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Effect of Agricultural Organic Materials Using Sulfur and Oil on Insect Control in Pepper and Tomato

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오일제제, 유황제제를 활용한 고추, 토마토 해충방제 효과

남춘우 · 조영상 · 문희자 · 안세웅 · 서태철 · 전희

This experiment was carried out to determine the optimal concentration of agricultural organic materials using sulfur and oil for the insect pest control in pepper and cherry tomato cultivation. The control value of aphids and Oriental tobacco budworm (OTB) was examined one day after spraying with sulfur preparation (SP) (0.33~0.17%), oil preparations (OP) (2.00~0.33%), SP+OP, OP+ginkgo leaf extracts (GLE), SP+OP+GLE on the “Super Manidaa”pepper. The aphid control in pepper was complete by applications of SP+OP (0.25+1.00%) in the early growth stage and the control value was above 98.1% by the application of OP+GLE (1.00+1.00 %), SP+OP+GLE (0.25+1.0+1%), SP+OP+GLE (0.25+1.0+0.5%) in the middle to late growth stage while showing 0% in the control treatment. The OTB was completely controlled by the 3 times application with the high concentration of SP+OP (0.25+1.00%) in pepper cultivation. This result indicates that the oil and the sulfur preparations should be applied at low concentration before insect pests do not appeared, and then sprayed at the high concentration after they appear at pepper plant. The greenhouse whitefly in ‘Minichal’ tomatoes was completely controlled by three times application of SP (0.25~0.33), OP (1.0~2.00%). and all the treatment of SP+OP. However, continuous control with intervals of 1~3 days was considered favorable in the tomato plant. By the periodical control with agricultural organic materials using sulfur and oil, the greenhouse whitefly, which is a high-temperature insect pest, several moths of OTB did not occur at all. In

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conclusion, SP+OP (0.17%+0.33%) treatment was the most economical combination to control the aphid, OTB, and greenhouse whitefly in pepper and tomato cultivation when considering operating cost. In addition, we recommend that SP should not be sprayed on the plant shoots during the day time from July to August because of high temperature.

Key words : *agricultural organic materials, insect control, sulfur, pepper, tomato*

Ⅰ. Introduction

Korea has entered the status of free trade agreements with agricultural super-powers and strong competitors in the developing world. Operating costs, safety and quality of the product will play important roles in agricultural industry in the future. In terms of operating costs, it costs 6.5 times higher at pepper production in Korea than in China. The cost is 2 to 6 times higher in most crops. Organic farming is being highlighted as a means to enhance the safety of product. However, most organic-certified pesticides only demonstrate 50 to 70 percent of control value of pests which is lower than chemical pesticides. For spreading of organic farming a more effective organic agricultural materials are needed. Sulfur and sulfur derivatives have been traditionally used to control pests, but they had some serious side-effects including damaging steel pipes and plastic. However, a sulfur solution was invented that need not require heating to make sulfur preparations along with oil preparations (Cho, 2012). Their effectiveness has been tested on vegetables, fruits, and many other crops (Jo, 2012). If specific manual for using sulfur and oil can be produced for different crops, pests, and diseases, that will be a significant step forward in the progress of organic farming. Recently, there was a study proving that 0.05% sulfur solution had 70 to 95 percent disease control effect against powdery mildew in tomatoes (Sim et al., 2014). Hong et al. rs (2014) applied microbial pesticide with organic synthesized fungicide diluted twice which demonstrated an effective rate of 70.3-70.9% which was similar to sole application of fungicide. Spraying organic fungicide and organic farm inputs in turns in seven days for two times can reduce the frequency and volume of chemical pesticide application (Hong et al., 2015). Mixing antagonistic microorganisms with fungicide could increase the effectiveness against pepper phytophthora blight (Kim et al., 1991). It was reported that lime-sulfur mixture was most effective against canker in ginseng; red clay-sulfur mixture (dilution 20 to 400) was also effective in proportion to the concentration (Lim et al., 2015). A study revealed that applying sulfur immediately harvest on onions increased carbohydrate, protein, crude ash, fat, and antioxidants like flavonoids (Jo and Surh. 2016). Sulfur preparations

not only has pesticide effect but also contributes to the nutrient level of the produce, urging some to predict that the 21st century will be the era of sulfur.

