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ORIGINAL ARTICLE/CONTROL

Insecticidal Activities of Polymers and Surfactants Against Sweet Potato Whitefly, *Bemisia tabaci* (Hemiptera: Aleyrodidae)

Changmann Yoon, Sun-Ran Cho, Sang-Rae Moon, Youn-Ho Shin and Gil-Hah Kim*

Dept. of Plant Medicine, Chungbuk National University, Cheongju 361-763, Korea

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Abstract

This study was performed to evaluate the polymers and surfactants as the potential control agents of sweet potato whitefly *Bemisia tabaci*, which is causing problems in ornamental garden and greenhouse. Polymers have an insecticidal activity to knock down and to be lethal to small winged insects by its viscosity. Among five polymers tested at 0.2% concentration, polinol P-24 showed the highest insecticidal activity as 59.4% against *B. tabaci* adult in cylindrical chamber, and followed by polinol P-20 (insecticidal activity, 57.1%). When treated at 0.1% or 0.3% concentrations, Polinol P-24 also showed the highest insecticidal activity with 43.3% and 54.5%, respectively. Among eight surfactants tested, insecticidal activity was the highest in 0.0005% NP10 treatment (70.0%), and followed by 0.001% NP7 (67.4%). The synergistic effect between polinol P-24 and eight surfactants was evaluated. After bioassays, the 0.2% polinol P-24 plus 0.005% NP10 was selected as a candidate control agent for controlling of *B. tabaci* adults. Polinol P-24/NP10 was showed the highest control efficacy against *B. tabaci* adults applied three times at three day-intervals in square rearing cage. In the greenhouse, the mixture treatment showed good control value over 70% seven days after treatment.

Key words polymer, surfactant, insecticidal activity, sweetpotato whitefly, *Bemisia tabaci*

Introduction

The whiteflies in general, *Bemisia tabaci* in particular, have a long history of devastating agricultural and horticultural crops (Gennadius, 1889; Oliveira *et al.*, 2001). They do severe damage to crop plants, have resistance against insecticides, and transmit the viruses that cause serious economic losses (Byrne and Bellows, 1991; van Lenteren, 1995; Brown *et al.*, 1995). As a result, there has been intensive research into their biology including incidence, population dynamics (Secker *et al.*, 1998); discrimination of biotypes with molecular-based assays (Ueda, 2006; Kim *et al.*, 2007); behavior including feeding, enzymatic activity in detoxification of insecticides, virus transmission ability (Perring, 2001; EPPO, 2004; Chu *et al.*, 2004); and control by biological, chemical, physical, cultural, and legislative methods (Perring, 2001; Palumbo *et al.*, 2001; Ellsworth *et al.*, 2001). Although research has achieved enormous results, the control of this pest still has problematic, especially in greenhouse vegetables and ornamental plants. Currently, effective control of whiteflies is a hot issue (Jeong *et al.*, 2010).

A polymer is an alternative one to control whiteflies effectively. A polymer is a macromolecule, composed of repeating structural units typically connected by covalent chemical bonds. While polymer in popular usage suggests plastic, the term actually refers to a large class of natural and synthetic materials with a variety of properties. Polymers have property of very high viscosity and may be possible to use as an insecticidal active agent (Williams *et al.*, 2008). Until now, very few researches about polymers for con-

*연락저자 : Tel. +82-43-261-2555, Fax. +82-43-273-4414
E-mail: khkim@chungbuk.ac.kr

trolling pest were reported in the form of patent-opened docile. In Japan, a method was described indicating that polymers such as acetate polymer, ethylene vinylacetate copolymer blended with insecticide, fungicide and herbicide solutions to have residual efficacy using their high viscosity (Japan patent 1989-228903, 1989). In USA, pest control active ingredients were blended with polymers such as polyvinyl chloride and then shaped into forms such as strips, animal collars and animal ear tags for use in controlling pests (US Patent 5437869, 1995). However, polymers are hardly used in the field of pest management, only in cases of polymer mulches.

