DOI : 10.5958/0974-0112.2018.00072.5

Indian J. Hort. 75(3), September 2018: 423-433

Effect of plant extracts and organic emulsifiers on control of anthracnose in persimmon

S.J. Jang, Y.B. Yun, S.S. Kim, H.S. Choi*** and Y.I. Kuk***

Department of Oriental Medicine Resources, Sunchon National University, Suncheon 540-742, Republic of Korea

ABSTRACT

The objective of this research was to determine suppression rate of anthracnose (*Colletotrichum coccodes*) in persimmon by using plant extracts from different extraction methods (water, boiling water, fermentation, and ethanol) from various plant parts (leaves, stems, fruits, and roots) in 47 species from 27 families. Suppression rate of *C. coccodes* was also studied by using mixers of various plant extracts and organic emulsifiers. Finally, the controlling effect on *C. coccodes* and leaf injury in persimmon trees was determined by using selected plant extracts and organic emulsifiers. Fermentation extracts of *Torilis japonica* roots and *Portulaca oleracea* above ground parts, ethanol extracts of *Rheum palmatum* roots, and *Cinnamomum cassia* barks among 47 plant species from 27 families were more effective on suppression rate of anthracnose, which was >83% suppressed by 10% of the plant extracts in the laboratory test. Anthracnose was 100% suppressed by 3% brown rice vinegar, 3% powder soap, 5% loess sulfur, and 5% natural emulsifier-B in a laboratory test. Synergistic effects on suppression rate of anthracnose by combination applications of plant extracts and organic emulsifiers did not appear. In the treatment of plant extracts alone, anthracnose was 63% and 51% reduced by 5% fermentation extract of *Torilis japonica* and 5% ethanol extract of *Rheum palmatum* compared with non-treated control, respectively in an organically produced persimmon plants. However, in combination treatments of plant extracts and organic emulsifiers, anthracnose was 79.2%, 67.3%, 62.7% and 55.7% reduced by 5% fermentation extract of *Torilis japonica* + natural emulsifier-B (1%), 5% fermentation extract of *Torilis japonica* + loess sulfur (1%), 5% ethanol extract of *Rheum palmatum* + natural emulsifier-B (1%), and 5% ethanol extract of *Rheum palmatum* + loess sulfur (1%) compared to non-treated control, respectively, in an organically produced persimmon plants. Persimmon leaf injuries did not show by treatments of 10% fermentation extract of *Torilis japonica*, 10% ethanol extract of *Rheum palmatum,* 5% natural emulsifier-B and 5% loess sulfur. Thus, the plant extracts and organic emulsifiers may be used for controlling anthracnose in organically produced crop fields.

Key words: *Colletotrichum coccodes*, *Diospyros kaki*, fermentation extracts, ethanol extracts, synergistic effect.

INTRODUCTION

Recently, conventional cultivation using pesticides and fertilizers has been changing quickly into organic agriculture using organic agricultural materials because of an increasing interest in and demand for organic products. However, organic agricultural materials used in organic agricultural plantations have low pest control effect and low residue activity. In addition, occurrence amount of pest in organic cultivation fields were much more than those found in conventional cultivation fields. Thus, pest control in organic cultivation was much more difficult than that of conventional cultivation (Jeon and Kim, 8).

Anthracnose fungus may violate nearly all parts of the plant and form a lesion in lesion leaves, stems, and fruits of host plants. Thereafter, plants infected with anthracnose show symptoms of tissue necrosis, rot, and blight. In some cases mobility rate of disease on anthracnose in organic cultivation is over 90%, so crops do not harvest (Kwon and Lee, 12). Occurrence of anthracnose (*Colletotrichum coccodes*) in various crops including peppers and persimmon trees bring about economic loss (Agrios, 1). To control pests such as anthracnose, pesticides have been used for a long time. Recently, however, the ecosystem destruction and environmental pollution has been caused by abuse of pesticides. In addition, resistant pests have emerged by repeated use of the same mode of pesticides (Cho *et al*., 2, Song *et al*., 23). Therefore, in recent years to overcome pesticide resistance, studies have focused on plant extracts and organic emulsifiers that do not significantly affect the environment and show low toxicity to natural enemies and wide spectrums of pest control (Choi *et al*., 3, Hwang *et al*., 5, Kim *et al*., 9, Kwak *et al*., 11, Park *et al*., 19, Park *et al*., 20).

Studies on the antimicrobial activity were performed in medicinal plants used in folk medicine

*Corresponding author's E-mail: yikuk@sunchon.ac.kr

**Department of Plant Medicine, Sunchon National University, Suncheon 540-742, Republic of Korea.

***Department of Floriculture, Catholic University of Daegu, Daegu, Republic of Korea

(Maregesi *et al*., 14, Paik *et al*., 17). In particular, medicinal plant extracts are wildly used as antimicrobial agents in medicine and food fields, and the antimicrobial effects of the pathogen to cause disease in plants have also been reported often (Kim *et al*., 10, Kwon *et al*., 13, Yoon *et al*., 25). Park *et al*. (18) reported on the highest bacterial effect against various plant pathogens including *Rhizoctonia solani* in *Hovenia dulcis* Thunb. extract among methanol extraction of 118 plant species. Antifungal activity on pepper anthracnose by a major component (1.0 mg urushiol/mL PDA) of *Rhus verniciflua* Stokes showed 18.3-39.5% (Song *et al*., 24). Mixtures of plant-derived extracts with bordeaux mixture, soapy water, a mixture of lime sulfur, sulfur, ethyl alcohol, paraffin, and vinegar have been used in organic farming (RDA, 21). Vinegar treatment has been reported on growth increase and disease control in peas and sweet silage (Daly and Stewart, 4). Oils are important organic materials that are used to control potato and rose pests in the United States and Australia (Nicetic *et al*., 15, 16). Choi *et al*. (3) reported that thyme oil among 43 plant oils had a high fungicidal activity against pepper anthracnose.

