on wheat seedlings at the 3-fold lower concentration (Fig. 2B). In particular, the extract of PcS also displayed high control value of 73% against wheat leaf rust even at the 9-fold lower concentration, 0.03 g fresh weight of plant tissue per ml. At lower concentrations, the extract of CpL had little antifungal activity against *P. infestans* on tomato seedlings. The two extracts of RaR and PcS, at the concentration of 0.1 g fresh weight of plant tissue per ml, exhibited control values of more than 70% against barley powdery mildew.

Curative efficacy of the active plant extracts. The curative activities of the seven plant extracts that have strong protective activities were summarized in Table 3. Two extracts of RpR and PcS showed moderate curative activities with control values of 31% against rice blast, and the other extracts have little or no curative activity. On the other hand, the extract of CjR displayed relatively high curative efficacy against rice sheath blight. The extract of CpL and two extracts of CjR and PcS had no curative activity against tomato late blight and wheat leaf rust, respectively. Of the two extracts tested for barley powdery mildew, only the extract of RaR displayed a little curative activity.

The above results indicate that the methanol extract of CjR has a potent protective activity against rice sheath blight and wheat leaf rust, and a curative activity against rice sheath blight. *C. japonicus* is a perennial herbaceous plant which is widely distributed especially in a humus-rich soil in some shade in Korea. The plant belongs to Chloranthaceae, Piperales, Dicotyledoneae. The Chloranthaceous plants have been found to be rich in unusual sesquiterpene lactones having a lindenane skeleton named shizukanolides, shizukanols and chloranthalactones (Kawabata and Mizutani, 1989 and 1992; Kawabata et al., 1990, 1995 and 1998). On the other hand, the extract of PcS has a potent protective activity against rice blast, wheat leaf rust and barley powdery mildew and a little curative activity against rice blast. *P. coreana* is a perennial woody plant which is widely

Table 3. Curative efficacy of several plant extracts against six plant diseases[a]

Scientific Name	Plant Part	Concentration (fresh wt (g) of plant tissue/ml)	Control Value (%)					
			RCB	RSB	TGM	TLB	WLR	BPM
Chloranthus japonicus	Roots	0.3	0	75	-	-	0	-
Rumex acetocella	Roots	"	0	-	-	-	-	35
Lysimachia clethroides	Whole plant	"	0	-	-	-	-	-
Rodgersia podophylla	Roots	"	31	-	-	-	-	-
Rodgersia podophylla	Stems, leaves	"	5	-	-	-	-	-
Paulownia coreana	Stems	"	31	-	-	-	0	0
Corchoropsis psilocarpa	Leaves	"	0	-	-	2	-	-

[a] The plant extracts that showed protective efficacy more than 90% against at least one of six plant diseases were sprayed onto foliage 1 day after inoculation of each of plant pathogenic fungi.
[b] RCB, rice blast (caused by *Magnaporthe grisea*); RSB, rice sheath blight (caused by *Corticium sasaki*); TGM, tomato gray mold (caused by *Botrytis cinerea*); TLB, tomato late blight (caused by *Phytophthora infestans*); WLR, wheat leaf rust (caused by *Puccinia recondita*); BPM, barley powdery mildew (caused by *Blumeria graminis* f. sp. *hordei*).

distributed in Korea, Japan, and China. It belongs to Scrophulariaceae, Tubiflorales, Metachlamydeae. In addition, RaR has a potent protective activity and a little curative activity especially barley powdery mildew. *R. acetocella* is a perennial herbaceous plant which belongs to Polygonaceae, Polygonales, Dicotyledoneae. It is distributed mainly in the southern parts of Korea. Young leaves of this plant are being consumed as a food in Korea. Roots of *R. acetocella* are yellow and a well-known chinese medicine for the itch and skin disease.

The two extracts of CjR and PcS have a broad-spectrum antifungal activity against plant pathogenic fungi, whereas the extract of RaR reduce specifically the development of barley powdery mildew. Their high efficacy against plant pathogenic fungi in a growth chamber led us to test them under glasshouse and field conditions. Further studies on characterization of antifungal substances from the active plant extracts are in progress.

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