A surfactant, another name for agricultural adjuvant, is another alternative one to control whiteflies. A surfactant is good dispersing agents, stable in cold water, and have low toxicity to both plants and animals (Weinberger and Greenhalgh, 1984). A surfactant is used to enhance the bioactivity of agricultural chemicals by reducing the surface tension of water by adsorbing at the liquid-gas interface (Stevens, 1993; Cai and Stark, 1997). They also reduce the interfacial tension between chemicals and water by adsorbing at the liquid-liquid interface (Paveglio *et al*., 1996). Some surfactants are known to be toxic to animals, ecosystems and humans, and can increase the diffusion of other environmental contaminants. However, some agricultural adjuvants increase pesticide efficacy and modify environmental fate (Weinberger and Greenhalgh, 1984; Sharma and Singh, 2001).

This study was performed to investigate the possibility of polymers and surfactants for controlling of small winged pests, mainly whitefly. The experiment will be achieved to control whitefly using polymer and surfactant in the laboratory and greenhouse. Water-soluble polymer having high viscosity property will demonstrate the possibility to develop new control agent for spraying, to minimize the population dynamics of small winged pests such as *Bemisia tabaci*, and to utilize an alternative agent instead of chemical insecticides. Water-soluble polymers and effect blended surfactant will not inhibit the growth of crops and be removed easily by water spraying. It is considered as a possibility for enhancing the insecticidal activity of polymers in the manner of synergistic effect by blended surfactants.

Materials and Methods

Sweetpotato whitefly – *Bemisia tabaci*

The sweetpotato whitefly population has been collected from the redpepper field at Miryang-Si, Gyeongnam, South Korea. The sweetpotato whitefly has been maintained in a square acrylic cage (25 × 30 × 45cm) through successive generations. The whitefly was discriminated the biotype as Q biotype using RFLP-PCR (Kim *et al*., 2007) and used the experiment. The host plants were provided as food with 4-week grown redpepper seedlings (*Capsicum annuum* cv. Cheongpungmyeongweol) plants, under conditions of a photoperiod of 16: 8 hr (light: dark) with 50 - 60% RH and a temperature of 25±1°C.

Polymers and Surfactants

Synthetic polymer

Hydrophilic synthetic polymers have a property of high viscosity. Polinol P-series (PVA) were purchased from Dong-Yang Chemicals Ltd. (Seoul, Korea) and Carbopol 940 was obtained from LG Household and Healthcare (Daejon, Korea). Their common name, chemical structures and characteristics are listed in Table 1.

Surfactants

Surfactants used in this study were as follows: APG [Alkyl polyglycoside] (Jayonmiin Co., Gwangju, Gyeonggi), Triton X-100 (Sigma Aldrich, St. Louis, MO) and Tween 20 (Samchun chemical Co., Seoul), and the others were obtained from Coseal. Co. Ltd. (Gunsan, Jeonbuk). The chemical structure and properties are listed in Table 2.

Bioassay of polymers and surfactants

Mortality in the cylindrical chamber

Insecticidal activity of five kinds of polymers and eight kinds of surfactants against Q biotype of *B. tabaci* adults was examined using a cylindrical chamber (Φ 9 × 15 cm). Upper side of the cylindrical chamber was covered by petri-dish with wire net (Φ 5 cm hole size) and released *B. tabaci* to bottom side. Polymer and surfactant solutions were sprayed with a pump-type spray (particle size: 400