The objective of this research was to determine suppression rate on *Colletotrichum coccodes* by using plant extracts from different extraction methods (water, boiling water, fermentation, and ethanol) from various plant parts (leaves, stems, fruits, and roots) in 47 species from 27 families. Suppression rate on *Colletotrichum coccodes* was also determined by using mixers of various plant extracts and organic emulsifiers. Finally, we determined controlling effect on *Colletotrichum coccodes* and leaf injury in persimmon trees by using selected plant extracts and organic emulsifiers.

MATERIALS AND METHODS

Of the 47 plant species used for this study. Some species of these plant species were collected directly in fields and other plant species were purchased from Chonnam Hanyaknonghyup Cooperation. Specific information on the plant species is given in Table 1.

Leaves, stems, roots, and barks of 47 plant species shown in Table 1 were dried and grinded; extraction methods were water, boiling water, ethanol, and fermentation used for this study. Fifty grams of each plant species were grinded and put in 1,000 ml distilled water for 24 h for water extract and put in 1000 ml ethanol instead of distilled water for 24 h for ethanol extract. In addition, 50 g of each grinded plant species were put in 1,000 ml distilled water and boiled at 100°C for 30 min for boiling water extract, but put in 1,000 ml distilled water and stored at room temperature for 20 days for fermentation extract. Each extract was concentrated under reduced pressure and the pellet was completely evaporated using a vacuum dryer (Hanbaek Scientific Co. Korea). Each extract was dissolved in distilled water to ensure that the final concentration was at 50% and was diluted with distilled water to attain 0, 1, 3, and 5% concentrations for experiment on inhibition rates of *Colletotrichum coccodes*. Ten ml of 0, 0.5, 1 and 3% of the extracts were added to potato dextrose agar (PDA) media in Petri dishes (90 mm). After solidification, a mycelia

Table 1. Suppression rate of *Colletotrichum coccodes* by various plant extracts in laboratory test (3 days after treatment).

Plant species	Plant part	Extraction method	Suppression rate (%)		
			Extract concentration (%)		
			0.5	1	3
Control			0.0	0.0	0.0
Cirsium japonicum var. maackii (Maxim.) Matsum.	Root	Ethanol	0.0	0.0	0.0
		Boiled water	0.0	0.0	0.0
		Fermentation	2.6	2.6	10.7
		Water	0.0	0.0	0.0
Polymnia sonchifolia Poepp. & Endl.	Leaf	Ethanol	0.0	0.0	16.0
		Boiled water	0.0	0.0	0.0
		Fermentation	0.0	2.4	10.5
		Water	0.0	0.0	0.0
	Root	Ethanol	0.0	0.0	6.7
		Boiled water	1.9	1.9	4.2
		Fermentation	0.0	2.1	0.0
		Water	0.0	0.0	0.0

Plant species	Plant part	Extraction method	Suppression rate (%)		
			Extract concentration (%)		
			0.5	1	3
Artemisia princeps Pomp. Hara	All parts of above ground	Ethanol	7.1	7.1	16.7
		Boiled water	0.0	0.0	0.0
		Fermentation	5.3	18.8	16.7
		Water	2.2	6.7	13.3
Chrysanthemum zawadskii Herb. *var. latilobum* (Maxim.) Kitamura	All parts of above ground	Ethanol	0.0	0.0	11.9
		Boiled water	4.2	4.2	8.3
		Fermentation	2.2	7.0	9.5
		Water	0.0	0.0	10.3
Xanthium strumarium L.	Fruit	Ethanol	0.0	0.0	0.0
		Boiled water	0.0	0.0	0.0
		Fermentation	2.4	15.8	50.0
		Water	2.1	4.3	6.7
Eclipta prostrata L.	All parts of above ground	Ethanol	0.0	0.0	0.0
		Boiled water	0.0	0.0	0.0
		Fermentation	0.0	0.0	2.4
		Water	0.0	0.0	2.2
Conyza canadensis L.	All parts of above ground	Ethanol	0.0	0.0	0.0
		Boiled water	0.0	0.0	0.0
		Fermentation	2.2	6.8	7.1
		Water	0.0	0.0	0.0
Helianthus tuberosus L.	Bulb	Ethanol	0.0	0.0	0.0
		Boiled water	0.0	0.0	0.0
		Fermentation	6.1	30.3	60.6
		Water	0.0	2.2	4.6
Lactuca indica var. laciniata	All parts of above ground	Ethanol	0.0	0.0	2.4
		Boiled water	0.0	0.0	0.0
		Fermentation	4.8	12.1	63.4
		Water	0.0	0.0	0.0
Erigeron annuus (L.) Pers.	All parts of above ground	Ethanol	3.7	7.4	7.4
		Boiled water	0.0	0.0	0.0
		Fermentation	9.2	16.2	65.1
		Water	0.0	0.0	0.0
Petasites japonicus (Siebold & Zucc.) Maxim.	Leaf	Ethanol	0.0	0.0	0.0
		Boiled water	0.0	0.0	0.0
		Fermentation	2.2	4.4	30.2
		Water	2.4	2.4	2.4
	Stem	Ethanol	7.4	19.0	22.2
		Boiled water	0.0	0.0	0.0
		Fermentation	4.4	6.8	7.0
		Water	5.1	10.3	15.4
Chrysanthemum cinerariaefolium (Trev.) Vis.	Leaf	Ethanol	0.0	0.0	0.0
	Seed	Ethanol	2.4	7.1	4.8