One of the main tasks of the pepper industry is to enhance its food safety. Oriental tobacco budworm (OTB) is a notorious pest in peppers. In Suwon, this moth is present from late May to early October. There are three climax periods from early June to early September for each generation. Damage starts from early June, peaks in early September. Infestation levels are significantly different each year (Hwang, 1987; Yang et al,. 2004). OTB drills into the pepper fruit, making it difficult to control with chemical pesticides. Damaged fruits fall immediately and cannot be marketed. This moth wreaks similar havoc on tomatoes. The high-temperature pests such as OTB, greenhouse whitefly, aphids, mites and so on are rampant in rain-shelter cultivation during hot periods. This study aimed to evaluate the effective concentration of organic farm inputs against the high-temperature pests, namely, OTBs and aphids in peppers, and greenhouse whitefly in tomatoes.

Ⅱ. Materials and methods

<Test 1> Effect of agricultural organic materials using SP and OP on insect control in pepper

Sulfur preparations is made by putting in sulfur (99.9%) 25 kg, NaOH (98%) 20 kg, sea salt 1.5 kg, red clay powder 500g, phyllite powder 500 g in order, adding water 50 L, and stirring with wooden stick in a 100 L heat-resistant plastic (Poly ethylene) container. Ingredients dissolve after about 20 minutes. More water (32 L) is added, stirred, and it is completed. The solution is allowed to sit for 1-3 days to sink the debris. Clear liquid is then transferred to thick-walled plastic containers, sealed, and stored (Jo. 2012).

Oil preparations (Jadam wetting agent) is made by putting in KOH (90%) 3.2 kg, then first water of 2.5 L in a 100 L heat-resistant container, rolling the container to dissolve it. Water has to be soft water. Pour in 18 L of canola oil, use electric drill to mix until it becomes like thin mayonnaise. Shut the lid, let sit for three days, and the substance hardens like butter. Add 20 L of water, use drill to separate all the solids from the wall of the container, and dissolve them. Add 60 L of water, stir with a clean wooden stick occasionally, and dissolving will be complete in 24 hours, producing a transparent liquid (Jo. 2012).

The test was done on pepper variety of “Super Manidda.” Seeds were sown on Mar 25 in Wanju county, transplanted on May 29. We tried to find effective recipe against OTBs and aphids by trying: SP (0.33, 0.25, 0.20, 0.17%), OP (2.00, 1.00, 0.50, 0.33%), SP+OPl (0.33+

2.00, 0.25+1.00, 0.20+0.50, 0.17+0.33%), OP+GLE (1+1%), SP+OP+GLE (0.25+1+1%), SP+OP +GLE (0.25+1+0.50%). They were repeatedly sprayed and the kill-rate for aphids and OTBs was investigated after a day. Triple repetition of randomized block design was used for allocation of test plots.

<Test 2> Effect of agricultural organic materials using SP and OP on insect control in tomato

This test was carried out on the tomato variety "Minichal". Tomato seeds were sown in Wanju district on March 25 and transplanted on May 27. We searched for an effective control method for greenhouse whiteflies that occurred naturally in the test plot. We tested with SP (0.33, 0.25, 0.20, 0.17%), OP (2.00, 1.00, 0.50, 0.33%), SP+OP (0.33+2.00, 0.25+1.00, 0.20+ 0.50, 0.17+0.33%), and investigated its kill-rate after one day. Triple repetition of randomized block design was used for allocation of test plots.

- Concentration damage rate (%) = Number of damaged leaves / total leaves × 100
- Disease rate (%) = Diseased leaves / total leaves × 100
- Kill rate (%) = ((Non-sprayed area pest rate – sprayed area pest rate) / Non-sprayed area pest rate) × 100

Statistical analysis was conducted using SAS software (Ver 9.2, Cary, NC, USA). The results of each parameter in all three applications were subjected to analysis of variance, and treatment means were compared by Duncan's multiple range test (DMRT) at the 5% probability level.