Table 1. List of polymers used in this study

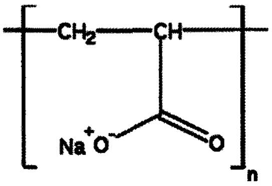
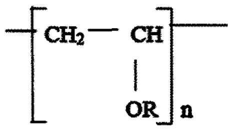
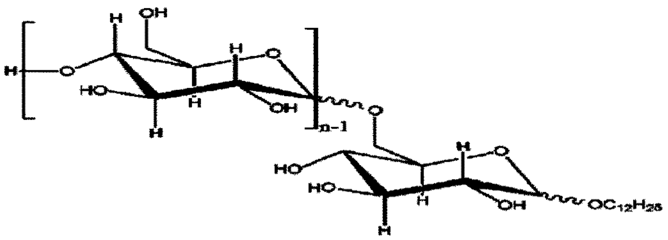
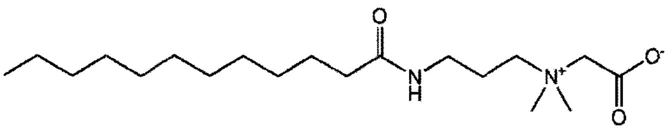
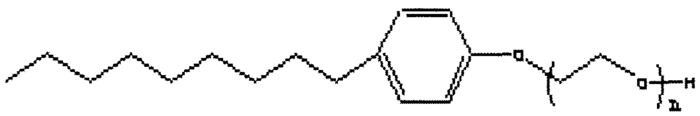
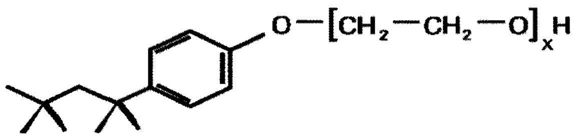
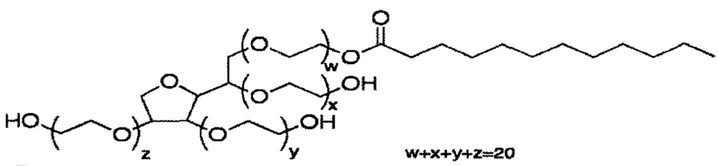
Brand name	Common name	Structural formula	Approx. molecular weight	Characteristics	Manufacturer
Carbopol 940	Sodium polyacrylate		1,250,000	viscosity (1%)= 45,000-80,000	LG household and healthcare
Polinol P-05	*Poly vinyl alcohol*			viscosity(4%)=5.0-5.6	DC Chemical Co. Ltd.
Polinol P-17	*Poly vinyl alcohol*			viscosity(4%)=21-24	DC Chemical Co. Ltd.
Polinol P-20	*Poly vinyl alcohol*			viscosity(4%)=31-35	DC Chemical Co. Ltd.
Polinol P-24	*Poly vinyl alcohol*	where R=H or $COCH_3$		viscosity(4%)=44-52	DC Chemical Co. Ltd.

Table 2. Chemical structures of various surfactants used in this study

Brand name	Chemical Structure	Full name and physical trait (additional mole no.)
APG		Alkylpolyglycoside Non-ion
CAPB		Cocamidopropyl betaine Amphiphilic
NP		Polyoxyethylene nonylphenyl ether Non-ion (3 mol; 5 mol; 7 mol; 10 mol)
Triton X-100		Polyoxyethylene octyl phenyl ether Non-ion
Tween 20		Polysorbate 20 Non-ion

nm). A pump-type spray, an orifice spray having an output capacity of 0.1 to 0.15 ml per activation, can comfortably support a single spray using a tip nozzle of 0.15 mm diameter. Upper side of the cylindrical chamber is headed to gather toward a light stand and sprayed polymer or surfactant to inner cylindrical chamber to fully spread into. It is necessary to spray carefully because the wind will blow back and pull the insect outside by blowing the wind power within a limited space. The polymers and surfactants were dissolved in distilled water and prepared after boiling to adjust concentration. Distilled water was used as a control. Sprays were done three to five times per replicate.

The test was performed at room temperature. The whiteflies were allowed to adjust to the cylinder chamber for five minutes before the spray was applied homogenously onto the whiteflies and sprayed in the direction of the sector. To achieve a homogenous spray, spraying was done to an empty space several times before spraying in the direction of the chamber. An amount of 0.4 ± 0.01 g was delivered with each spray. Each bioassay was performed with at least three replicates. The insects were considered dead when they were not moved or knock downed. Mortality was assessed 6 hr later after the chamber was completely dried.

Among tested polymers and surfactants, each chemical showing good bioactivity was narrow-downed and synergistic effect was tested with three different concentrations by combinations.

Control efficacy in square rearing cage

From the above result, polymer and surfactant showing good mortality was selected and tested the control efficacy in a square rearing cage (40 × 40 × 40 cm). To get a control efficacy in a square rearing cage, a four-week grown potted redpepper was provided as food in a square cage and the *B. tabaci* were released with 200 individuals. Test conditions as follows: polinol alone, surfactant alone, polymer + surfactant combinations, and the control. Control efficacy of each polymers and surfactants was evaluated by spraying with the intervals of three days with three times and comparing the mortality of *B. tabaci*. The bioactive materials such as selected polymers and surfactants were mixed by combination for controlling of *B. tabaci* and evaluated the insecticidal activity in a square cage.