Plant species	Plant part	Extraction method	Suppression rate (%)		
			Extract concentration (%)		
			0.5	1	3
Taraxacum platycarpum Dahlst	All parts of above ground	Ethanol	0.0	0.0	0.0
		Boiled water	0.0	0.0	0.0
		Fermentation	0.0	0.0	22.7
		Water	0.0	0.	7.3
Salvia miltiorrhiza Bunge	Root	Ethanol	7.3	7.3	20.0
		Boiled water	0.0	4.2	4.2
		Fermentation	2.4	2.4	19.8
		Water	0.0	0.0	0.0
Leonurus japonicus Houtt.	All parts of above ground	Ethanol	2.4	4.8	4.8
		Boiled water	0.0	0.0	0.0
		Fermentation	0.0	0.0	16.0
		Water	0.0	0.0	0.0
Mentha arvensis L.	All parts of above ground	Ethanol	4.9	9.9	17.4
		Boiled water	0.0	0.0	0.0
		Fermentation	4.4	6.7	15.6
		Water	0.0	2.1	15.1
Angelica gigas N.	Root	Ethanol	4.9	9.9	12.3
		Boiled water	0.0	0.0	2.2
		Fermentation	4.9	9.9	19.8
		Water	2.2	4.4	6.7
Torilis japonica (Houtt.) DC.	Root	Ethanol	3.2	7.4	23.1
		Boiled water	0.0	0.0	0.0
		Fermentation	15.2	45.5	81.8
		Water	2.2	4.4	6.7
Angelica dahurica (Fischer) Bentham et Hooker F.	Root	Ethanol	0.0	7.4	22.7
		Boiled water	0.0	0.0	0.0
		Fermentation	0.0	0.0	0.0
		Water	0.0	0.0	4.4
Rheum palmatum L.	Root	Ethanol	19.4	50.0	69.4
		Boiled water	0.0	0.0	2.2
		Fermentation	0.0	5.8	36.9
		Water	2.1	15.1	41.3
Rumex crispus L.	All parts of above ground	Ethanol	0.0	0.0	0.0
		Boiled water	0.0	0.0	2.2
		Fermentation	0.0	0.0	0.0
		Water	0.0	0.0	2.2
Aleurites fordii (Hemsl.) Airy Shaw	Leaf	Ethanol	0.0	0.0	0.0
		Boiled water	0.0	0.0	0.0
		Fermentation	0.0	0.0	2.6
		Water	0.0	0.0	2.4
	Stem	Ethanol	2.8	5.6	8.3
		Boiled water	0.0	0.0	0.0
		Fermentation	0.0	12.1	33.3
		Water	2.6	7.7	5.1

Plant species	Plant part	Extraction method	Suppression rate (%)		
			Extract concentration (%)		
			0.5	1	3
Ricinus communis L.	All parts of above ground	Ethanol	0.0	4.8	4.9
		Boiled water	0.0	0.0	0.0
		Fermentation	2.2	2.2	2.2
		Water	0.0	0.0	0.0
Sophora flavescens Ait	Root	Ethanol	0.0	0.0	9.5
		Boiled water	0.0	0.0	0.0
		Fermentation	0.0	4.6	9.2
		Water	2.2	2.2	7.1
Astragalus membranaceus Bunge	Root	Ethanol	0.0	0.0	0.0
		Boiled water	0.0	0.0	0.0
		Fermentation	2.2	2.2	13.8
		Water	0.0	0.0	7.7
Camellia japonica L.	Leaf	Ethanol	0.0	0.0	0.0
		Boiled water	0.0	0.0	2.2
		Fermentation	2.2	2.2	4.4
		Water	0.0	0.0	0.0
	Stem	Ethanol	2.8	8.3	13.9
		Boiled water	0.0	0.0	0.0
		Fermentation	2.2	6.8	13.8
		Water	0.0	2.4	7.1
Camellia spp.	Leaf	Ethanol	5.6	0.0	33.3
		Boiled water	0.0	0.0	0.0
		Fermentation	0.0	0.0	5.8
		Water	0.0	0.0	2.2
	Stem	Ethanol	5.6	8.3	11.1
		Boiled water	0.0	0.0	2.2
		Fermentation	2.2	2.2	2.2
		Water	0.0	2.4	7.1
Portulaca oleracea L.	All parts of above ground	Ethanol	0.0	2.4	7.5
		Boiled water	0.0	0.0	0.0
		Fermentation	10.5	23.7	68.4
		Water	0.0	0.0	0.0
Acorus gramineus Sol.	All parts of above ground	Ethanol	0.0	7.0	37.8
		Boiled water	6.3	6.4	16.9
		Fermentation	0.0	0.0	4.4
		Water	0.0	0.0	0.0
Rehmannia glutinosa var. *purpurea* (Makino) Makino & Nemoto	Root	Ethanol	0.0	0.0	0.0
		Boiled water	0.0	0.0	0.0
		Fermentation	0.0	2.6	10.7
		Water	0.0	0.0	2.2
Chelidonium majus var. asiaticum Ohwi	All parts of above ground	Ethanol	0.0	0.0	2.8
		Boiled water	0.0	0.0	2.2
		Fermentation	20.8	30.2	65.1
		Water	2.2	2.2	4.4