Ⅲ. Results and Discussion

<Test 1> Effect of organic agricultural materials using SP and OP on insect control in pepper

We applied organic pesticide after aphids appeared. In the early stage, the kill-rate was 100% just with 1% of SP (Table 1). The kill-rate was above 90 percent for 0.5 to 0.33% of OP. SP+ OP treatment also showed similar kill-rate to OP, meaning that stronger solution achieved higher kill-rate. In mid-growth stage, kill-rate was 90 percent in strong concentration of higher than 1%. SP+OP also showed similar results. However, OP+GLE showed over 97% kill-rate. Kill-rate was 100% at stronger solution than 1% OP. SP+OP mixture had slightly higher kill-rate. Adding ginkgo extracts also increased the kill-rate slightly. There were previous researches dealing with pesticide soap + 25% palm fatty acid (organic input). This material had over 92% kill-rate for pepper aphids in 50 dilution with two times applications in five days interval. In 100 dilution, with three times applications in five days interval, it had 94% kill-rate (Lee et al., 2002). Egg

yolk oil produced 53.2% kill-rate for aphids, however, when used as Neem oil + egg yolk oil (20 ppm), it had 96.3% kill-rate (Jee et al., 2010). Previous studies mostly demonstrated that kill-rate increased when sprayed more than twice. This research suggests that an effective control of aphids was possible by applying it once in every growth stages of the pepper. Application of SP alone demonstrated 40~77% kill-rate according to its concentration. Although it is lower kill-rate than using oil alone, it still had some effect. The mixing seems to create a synergistic effect (Table 1). Although not shown on the table, the pepper did not reveal any difference in growth according to different sprays, implying that sulfur and oil do not affect the pepper plant growth.

Table 1. The control effect of aphid as affected by organic agricultural materials using sulfur and oil preparation in organic pepper farming

Treatments (sulfur % + oil %)		Control value of aphid (%)		
		Field test (growth stage)		In vitro
		Early	Middle to late	
Control		0d	0d	0d
Sulfur	sulfur 0.33%	50.1c	77.6c	50.0c
	sulfur 0.25	45.3c	68.2c	45.2c
	sulfur 0.20	45.0c	68.3c	45.0c
	sulfur 0.17	40.6c	60.0c	39.5c
Oil	oil 2.0	100a	91.2b	**100a**
	oil 1.0	100a	90.0b	**100a**
	oil 0.50	90.7b	90.0b	90.3b
	oil 0.33	90.2b	90.0b	90.0b
Sulfur+oil	sulfur 0.33+oil 2.0	**100a**	93.4b	**100a**
	sulfur 0.25+oil 1.0	**100a**	92.0b	**100a**
	sulfur 0.20+oil 0.5	90.2b	93.3b	**100a**
	sulfur 0.17+oil 0.33	90.3b	90.0b	98.5b
Oil+ginko leaf extracts	Oil 1.0+GLE 1.0%	-	**98.1a**	**100a**
Sulfur+oil+ginko leaf extracts	sulfur 0.25+oil 1.0+GLE 1.0	-	**99.2a**	**100a**
Sulfur+oil+ginko leaf extracts	sulfur 0.25+oil 1.0+GLE 0.5	-	**97.4a**	**100a**
DMRT 0.05[z]		*	*	*

z : Means separation within columns by Duncan's multiple rage test ($p \leq 0.05$)

In case of OTB, the pest control was complete with three times applications of SP+OP (0.25+1.00%). SP+OP (0.25+1.00%)+GLE also had high kill-rate. However, the precise effect of ginkgo leaves was still unknown. Regular spraying at low concentration of agricultural organic materials is desirable when there were no pest outbreak. Increase of application concentration is more effective and economical (Table 2).

Table 2. The degree of occurrence oriental tobacco budworm (OTB) and control value as affected by organic agricultural materials using sulfur and oil preparation in organic pepper farming

Treatments (sulfur % + oil %)		Degree of occurrence (0-5)[z]			
		Before	Application frequency		
			One	Two	Three
Control		3.0	5.0a	5.0a	5.0a
Sulfur	sulfur 0.33%	3.0	3.3b	3.7b	3.7b
	sulfur 0.25	3.0	3.7b	3.7b	4.0b
	sulfur 0.20	3.0	3.3b	4.7a	4.7a
	sulfur 0.17	3.0	3.3b	4.7a	5.0a
Oil	oil 2.0	3.0	3.3b	3.3b	4.7a
	oil 1.0	3.0	3.7b	3.7b	4.7a
	oil 0.50	3.0	5.0a	5.0a	5.0a
	oil 0.33	3.0	**2.0c**	**1.0e**	5.0a
Sulfur+oil	sulfur 0.33+oil 2.0	3.0	**2.3c**	**1.0e**	**0.0d**
	sulfur 0.25+oil 1.0	3.0	**2.7c**	2.3c	**0.0d**
	sulfur 0.20+oil 0.5	3.0	4.0b	2.7c	1.3c
	sulfur 0.17+oil 0.33	**3.0**	**2.0c**	**1.0e**	1.3c
Oil+ginko leaf extracts	Oil 1.0+GLE 1.0%	**3.0**	**2.3c**	**1.0e**	**0.0d**
Sulfur+oil+ginko leaf extracts	sulfur 0.25+oil 1.0+GLE 1.0	**3.0**	**2.3c**	**1.3e**	**0.0d**
Sulfur+oil+ginko leaf extracts	sulfur 0.25+oil 1.0+GLE 0.5	**3.0**	**2.3c**	1.7d	**0.3d**
DMRT 0.05		ns	*	*	*