Control efficacy in a greenhouse test

Control efficacy using polymer and surfactant was performed in redpepper greenhouse of 100 m^3 (10 × 5 × 2 m) in Chungbuk National University. Redpepper seedlings were transplanted onto the greenhouse with four rows and each row is planted with 20 seedlings. The *B. tabaci* was released with the four whole tomato plants with high densities to suffuse the greenhouse.

To estimate the control efficacy of selected polymer blended with surfactant, this mixture was sprayed three times at the intervals of three days. Pre-control density was investigated one day before and post-control density was surveyed three and seven days after treatment. The greenhouse was closed the door and covered side wall window with fine net to prohibit in and out of *B. tabaci* moving inside and outside. The mixture was sprayed with manual sprayer with two spraying holes to equally spread onto the upper and under leaves. After the mixture was sprayed, three and seven days after treatment, *B. tabaci* on leaf was counted the individuals, and then the mortality was examined.

Statistical analysis

Data were compared by one-way analysis of variance (ANOVA) using Tukey's Studentized Range (HSD) Test (at $P<0.05$) to compare the insecticidal activity of polymers and surfactants in cylindrical chamber and the control value from rearing cage and greenhouse in the SAS 2.0 program (SAS Institute, 2003).

Results

Insecticidal activity of polymer

Insecticidal activity of polymer against *B. tabaci* adults was evaluated in a cylindrical chamber. In our previous research, PVA with surfactant has a good potential as insecticidal active agents (Cho, 2009). This study was done to complement that research.

Various polymers obtained from manufacturers were tested for their insecticidal activity with different concentrations (0.1, 0.2, and 0.3%) in a cylindrical chamber (Table 3).

At the concentration of 0.3% polymers, polinol P-24 showed the highest insecticidal activity (54.5%) with significance and polinol P-20 (50.3%) was the followed. At the concentration of 0.2% polymers, polinol P-24 was also showed the highest insecticidal activity (59.4%), with similar result as treated with 0.3% polymers. All polymers at the concentration of 0.1% showed lower activity than those of 0.3 and 0.2% concentrations. From these results, polymers

Table 3. Insecticidal activity of five polymers in 1L a cylindrical acrylic cage

Polymer	Concentration (%)	Number of samples	Mortality (Mean±SD)
Carbopol 940	0.3	30	9.7 ± 10.0 cd
	0.2	30	11.1 ± 11.1 cd
	0.1	31	8.3 ± 14.4 d
Polinol P-05	0.3	30	24.1 ± 8.5 bcd
	0.2	30	2.8 ± 4.8 bcd
	0.1	32	0.0 ± 0.0 d
Polinol P-17	0.3	28	11.2 ± 3.0 cd
	0.2	30	10.4 ± 11.2 cd
	0.1	31	9.4 ± 9.1 cd
Polinol P-20	0.3	32	50.3 ± 8.4 ab
	0.2	30	57.1 ± 8.6 a
	0.1	31	38.5 ± 7.8 abc
Polinol P-24	0.3	31	54.5 ± 12.7 ab
	0.2	28	59.4 ± 10.0 a
	0.1	34	43.3 ± 15.3 cd
Control	-	30	3.0 ± 5.2 d

Table 4. Insecticidal activity of eight surfactants in 1L a cylindrical acrylic cage

Surfactant	Concentration (%)	Number of samples	Mortality (Mean±SD)
APG	0.005	25	37.4 ± 11.9 abcde
	0.001	23	29.8 ± 13.4 abcde
	0.0005	19	15.2 ± 15.1 bcde
CAPB	0.005	25	42.5 ± 6.6 abcd
	0.001	28	31.7 ± 7.6 abcd
	0.0001	28	20.8 ± 8.8 abcde
NP 3	0.005	30	53.3 ± 5.8 abcd
	0.001	29	47.8 ± 13.5 abcd
	0.0005	30	46.7 ± 15.3 abcd
NP 5	0.005	29	62.2 ± 10.7 abc
	0.001	29	61.3 ± 14.9 abc
	0.0005	28	50.4 ± 34.5 abcd
NP 7	0.005	28	60.0 ± 17.3 abc
	0.001	28	67.4 ± 12.2 a
	0.0005	30	64.4 ± 16.9 abc
NP 10	0.005	29	62.2 ± 3.8 abc
	0.001	29	65.19 ± 21.7 ab
	0.0005	27	70.0 ± 7.6 a
Triton X-100	0.005	30	54.9 ± 8.7 abcd
	0.001	31	45.9 ± 16.3 abcd
	0.0005	29	22.3 ± 11.1 de
Tween 20	0.005	32	28.3 ± 9.2 abcde
	0.001	31	25.9 ± 10.4 cde
	0.0005	28	13.8 ± 2.4 de
Control	-	42	0.0 ± 0.0 e