Plant species	Plant part	Extraction method	Suppression rate (%)		
			Extract concentration (%)		
			0.5	1	3
Stemona japonica (Bl.) Miq.	Root	Ethanol	4.9	9.9	19.0
		Boiled water	0.0	0.0	0.0
		Fermentation	0.0	2.2	13.8
		Water	0.0	5.1	20.5
Cyperus rotundus L.	Fruit	Ethanol	4.8	7.1	11.9
		Boiled water	0.	0.0	0.0
		Fermentation	6.7	6.7	8.9
		Water	0.0	0.0	0.0
Cnidium officinale Makino	Root	Ethanol	4.8	7.3	29.9
		Boiled water	4.2	4.2	6.3
		Fermentation	2.4	2.4	20.0
		Water	0.0	4.4	4.4
Coptis japonica (Thunb.) Makino	Root	Ethanol	6.8	6.8	28.3
		Boiled water	2.2	11.1	53.3
		Fermentation	5.3	34.2	52.8
		Water	20.3	29.5	49.8
Melia azedarach L.	Fruit	Ethanol	0.0	0.0	2.2
		Boiled water	0.0	0.0	0.0
		Fermentation	6.7	8.9	13.3
		Water	8.6	13.1	17.2
Plantago asiatica L.	All parts of above ground	Ethanol	0.0	0.0	0.0
		Boiled water	0.0	0.0	0.0
		Fermentation	8.9	22.2	64.4
		Water	0.0	0.0	6.7
Geranium thunbergii Siebold & Zucc.	All parts of above ground	Ethanol	0.0	0.0	0.0
		Boiled water	0.0	0.0	0.0
		Fermentation	10.7	18.8	48.5
		Water	0.0	0.0	0.0
Curcuma longa L.	Root	Ethanol	0.0	0.0	2.8
		Boiled water	0.0	0.0	0.0
		Fermentation	0.0	6.1	9.1
		Water	2.2	8.9	11.1
Cinnamomum cassia Blume	Bark	Ethanol	0.0	23.8	66.7
		Boiled water	0.0	0.0	0.0
		Fermentation	0.0	0.0	0.0
		Water	0.0	0.0	0.0
Chenopodium album L. *var. centrorubrum* Makino	All parts of above ground	Ethanol	0.0	2.4	7.1
		Boiled water	0.0	0.0	0.0
		Fermentation	0.0	0.0	0.0
		Water	0.0	4.4	4.4
Thuja orientalis L.	Leaf	Ethanol	0.0	0.0	0.0
		Boiled water	0.0	0.0	0.0
		Fermentation	2.4	10.5	15.4
		Water	0.0	0.0	0.0

Plant species	Plant part	Extraction method	Suppression rate (%)		
			Extract concentration (%)		
			0.5	1	3
	Stem	Ethanol	2.8	8.3	13.9
		Boiled water	0.0	0.0	0.0
		Fermentation	0.0	2.4	4.8
		Water	5.1	7.7	7.7
Pittosporum tobira (Thunb.) Ait.	Leaf	Ethanol	0.0	0.0	2.4
		Boiled water	0.0	0.0	0.0
		Fermentation	2.6	10.5	13.0
		Water	4.8	4.8	4.8
	Stem	Ethanol	5.6	8.3	16.7
		Boiled water	0.0	0.0	0.0
		Fermentation	9.2	9.2	9.5
		Water	0.0	0.0	0.0
Styrax japonicus Sieb. et Zucc.	Leaf	Ethanol	0.0	5.6	19.4
		Boiled water	0.0	0.0	0.0
		Fermentation	5.1	7.7	15.6
		Water	6.8	6.8	23.2
	Stem	Ethanol	0.0	0.0	2.2
		Boiled water	0.0	0.0	0.0
		Fermentation	2.4	4.8	4.8
		Water	0.0	0.0	0.0
Nerium indicum MILL	All parts of above ground	Ethanol	4.8	4.8	4.8
		Boiled water	0.0	0.0	0.0
		Fermentation	5.6	11.4	34.3
		Water	0.0	0.0	0.0
Houttuynia cordata Thunb.	All parts of above ground	Ethanol	2.8	13.9	13.9
		Boiled water	0.0	0.0	0.0
		Water	0.0	5.6	16.7
Nicotiana tabacum L.	All parts of above ground	Boiled water	0.0	0.0	0.0

plug (10 mm diameter) of *Colletotrichum coccodes* was placed in the center of the Petri dishes and incubated at 26°C in darkness (Jang *et al*., 6). Three-day-old cultures of the test fungus grown on PDA medium were used for bioassays. Radial mycelia growth of the test fungus was recorded at 3 days after treatment. The suppression activity was calculated using colony diameter growth of treated plates compared to control plates (PDA medium without extract).

Four plant extracts, fermentation extracts of *Torilis japonica* (Houtt.) DC. and *Portulaca oleracea* L., and ethanol extracts of *Rheum palmatum* L. and *Cinnamomum cassia* Blume were selected based on inhibition rates on anthracnose from experiments on inhibition effects of anthracnose by plant parts and extraction methods in various plant species. Inhibition effect of anthracnose was determined by the selected plant extracts at 0, 0.1, 0.3, 0.5, 1, 3, 5, and 10% concentrations. Other procedures were as described in the above experiment.