z : 0: not occurrence, 1: very little, 2: a little, 3: middle, 4: severe, 5: very severe

y : ginkgo leaf extracts

x: Means separation within columns by Duncan's multiple rage test ($p \leq 0.05$)

Organic pesticides are usually sprayed in the evening or in a cloudy day to increase its potency. It is thought that spraying after sunset will allow the pesticide to remain on the pest for over 4 hours with the delivery improvement. It is suggested that spraying against OTB is effective in the evening by excluding direct sunlight or cloudy day, particularly in 1 or 2 days interval because OTB seems to move between the pepper fruits in one or two days. It is difficult to spray the agricultural organic materials when OTB is inside the fruit. However, the killing effect of spraying the materials is getting higher during OTB moving time. Pepper did not show any signs of stress by the spraying the high-concentration of SP (0.33%). However, the application of strong concentration of SP in direct sunlight condition caused partial leaf burning. It is important to use sulfur in the evening out of direct sunlight or cloudy days (Table 1, 2).

<Test 2> Effect of organic agricultural materials using SP and OP on insect control in tomato

The application organic agricultural materials made of oil, sulfur, ginkgo leaf extract does not

Table 3. The growth characteristic as affected by organic agricultural materials using sulfur and oil preparation in organic tomato farming

Treatments (sulfur % + oil %)		Plant height (cm)	Leaf length (cm)	Leaf width (cm)	No. of node	No. of flower truss
Control		230.1a	46.1a	33.8a	33.6a	10.0a
Sulfur	sulfur 0.33	236.2a	46.5a	34.5a	33.0a	10.2a
	sulfur 0.25	237.5a	47.1a	35.1a	32.9a	9.5a
	sulfur 0.20	229.3a	46.0a	36.7a	31.6a	9.7a
	sulfur 0.17	224.1a	44.3a	35.0a	32.7a	9.7a
Oil	oil 2.0	231.7a	46.7a	35.0a	32.9a	9.8a
	oil 1.0	231.7a	45.3a	35.5a	33.2a	9.7a
	oil 0.50	229.9a	46.3a	35.3a	31.7a	9.2a
	oil 0.33	238.7a	48.3a	35.3a	33.7a	9.8a
Sulfur+oil	sulfur 0.33+oil 2.0	233.3a	46.9a	33.5a	32.8a	10.3a
	sulfur 0.25+oil 1.0	236.6a	47.3a	34.9a	32.9a	10.2a
	sulfur 0.20+oil 0.5	230.6a	47.3a	34.1a	32.1a	9.8a
	sulfur 0.17+oil 0.33	233.6a	48.2a	35.3a	32.7a	9.3a
DMRT 0.05[z]		ns	ns	ns	ns	ns

z: Means separation within columns by Duncan's multiple rage test ($p \leq 0.05$)

affect the growth of the cherry tomato plant. There was no statistical significance in the leaf length, leaf width, number of nodes, flowers, etc. (Table 3).

Greenhouse whiteflies on cherry tomatoes was killed by 100% with three times application of SP (0.17%)+OP (0.33%). When used respectively, sulfur killed them in 400 dilution (SP 0.25%) and oil in 100 dilution (OP 1.0%). Previous researches on microbial solution and egg yolk oil showed that microbial input's kill-rate was 49.0~55.9% for grey fungus and 39.2~58.2% for leaf fungus. Egg yolk oil mixture featured a 97.6% for tomato powdery mildew (Hong et al., 2012). Against tomato powdery mildew, *P. polymyxa* CW pathogen culture has been applied at different dilutions of 106, 107, 108 cfu/ml. Non-treated field showed that the diseased area percentage of 56.3% whereas treated field had much less disease occurrence of 0.03, 19.5, 45.7% (Kim et al., 2013). For tomato grey fungus, EXTN-1 and Bacillus subtilis strain B17 had been applied during transplant through drip irrigation, twice in two weeks on the soil, and four times on the leaves from early flowering. This showed the highest disease-control rate of 57.0% and 55.1% (Kim et al., 2012). Although many reports earlier mentioned, there are not any researches on prevention of insect pest problem in tomatoes such as greenhouse whiteflies. Our results showing high kill-rate of this pest demonstrate that this natural pesticide utilizing sulfur and oil has high potential and needs further research.