are affected by dose-dependent-manner. When the polymer sprayed was over 0.3%, a very high viscosity caused the problem to spray by clogging the nozzle tip. Therefore, I judged that the applicable concentration is 0.2%, with the consideration of economical level and easy usage.

Insecticidal activity of surfactants

Various surfactants were estimated for their insecticidal activity with the different concentrations (0.005, 0.001, and 0.0005%) (Table 4). Insecticidal activity of a surfactant was the highest in NP10 with 70.0% at 0.0005% concentration and followed by NP7 with 67.4% at 0.001% concentration. At the concentration of 0.005%, insecticidal activity of surfactants were the highest in NP 5 (62.2%), and NP 10 (62.2%) and followed by NP7 (60.0%) > Triton X-100 (54.9%) > NP3 (53.3%) > CAPB (42.5%). At the concentration of 0.001%, insecticidal activity of surfactants was highest in NP7 (67.4%), and followed by NP10 (65.2%) > NP5 (61.3%) > NP3 (47.8%) > Triton X-100 (45.9%). In case of the concentration of 0.0005%, insecticidal activity of surfactants was the highest in NP10 (70.0%), and followed by NP7 (64.4%) > NP5 (50.4%) > NP3 (46.7%). Not similarly with polymers, most surfactants act in a dose-independent manner. Generally, insecticidal activities of surfactants were high in NP series and Triton X-100.

Synergistic effect of polymer and surfactants

Polymers were evaluated for the synergistic effect with

Table 5. Insecticidal activity of mixtures of 0.1% polymer and surfactants in 1L a round acryl cage

Polymer	Surfactant	Concentration (%)	Number of samples	Mortality (%) (Mean ± SD)
Polinol P-24	-	0.1	34	43.3 ± 15.3 ab
Polinol P-24 (0.1%)	APG	0.005	29	38.1 ± 16.0 ab
		0.001	26	34.2 ± 10.7 ab
		0.0005	27	22.0 ± 19.6 ab
	CAPB	0.005	27	68.1 ± 18.9 a
		0.001	28	45.1 ± 18.1 ab
		0.0005	26	38.5 ± 14.0 ab
	NP 3	0.005	24	57.9 ± 11.8 a
		0.001	27	52.7 ± 11.5 a
		0.0005	25	48.6 ± 14.6 ab
	NP 5	0.005	26	57.9 ± 11.8 a
		0.001	31	50.9 ± 35.5 a
		0.0005	30	43.2 ± 21.0 ab
	NP 7	0.005	26	59.9 ± 14.3 a
		0.001	38	54.1 ± 19.8 a
		0.0005	27	51.0 ± 11.9 a
	NP 10	0.005	30	68.1 ± 3.4 a
		0.001	26	52.5 ± 24.1 a
		0.0005	28	66.3 ± 8.9 a
	Triton X-100	0.005	30	63.1 ± 7.2 a
		0.001	30	44.0 ± 10.2 ab
		0.0005	31	26.3 ± 7.6 ab
	Tween 20	0.005	29	47.8 ± 5.8 ab
		0.001	28	46.7 ± 8.0 ab
		0.0005	31	38.4 ± 7.8 ab
Control	-	-	30	0.0 ± 0.0 b

different concentrations (0.005, 0.001, and 0.0005%/L) of surfactants in a cylindrical chamber against *B. tabaci* (Tables 5~7). The treatment was used the same method as single treatment. Surfactants selected from single treatment showed higher mortality than the others. It was included as CAPB, NP3, NP5, NP7, NP10, Triton X-100 and Tween 20.

Polymers with different concentrations were blended with six or eight selected surfactants with different concentrations (0.005, 0.001, and 0.0005%) and sprayed into cylindrical chamber. By combination, it shows the synergistic and/or additive mortality when they were mixed. Among tested surfactants with polymer mixtures showing good insecticidal activity were selected again for further study.