To determine inhibition level of anthracnose by various organic emulsifiers, we used natural emulsifier-A or B, loess sulphur, brown rice vinegar, and powder soap. The organic emulsifiers used in this study are approved for use in organic farming by the Rural Development Administration Guideline in Korea. The detailed information of organic emulsifiers on manufacturing procedures was described in the previous study (Jang *et al*., 6). Inhibition effect of

anthracnose by the organic emulsifiers at 0, 0.05, 0.1, 0.5, 1, 3, and 5% was carried out the same as the above experiment on inhibition effect of anthracnose by plant parts and extraction methods in various plant species.

In addition, plant extracts (fermentation extracts of *Torilis japonica* (Houtt.) DC. and *Portulaca oleracea* L., and ethanol extracts of *Rheum palmatum* L. and *Cinnamomum cassia* Blume at 1% concentration) and organic emulsifiers (natural emulsifier-A at 1.0%, natural emulsifier-B at 0.1%, loess sulfur at 0.1%, brown rice vinegar at 0.1%, and powder soap at 0.1%) alone or with combination were used for inhibition effect of anthracnose. Other procedures were the same as described in the previous section.

The selected plant extracts, fermentation extract of *Torilis japonica* (Houtt.) DC. and ethanol extract of *Rheum palmatum* L. at 5% concentration alone or combination with natural emulsifier-B at 1%, or loess sulfur at 0.1% were sprayed on leaves of persimmon tree infected anthracnose at organic cultivation fields in Suncheon, South Korea (latitude 34° 57' and longitude 127° 29') and then evaluated controlling effect at 7 days after treatment.

Damage (visual rate; 0-100%, 0 = no damage) of persimmon tree leaves (15 years old, cv. Charang) was investigated at 1, 3, 5, and 7 days after treatments of finally selected fermentation extract of *Torilis japonica* (Houtt.) DC. and ethanol extract of *Rheum palmatum* L. at 0, 0.5, 1, 5, and 10%, and organic emulsifiers, natural emulsifier-B, loess sulfur, and powder soap at 0, 0.5, 1, and 5% in Suncheon, South Korea for safety of plant extracts and organic emulsifiers. Data were analyzed using analysis of variance (ANOVA) procedure in the Statistical Analysis Systems (SAS, 22) software. Means were separated using Duncan's multiple range test (*P=0.05*).

RESULTS AND DISCUSSION

Suppression of anthracnose fungus was investigated in water, boiling water, ethanol, and fermentation extracts of leaves, stems, and barks of 48 species (Table 1). Plant species, plant parts, and extraction methods showing 50-80% suppression on anthracnose fungus in plant extracts at 3% concentration among 47 plant species were fermentation extracts of *Xanthium strumarium* L. fruit, *Coptis japonica* (Thunb.) Makino root, *Helianthus tuberosus* L. bulb, *Lactuca indica var. laciniata* all parts above ground, *Portulaca oleracea* L. all parts above ground, *Chelidonium majus* L. *var. asiaticum* Ohwi*.,* all parts above ground, *Plantago asiatica* L. all parts above ground, *Torilis japonica* (Houtt.) DC. root and *Erigeron annuus* (L.) Pers. all parts above ground and ethanol extracts of *Rheum palmatum* L. root and *Cinnamomum cassia* Blume bark. Among extraction methods, fermentation extract was better in suppression of anthracnose than other extracts, water, boiling water, and ethanol. These results mean that the suppression rates of anthracnose were different from plant species, plant parts such as leaves and stems, and extraction methods. In addition, Jang *et al*. (7) reported that suppression rates on rice blast were different from extraction methods and plant parts such as leaves in 20 plant species. Extracts of medicinal herbs and medicinal plants showed antimicrobial effects on pathogens that cause disease in crops (Kim *et al*., 10, Kwon *et al*., 12, Yoon *et al*., 25). For example, the mycelial growth and spore germination of anthracnose were inhibited 18-39% and over 50% in response to crude extract of *Rhus verniciflus* (1.0 mg/mL), respectively (Song *et al*., 24).

We selected 4 plant extracts (fermentation extract of *Torilis japonica* and *Portulaca oleracea,* ethanol extracts of *Rheum palmatum* and *Cinnamomum cassia*) showing higher suppression rate on anthracnose from the experiment in Table 1. Anthracnose fungus was inhibited 100% by extract of *Torilis japonica* at 10% concentration and inhibited over 80% by other extracts, *Portulaca oleracea,* ethanol extracts of *Rheum palmatum* and *Cinnamomum cassia* (Table 2). The order of inhibition rates on anthracnose was *Torilis japonica* > *Rheum palmatum* > *Portulaca oleracea* > *Cinnamomum cassia.*