The number of greenhouse whiteflies decreased with all treatments. It is thought that three times of continued application with one or two days interval is a way to increase the potency (Table 4). In our experiment, tomatoes did not show any concentration damage in strong solution of OP (0.33%). Damage was observed with complete spray of SP+OP (0.33+1.0%) and SP+OP (0.25+0.5%). However, there were no damages when sprayed beneath the flower buds. Concentration damage from SP usually appears in July to August in the hot season. Therefor this research suggests that the spray of these materials should not be used for flower buds on new shoots (Nam et al., 2015) and sulfur should be used on evening with no existence of direct sunlight or cloudy days. Concentration damage issue of sulfur needs further study; it was reported that continued use of sulfur could cause damage on grapes, persimmons, and walnuts if it is too strong (Cho. 2012). Meanwhile, sulfur has been used as a raw material for lime sulfur mixture, but it has been limited to use because it is weak. However, the sulfur preparations used in this study were produced through chemical reaction without any heat, and showed almost no side effect. Although not shown in the data, as a result of analysis of As, Cd, Hg and Pb, 0.33% of sulfur and 0.33~2.0% of oil were not detected for the harmful effects of sulfur and oil preparation.

Table 4. The degree of occurrence of greenhouse whitefly and control result as affected by agricultural materials of organic farming in tomato

Treatments (Sulfur % + oil %)		Degree of occurrence (0-5)[z]			
		before	Application frequency		
			One	Two	Three
Control		3.0	3.7a	5.0a	5.0a
Sulfur	sulfur 0.33	3.0	2.3b	1.0b	**0.0c**
	sulfur 0.25	3.0	2.0b	1.0b	**0.0c**
	sulfur 0.20	3.0	2.0b	1.0b	1.0b
	sulfur 0.17	3.0	2.0b	1.0b	1.0b
Oil	oil 2.0	3.0	2.0b	1.0b	**0.0c**
	oil 1.0	3.0	2.0b	1.0b	**0.0c**
	oil 0.50	3.0	2.0b	1.0b	1.0b
	oil 0.33	3.0	2.0b	1.0b	1.0b
Sulfur+oil	sulfur 0.33+oil 2.0	3.0	2.0b	1.0b	**0.0c**
	sulfur 0.25+oil 1.0	3.0	2.0b	1.0b	**0.0c**
	sulfur 0.20+oil 0.5	3.0	2.0b	1.0b	**0.0c**
	sulfur 0.17+oil 0.33	3.0	2.0b	1.0b	**0.0c**
DMRT 0.05[y]		ns	*	*	*

z: 0:not occurrence, 1: very little, 2: a little, 3: middle, 4: severe, 5: very severe
y: Means separation within columns by Duncan's multiple rage test ($p \leq 0.05$)

Hearafter the studies on the effect of SP+OP application on another pests and diseases such as greenhouse greenlies, mites, canker and fungus rampant in nearby pepper fields will be necessary because there are free of them in the test field during the experiment.

Ⅳ. Conclusions

This study was carried out to determine the optimal concentration of agricultural organic materials using sulfur and oil for the insect pest control in pepper and tomato cultivation. The aphid control in pepper was complete by applications of SP+OP (0.25+1.0%) in the early growth

stage and the control value was above 98.1% by the application of OP+GLE (1.0+1.0%), SP+OP+GLE (0.25+1.0+1.0%), SP+OP+GLE (0.25+1.0+0.5%) in the middle to late growth stage while showing 0% in the control treatment. The OTB were completely controlled by the 3 times application with the high concentration of SP+OP (0.25+1.0%) in pepper cultivation. The greenhouse whitefly in 'Minichal' tomatoes was completely controlled by three times application of SP (0.25~0.33), OP (1.0~2.0%). and all the treatment of SP+OP. As the results, SP+OP (0.17+0.33%) treatment was the most economical combination when considering operating cost.

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