Control efficacy of various combinations in square plastic cage

Polymers and surfactants were evaluated on the control efficacy by combinations in square rearing cage against *B. tabaci* (Fig. 1). When first applied to population of *B. tabaci* in a square rearing cage, only surfactant 0.005% showed higher control value than others. However, control value after second application was the highest in polinol+surfactant (0.2+0.005%) and followed by polinol+surfactant (0.2+0.001%). Surfactant 0.005% also showed good control value with significance. After third application, it obviously showed the control efficacy among treatments. Both concentrations of surfactant (0.005 and 0.001%) with polinol has good control efficacy with 72 and 65%, respectively,

Table 6. Insecticidal activity of mixtures of 0.2% polymer and surfactants in 1L a round acryl cage

Polymer	Surfactant	Concentration (%)	Number of samples	Mortality (%) (Mean ± SD)
Polinol P-24	-	0.2	28	59.4 ± 10.0 a
Polinol P-24 (0.2%)	APG	0.005	31	64.5 ± 15.0 a
		0.001	29	58.9 ± 16.4 a
		0.0005	24	49.9 ± 10.9 ab
	CAPB	0.005	32	69.4 ± 12.6 a
		0.001	31	59.6 ± 15.9 a
		0.0005	30	52.1 ± 13.7 a
	NP 3	0.005	31	51.2 ± 27.9 a
		0.001	27	39.4 ± 18.3 ab
		0.0005	28	28.1 ± 2.9 ab
	NP 5	0.005	41	64.8 ± 17.6 a
		0.001	25	32.1 ± 19.9 ab
		0.0005	44	28.6 ± 14.3 ab
	NP 7	0.005	37	63.9 ± 23.6 a
		0.001	32	49.7 ± 5.1 ab
		0.0005	40	30.2 ± 13.1 ab
	NP 10	0.005	46	62.0 ± 28.1 a
		0.001	33	45.7 ± 15.9 ab
		0.0005	41	29.2 ± 13.0 ab
	Triton X-100	0.005	30	65.9 ± 12.3 a
		0.001	31	48.1 ± 9.2 ab
		0.0005	34	30.7 ± 3.6 ab
	Tween 20	0.005	33	50.8 ± 6.3 a
		0.001	43	44.5 ± 8.9 ab
		0.0005	42	30.6 ± 10.5 ab
Control	-	-	30	0.0 ± 0.0 b

Table 7. Insecticidal activity of mixtures of 0.3% polymer and surfactants in 1L a round acryl cage

Polymer	Surfactant	Concentration (%)	Number of samples	Mortality (%) (Mean ± SD)
Polinol P-24	-	0.3	31	54.5 ± 12.7 d
Polinol P-24 (0.3%)	CAPB	0.005	26	75.9 ± 19.8 abc
		0.001	29	71.2 ± 26.4 bcd
		0.0005	31	63.5 ± 18.7 bcd
	NP 3	0.005	29	61.5 ± 17.8 bcd
		0.001	30	59.1 ± 14.2 cd
		0.0005	28	63.6 ± 8.6 bcd
	NP 5	0.005	30	76.7 ± 12.7 abc
		0.001	28	52.1 ± 13.6 d
		0.0005	27	65.9 ± 14.3 bcd
	NP 7	0.005	29	81.3 ± 7.0 ab
		0.001	31	70.0 ± 10.0 bcd
		0.0005	29	77.8 ± 13.3 abc
	NP 10	0.005	31	93.3 ± 5.8 a
		0.001	30	92.8 ± 6.5 a
		0.0005	31	70.1 ± 6.7 bcd
	Triton X-100	0.005	39	71.8 ± 2.2 bcd
		0.001	41	49.4 ± 7.8 de
		0.0005	37	29.6 ± 3.3 e
Control	-	-	31	0.0 ± 0.0 e

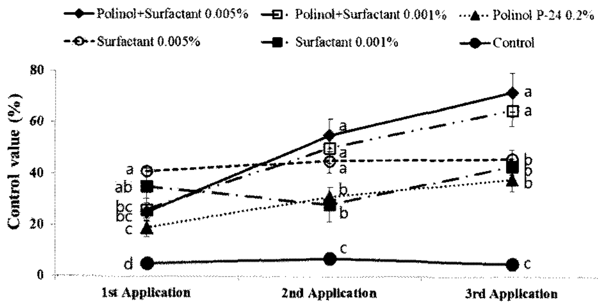


Fig. 1. Insecticidal activity of mixtures of Polinol P-24 (0.2%) and NP10 (0.005%) against *Bemisia tabaci* adults when they were applied three times at three day-intervals in a square rearing cage (40 × 40 × 40 cm) under laboratory conditions. Sample size, n=141 - 158 adults per plot.