Natural emulsifier-A or natural emulsifier-B, loess sulfur, brown rice vinegar, and powder soap at 0, 0.05, 0.1, 0.5, 1, 3, and 5% were treated to determine suppression rate of anthracnose (Table 3). Anthracnose fungus was completely suppressed by brown rice vinegar and powder soap at 3%, and loess sulfur and natural emulsifier-B at 5%. In addition, anthracnose was inhibited 73-88% by natural emulsifier-B, loess sulfur, brown rice vinegar, and powder soap at 1% except for natural emulsifier-A. The order of inhibition level on anthracnose by organic emulsifiers was natural emulsifier-B > loess sulfur > powder soap > brown rice vinegar > natural emulsifier-A. Choi *et al*. (3) reported that thyme oil among 43 plant oils had a higher fungicidal activity on anthracnose fungus. The result was similar to emulsifier-A containing canola oil used in our study. The significant inhibition effects on spore formation of anthracnose fungus were shown in vitro with a water dispersible pesticide containing sulfur [BTB (100%)] (Kwak *et al*., 11). Similar to this result, anthracnose fungus was inhibited 100% by loess sulfur at 5% in our study. To increase the effect of plant extracts on suppression of anthracnose fungus, we used plant extracts and organic emulsifier mixtures (Table 4). Synergism on suppression of anthracnose fungus by the selected plant extracts and organic emulsifier mixtures did not appear or show antagonism

Table 2. Suppression rate of *Colletotrichum coccodes* by selected plant extracts in laboratory test (3 days after treatment).

Plant species	Plant part	Extraction method	Suppression rate (%)						
			Extract concentration (%)						
			0.1%	0.3%	0.5%	1%	3%	5%	10%
Control			0.0^{b}	0.0^{c}	0.0^{b}	0.0^{c}	0.0^{b}	0.0^{c}	0.0^{c}
TJ	Root	Fermentation	5.3^{a}	10.9^{a}	16.2^{a}	43.2^{a}	75.9^{a}	86.5^{a}	100.0^{a}
RP	Root	Ethanol	0.0^{b}	8.1^{ab}	18.8^{a}	48.7^{a}	67.5^{a}	72.9^{b}	89.1^{b}
PO	All parts of above ground	Fermentation	0.0^{b}	5.3^{ab}	13.5^{a}	22.0^{b}	73.1^{a}	77.7^{ab}	83.8^{b}
CC	Bark	Ethanol	0.0^{b}	2.6^{b}	2.6^{b}	21.4^{b}	67.5^{a}	70.3^{b}	86.3^{b}

TJ - *Torilis japonica*, RP - *Rheum palmatum*, PO - *Portulaca oleracea*, CC - *Cinnamomum cassia*
Means within a column followed by the same letters are not significantly different at 5% level (Duncan's Multiple Range test).

Table 3. Effect of various organic emulsifiers on suppression of *Colletotrichum coccodes* in laboratory test (3 days after treatment).

Emulsifiers	Suppression rate (%)					
	Extract concentration (%)					
	0.05%	0.1%	0.5%	1%	3%	5%
Control	0.0^{d}	0.0^{c}	0.0^{d}	0.0^{c}	0.0^{c}	0.0^{c}
Natural emulsifier-A	0.0^{d}	0.0^{c}	9.0^{d}	18.8^{b}	30.5^{b}	57.0^{b}
Natural emulsifier-B	32.8^{a}	83.4^{a}	85.7^{a}	87.9^{a}	92.8^{a}	100.0^{a}
Loess sulfur	18.6^{b}	32.9^{b}	64.2^{b}	87.9^{a}	97.8^{a}	100.0^{a}
Brown rice vinegar	0.0^{d}	11.4^{c}	37.9^{c}	80.7^{a}	100.0^{a}	100.0^{a}
Powder soap	8.7^{c}	25.9^{b}	68.9^{b}	73.4^{a}	100.0^{a}	100.0^{a}

Means within a column followed by the same letters are not significantly different at 5% level according to (Duncan's Multiple Range Test).

in several treatments. However, synergistic effects on suppression of rice blast by several plant extracts and organic emulsifier mixtures appeared (Jang *et al*., 7). These result means that synergistic effects may be different with different kinds of pathogens, plant extracts, and organic emulsifiers.

Anthracnose was reduced 63% and 51% by fermentation extract of *Torilis japonica* at 5% and ethanol extracts of *Rheum palmatum* at 5% alone treatment, respectively compared with untreated control in organic cultivation (Fig. 1). However, anthracnose was reduced 79.2% and 67.3% by fermentation extract of *Torilis japonica* at 5% + natural emulsifier-B at 1% and fermentation extract of *Torilis japonica* at 5% + loess sulfur at 1%, respectively compared with untreated control. In addition, anthracnose was reduced 62.7% and 55.7% by ethanol extract of *Rheum palmatum* at 5% + natural emulsifier-B at 1% and ethanol extract of *Rheum palmatum* at 5% + loess sulfur at 1%, respectively compared with untreated control. Synergistic effects on plant extract and organic emulsifier mixtures did also not appear under organic cultivation field conditions. Thus, we need plant extracts or organic emulsifiers alone treatment with higher concentration (10% for plant extracts and 5% for organic emulsifiers) for control of anthracnose in organic cultivation.

Fermentation extract of *Torilis japonica* and ethanol extract of *Rheum palmatum* at 0, 0.5,

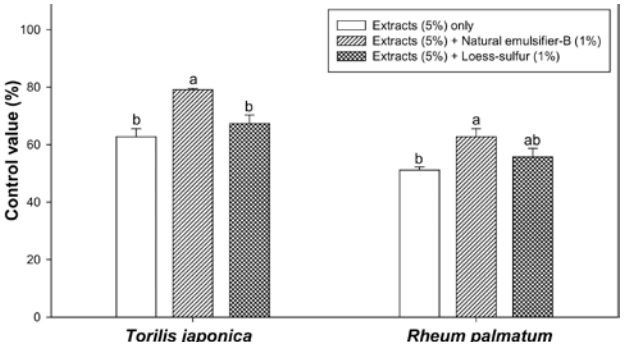

Fig. 1. Effect of plant extracts and emulsifiers on control values in *Colletotrichum coccodes* infected organic field grown persimmon trees (cv. Charang). Parameter was recorded at 7 days after treatment. Means on the bar followed by the same letters are not significantly different at 5% level (Duncan's Multiple Range Test).