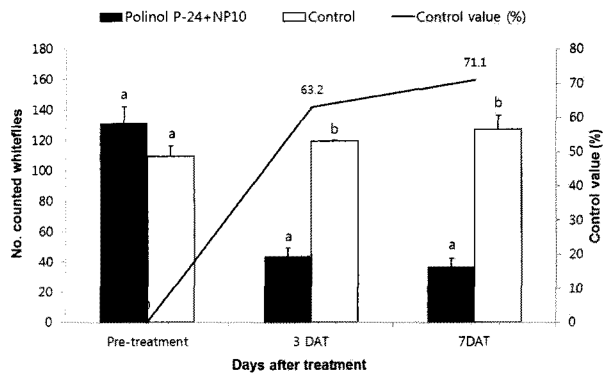


Fig. 2. Control effect of mixtures of Polinol P-24 (0.2%) and NP10 (0.005%) against *Bemisia tabaci* adults on redpepper three and seven days after treatment in redpepper greenhouse condition. Sample size, n=3282 - 3943 adults per plot.

with significance. Polinol alone and surfactant alone treatment showed control value range from 38 to 46%. Therefore, the mixture of polinol+surfactant (0.2+0.005%) showed good insecticidal activity when applied three times at three day-intervals in a square rearing cage.

Control efficacy on the greenhouse

From above results, polymer and surfactant showed high insecticidal activity. Polinol 0.2% combined with surfactant 0.005% was sprayed and control values were evaluated three and seven days after treatment in the greenhouse. These results were showed in Fig. 2.

Sweetpotato whiteflies contacted with polymer and surfactant were knocked down or killed. In pretreatment of polinol+surfactant, the population densities of whiteflies were over 130, but sharply decreased after three days and seven days after treatment. Vice versa, the control showed increasing pattern of population density of *B. tabaci* over time. Polinol+surfactant showed the control value with 63.2% at three days after treatment, and 71.1% at seven days after treatment.

Discussion

Polymers have the property of very high viscosity. Their characteristics are potential to use as an insecticidal active agent (Williams *et al.*, 2008). Generally, polymers are easily soluble in water and stick to materials to some degree. When applied to micro winged pests such as whitefly, fruit fly, and aphids, these polymers stick to the wings and/or legs of the pest insect (but big-size pests are not). Polymers harden on the body of pest insect with like thin film being evaporated the water status. Therefore, they become dull and physically knocked down, and eventually die. This concept has potential to develop as an insecticidal active agent for this reason.

In nature, polymers have enormous functions. Natural polymers (macromolecules) included molecules such as gelatin, pectin, dextran, collagen, and agar. They do not only have effects on the insect's behavior but also help growth, as they are secondarily by their kinds a nutritional source for the crop. Semi-synthetic polymers have macromolecules such as methyl cellulose, ethyl cellulose, hydroxy ethyl cellulose, sodium carboxy methyl cellulose, soluble starch, dextrine, carboxy methyl starch, and dialdehyde starch.

Also synthetic polymers are classified as soluble materials such as polyvinyl alcohol, polyvinyl pyrrolidone, polyvinyl methacrylate, poly acrylic acid or its salt, polyethylene oxide, acryl resin with carboxy residue, polyester resin with carboxy residue, soluble polyamide, soluble polyurethane, maltodextrin, and polydextrous.

Surfactants are critical constituents as an additive of agricultural formulations for the control of insect pests, plant pathogens, and weeds. The roles of surfactants have varied, ranging from their obvious use as emulsifiers in spray preparations to their role as wetting and penetration aids and, in some cases, as active pest control agents (Sharma and Singh, 2001). Surfactants also improve application efficiency by facilitating the transport of the active ingredient into the plant through pores and membrane walls. Foam formation during application can also be a problem since the presence of foam will, in most cases, significantly reduce the effectiveness of the applied material.

There are four basic groups of agricultural surfactants: (1) anionic, (2) cationic, (3) nonionic, and (4) amphoteric. Anionic and cationic surfactants form electrical charges in water (negative and positive, respectively). Nonionic surfactants do not form an overall charge. Amphoteric surfactants may or may not form a charge depending on the acidity of the spray solution. Nonionic surfactants are the type usually sold for adding to herbicide spray solutions.

These surfactants are good dispersing agents, stable in cold water, and have low toxicity to both plants and animals. Cationic surfactants can be toxic to plants and are not generally used with insecticides. Anionic surfactants have good foaming abilities and are often blended with nonionics to provide the wetting and emulsifying properties of an insecticide formulation.

Surfactant was usually blended with the chemicals as an additive. They have the property spreading widely or to fasten agrochemicals to plants. It was well known that only spraying surfactant has bioactivity to some extent (Stevens, 1993; Cai and Stark, 1997). In this study, polymers and surfactants showing good activity were selected and evaluated by combinations.

In some applications, the choice of surfactant for a given active component can be critical. Since many pest control chemicals carry electrical charges, it is vital to use a surfactant that is electrically compatible with that ingredient. If the active material is positively charged, the addition of an anionic surfactant can, and probably will, result in the formation of a poorly soluble salt that will precipitate out directly before being applied, or the salt will be significantly less active, resulting in an unacceptable loss of cost-effectiveness.

I do not know how they have high activity at current status. In one surfactant series, there was no coincidence with insecticidal activity by adding repeated molecules. I had thought, from the case of NP series, it was considered that when they increased their molecular weight, the insecticidal activity will increased, but result was different.

When polymer (polinol P-24) was combined with surfactant (NP10) for insecticidal activity, whiteflies were contacted with polymer and surfactant were knocked down or killed. However, it still has the problems to low insecticidal activity and to utilize for developing of alternative agent. To complement this, the use of yellow sticky trap can be considered. Yellow sticky trap for the attraction by the visual cue and the lure absorbed with attractant like as pheromones or essential oils by olfactory cue will be possible to use for controlling whiteflies. Therefore, whiteflies escaped from the polinol and surfactant spraying on plants were induced toward the yellow sticky trap.

From the above results, test chemicals will be available for use as a control agent against *Bemisia tabaci* in the greenhouse, and the potential of controlling microscopic pests such as mites, thrips, and aphids will be expected.

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담배가루이에 대한 폴리머와 전착제의 살충효과

윤창만 · 조선란 · 문상래 · 신윤호 · 김길하*

충북대학교 식물의학과

요 약 본 연구는 관상용 정원과 온실에서 문제를 야기하는 담배가루이(*Bemisia tabaci*) 성충의 잠재적 방제제로서 폴리머와 전착제를 이용하여 생물검정을 수행하였다. 폴리머는 점성의 특성이 있어 날개가 있는 작은 곤충에게 넉다운시키거나 치명적일 가능성이 있다. 5종의 폴리머를 0.2%의 농도로 처리시, polinol P-24는 원통형챔버 안에서 담배가루이 성충에 대해 59.4% 이상의 가장 높은 살충활성을 보였으며 그 뒤를 polinol P-20(57.1%)이 따랐다. 0.1%와 0.3%의 농도로 처리시, polinol P-24는 각각 43.4%와 54.5%의 살충활성을 보였다. 8종의 전착제를 실험한 결과 살충활성이 NP10(0.0005%)에서 70.0% 이상으로 가장 높게 나타났고 그 뒤로 NP7(0.001%)이 67.4%로 나타났다. 살충활성을 높이기 위하여, polinol P-24를 전착제와의 다양한 조합으로 상승효과를 평가하였는데, 0.2% polinol P-24와 0.005% NP10을 후보물질로 선발하여 포장에서 담배가루이 방제 실험을 실시하였다. Polinol P-24와 NP10는 담배가루이 성충에 대하여 실내에서 3일간격으로 3번 처리시 가장 높은 살충활성을 보였다. 야외에서는 처리 후 7일후에 70% 이상의 방제가를 보였다.

색인어 폴리머, 전착제, 살충활성, 담배가루이, *Bemisia tabaci*