Table 4. Effect of plant extracts and emulsifiers on suppression of *Colletotrichum coccodes* (3 days after treatment).

Treatment	Emulsifiers (%)	Suppression rate (%)				Emulsifiers (alone)
		Extract concentration (%)				
		TJ (1.0%)*	RP (1.0%)	PC (1.0%)	CC (1.0%)	
Plant extracts + Emulsifiers (mixed)	Natural emulsifier-A (1.0)	48.6^{b}	37.6^{a}	28.6^{a}	22.3^{a}	12.5^{a}
	Natural emulsifier-B (0.1)	49.2^{b}	43.6^{a}	43.5^{b}	38.6^{b}	75.2^{d}
	Loess sulfur (0.1)	43.2^{b}	38.6^{a}	38.4^{ab}	21.4^{a}	38.8^{c}
	Brown rice vinegar (0.1)	49.8^{b}	48.3^{b}	30.7^{a}	24.5^{a}	12.5^{a}
	Powder soap (0.1)	38.6^{a}	42.8^{a}	42.7^{b}	26.4^{a}	22.8^{b}
Plant extracts (alone)		38.5^{a}	42.2^{a}	34.0^{a}	19.5^{a}	

TJ = *Torilis japonica,* RP = *Rheum palmatum,* PC = *Portula caoleracea*, CC = *Cinnamomum cassia ;* Means within a column followed by the same letters are not significantly different at 5% level (Duncan's and Multiple Range Test).

1, 5, and 10%, and natural emulsifier-B, loess sulfur, and powder soap at 0, 0.5, and 5% were sprayed on persimmon tree leaves, and injury of leaves was investigated at 1, 3, 5, and 7 days after treatment (Table 5). Leaf injuries of persimmon tree by the above extracts and organic emulsifier had no significant difference between treated plots and untreated plots. Thus, the selected plant extracts and organic emulsifiers can be used in organic persimmon tree cultivation because they showed higher controlling effect on anthracnose without leaf injury of persimmon.

Table 5. Effect of selected plant extracts and emulsifiers on leaf injury in persimmon trees (cv. Charang).

Plant species/ Emulsifiers	Plant part	Extraction method	Extract conc. (%)	Leaf injury (%)			
				1 DAT	3 DAT	5 DAT	7 DAT
Control				0.0	0.0	0.0	0.0
TJ	Root	Fermentation	0.5	0.0	0.0	0.0	0.0
			1	0.0	0.0	0.0	0.0
			5	0.0	0.0	0.0	0.0
			10	0.0	0.0	0.0	0.0
RP	Root	Ethanol	0.5	0.0	0.0	0.0	0.0
			1	0.0	0.0	0.0	0.0
			5	0.0	0.0	0.0	0.0
			10	0.0	0.0	0.0	0.0
Natural emulsifier-B	-	-	0.5	0.0	0.0	0.0	0.0
			1	0.0	0.0	0.0	1.7
			5	0.0	0.0	0.0	0.0
Loess sulfur	-	-	0.5	0.0	0.0	0.0	0.0
			1	0.0	0.0	0.0	0.0
			5	0.0	0.0	0.0	0.0
Powder soap	-	-	0.5	0.0	0.0	0.0	1.7
			1	0.0	0.0	0.0	0.0
			5	0.0	0.0	0.0	1.7

DAT = days after treatment, TJ = *Torilis japonica,* RP = *Rheum palmatum*

ACKNOWLEDGEMENTS

This work was carried out with the support of "Cooperative Research Program for Agriculture Science & Technology Development (Project No. PJ008423), Rural Development Administration, Republic of Korea.

REFERENCES

1. Agrios, G.N. 2005. *Plant Pathology* (5th Edn.), Elsevier Academic Press, USA, 23 p.

2. Cho, J.R., Kim, Y.J., Ahn, Y.J., Yoo, J.K. and Lee, J.O. 1995. Monitoring of acaricide resistance in field-collected populations of *Tetranychus urticae* (Acari: Tetranychidae) in Korea. *Korean J. Appl. Entom*. **34**: 40-45.

3. Choi, K.J., Kim, J.C., Jang, K.S., Lim, H.K., Park, I.K., Shin, S.C. and Cho, K.Y. 2006. *In vivo* antifungal activities of 67 plant fruit extracts against six plant pathogenic fungi. *J. Microbiol. Biotech.* **16**: 491-95.

4. Daly, M.J. and Stewart, D.P.C. 1999. Influence of "effective microorganism" (EM) on vegetable production and carbon mineralization-a preliminary investigation. *J. Sustain Agric.* **14**: 15-25.

5. Hwang, I.C., Kim, J., Kim, H.M., Kim, D.I., Kim, S.G., Kim, S.S. and Jang, C. 2009. Evaluation of toxicity of plant extract made by neem and matrine against main pests and natural enemies. *Korean J. Appl. Entomol*. **48**: 87-94.

6. Jang, S.J., Jung, H.I., Yun, Y.B., Hyun, K.H., Kim, D.I., Mallory-Smith, C. and Kuk, Y.I. 2015. Use of emulsifiers for control of rice blast sheath blight in organic rice cultivation. *J. Food Agric. Env*. **13**: 213-17.

7. Jang, S.J., Yun, Y.B., Shin, D.Y., Hyun, K.H., Kim, S.S. and Kuk, Y.I. 2016. Effect of various plant extracts and organic emulsifiers on control of rice blast (*Pyricularia oryzae*). J. Food, Agriculture & Environment. **14**: 104-110.

8. Jeon, H.Y. and Kim, H.H. 2006. Damage and seasonal occurrence of major insect pests by cropping period in environmentally friendly lettuce greenhouse. *Korean J. Appl. Entomol.* **45**: 275-82.

9. Kim, S.K., Jin, J.H., Lim, C.K., Hur, J.H. and Cho, S.Y. 2009. Evaluation of insecticidal efficacy of plant extracts against major insect pests. *Korean J. Pesticide Sci.* **13**: 165-70.

10. Kim, J.Y., Yoon, W.J., Yim, E.Y., Park, S.Y., Kim, Y.J. and Song, G.P. 2011. Antioxidative and antimicrobial activities of *Castanopsis cuspidata* var. sieboldii extracts. *Korean J. Plant Res.* **24**: 200-07.

11. Kwak, Y.G., Kim, I.S., Cho, M.C., Lee, S.C. and Kim, S. 2012. Growth inhibition effect of environment-friendly farm materials in *Colletotrichum acutatum in vitro*. *J. Biol. Env. Control*. **21**: 127-33.

12. Kwon, C.S. and Lee, S.G. 2002. Occurrence and ecological characteristics of red pepper anthracnose. *Res. Plant Dis*. **8**: 120-23.

13. Kwon, S.B., Lee, H.Y., Kim, B.S. and Choi, J.K. 2010. Inhibitory effect of extracts from 33 medicinal herbs against TMV and CMV infection. *Korean J. Pesticide Sci.* **14**: 280-83.

14. Maregesi, S.M., Pieters, L., Ngassapa, O.D., Apers ,S., Vingerhoetsr, P., Cos, P., Berghe, D.A. and Vlietinck, A.J. 2008. Screening of some Tanzanian medicinal plants from Bunda district for antibacteral, antifungal and antiviral activities. *J. Ethnopharmacol.* **119**: 58-66.

15. Nicetic, O., Watson, D.M., Beattie, G.A.C., Meats, A. and Zheng, J. 2001. Integrated pest management of two-spotted mite *Tetranychus urticae* on greenhouse roses using petroleum spray oil and predatory mite *phytoseiulus persimilis*. *Exp. Appl. Acarol*. **25**: 67-53.

16. Nicetic, O., Watson, D.M. and Beattie, G.A.C. 2002. A horticultural mineral oil-based program for control of two-spotted mite and powdery mildew on roses in greenhouses. In: Beattie GAC, Watson DM, Stevens ML, Rae DJ, Spooner-Hart RN (eds) Spray Oils Beyond 2000. University of Western Sydney, pp. 387-95.

17. Paik, S.B., Chung, I.M. and Doh, E.S. 1998. Screening of medicinal plants with antifungal activity on major seedborne disease. *Korean J. Medicinal Crop Sci.* **6**: 277-85.

18. Park, I.K., Lee, S.G., Park, J.D., Shin, S.C. and Ahn, Y.J. 2003. Fungicidal activity of domestic plant extracts against six major phytopathogenic fungi. *Korean J. Pesticide Sci.* **7**: 83-91.

19. Park, J.H., Ryu, K.Y., Lee, B.M. and Ji, H.J. 2008. Effect of COY (cooking oil and yolk mixture) on control of *Tetranychus urticae*. *Korean J. Appl. Entomol*. **47**: 249-54.

20. Park, S.J., Kim, K.H., Kim, A.H., Lee, H.T., Gwon, H.W., Kim, J.H., Lee, K.H. and Kim, H.T. 2012. Controlling effect of agricultural organic materials on phytophthora blight and anthracnose in red pepper. *Res. Plant Dis.* **18**: 1-9.

21. RDA, National Academy of Agricultural Science. 2008. 293 p.

22. Statistical Analysis System. 2000. SAS/STAT Users Guide, Version 7. Cary, NC : Statistical Analysis System Institute, Electronic Version.

23. Song, C., Kim, G.H., Ahn, S.J., Park, N.J. and Cho, K.Y. 1995. Acaricide susceptibilities of field-collected populations of two-spotted spider mite, *Tetranychus urticae* from apple orchards. *Korean J. Appl. Entomol.* **34**: 328-33.

24. Song, C.H., Chung, J.B., Jeong, B.R., Park, S.Y. and Lee, Y.S. 2012. Antifungal activity of crude extract compound from *Rhus verniciflua* against anthracnose fungi (*Collectotrichum* spp.) of red-pepper. *Korean J. Env. Agric.* **31**: 60-67.

25. Yoon, M.Y., Kim, Y.S., Choi, G.J., Jang, K.S., Choi, Y.H., Cha, B.J. and Kim, J.C. 2011. Antifungal activity of decursinol angelate isolated from *Angelica gigas* roots against *Puccinia recondita*. Res. *Plant Dis*. **17**: 25-31.

Received : April, 2016; Revised : February, 2018;
Accepted : August, 2018