The Effects of Unmanned Control Systems for Optimum Pest Control in Protected Paprika Cultivation Facilities

Lee, You Kyoung
Department of Applied Biology, College of Agriculture and Life Sciences, Chungnam National University | Laboratory of Insect Pathology and Microbial Control, Institute of Biological Control, Faculty of Agriculture, Kyushu University

Jin, Na Young
Department of Applied Biology, College of Agriculture and Life Sciences, Chungnam National University | Laboratory of Insect Pathology and Microbial Control, Institute of Biological Control, Faculty of Agriculture, Kyushu University

Kim, Yu Seop
Department of Applied Biology, College of Agriculture and Life Sciences, Chungnam National University | Laboratory of Insect Pathology and Microbial Control, Institute of Biological Control, Faculty of Agriculture, Kyushu University

Kim, Hee Ji
Department of Applied Biology, College of Agriculture and Life Sciences, Chungnam National University | Laboratory of Insect Pathology and Microbial Control, Institute of Biological Control, Faculty of Agriculture, Kyushu University

他

https://doi.org/10.5109/1854014

出版情報：九州大学大学院農学研究院紀要. 62 (2), pp.411-417, 2017-09-08. Faculty of Agriculture, Kyushu University

J. Fac. Agr., Kyushu Univ., **62** (2), 411–417 (2017)

The Effects of Unmanned Control Systems for Optimum Pest Control in Protected Paprika Cultivation Facilities

You Kyoung LEE[1], Na Young JIN[1], Yu Seop KIM[1], Hee Ji KIM[1], Young A HUR[1], Young Shin KIM[2], Chi Hwan LIM[2], Young Nam YOUN[1], Chisa YASUNAGA–AOKI* and Yong Man YU[1]*

Laboratory of Insect Pathology and Microbial Control, Institute of Biological Control,
Faculty of Agriculture, Kyushu University, Fukuoka 812–8581, Japan
(*Received April 28, 2017 and accepted May 10, 2017*)

In this study, the spraying effects of unmanned controllers for the efficient control and safe use of pesticides in protected paprika cultivation facilities were reviewed. Whether or not pesticides were deposited and the quantities of active components and pest control effects of the pesticides according to the plant length and locations of paprika were examined. Experimental plots consisting of nine sections (comprising three repetitions of three different experimental chemical treatments) were arranged in a 13,500 m^2 wide test field to conducts experiments with *Leveillula taurica*, *Bemisia tabaci*, and *Aphis gossypii* that occurred in protected paprika cultivation facilities. Deposit degrees following pesticide spraying with unmanned fogging type controllers were measured; according to the results, water–sensitive papers showed a deposit rate of 100% in all experimental plots. With regard to pest control, when Pyrifluquinazon 6.5% SC was sprayed, 93.5% of *Bemisia tabaci* was controlled and 93.9% of *Aphis gossypii* was controlled. In the case of *Leveillula taurica*, diseased leaf rates were examined 7 days after the final treatment with Fluopyram 40% SC; the results showed that, as chemical control effects, diseased leaf rates were 52.2% in untreated plots while being approximately 8.8% in the treated plots, indicating that the control value was at least 83.2%. According to the results of examination of the quantities of active components on the front and rear of the leaves, chemical effects persisted when the quantities of active components on the front and rear of the leaves were on average 1.30 (μg/50 cm^2) and 1.05 (μg/50 cm^2) respectively, in the case of spraying of Fluopyram 40% SC; when the quantities of active components on the front and rear of the leaves were on average 0.62 (μg/50 cm^2), 0.49 (μg/50 cm^2), respectively, in the case of spraying of Pyrifluquinazon 6.5% SC; the overall deposit amounts on the front and rear were not considerably different.

Key words: *Aphis gossypii*, *Bemisia tabaci*, *Leveillula taurica* paprika, unmanned controller

INTRODUCTION

After the first cultivation of paprika in facilities in 1994 in South Korea, the cultivation area and demand of paprika have been continuously increasing; paprika has been playing an important role in agricultural production as a major export crop of South Korea (Kim *et al*., 2013). However, with the increase of protected cultivation facilities and possibility of year–round production of paprika, the occurrence of uncontrollable pests in paprika facilities has become a problem. Major pests occurring in the facilities, such as *Bemisia tabaci*, *Frankliniella occidentalis*, and *Aphis gossypii*, hide themselves in the regions that are not exposed to chemicals, rapidly increase in population, live in a wide range of hosts, and have short generation times to aggravate the development of resistance to pesticides (Jin *et al*., 2016). Unlike the pathogenic fungi that cause diseases to solanaceous crops, *Leveillula taurica*, which becomes a problem in paprika, grows in the high–temperature dry environments of paprika cultivated in facilities and cannot be easily identified early from the leaves infected with it; therefore, continuous efforts are required to control it (Lee *et al*., 2010a). Pesticides are widely used for diverse purposes, such as the protection of agricultural products from pests and weeds occurring in crops, yield increases, quality enhancement, and the prevention of losses of harvested agricultural products during storage periods; therefore, pesticides are important agricultural materials in modern agriculture (Lee *et al*., 2010b; Lee *et al*., 2013). Although the pesticides as such are effectively used to control pests and weeds, the possibility of harms caused by residual pesticides in agricultural products has been suggested. Therefore, pesticides should be carefully used and managed to ensure safety of agricultural products (Kim, 2011). In general, various pesticide sprayers, such as unmanned fogging machines and high–pressure sprayers (U–shaped sprayers), are widely used in protected paprika cultivation facilities. Depending on spraying persons, pesticides are not deposited on the rear or medial sides of leaves. These regions play the role of hiding or lurking places of pests and therefore have become a reason for increases in the density of pests again after control (Seo *et al*., 2015). Even if large amounts of pesticides are used, if they do not come into contact with pests, their control effects should be insignificant and they will promote the expression of resistance to pesticides (Jin *et al*., 2014). In addition, workers who perform pest control work in facilities are very likely to have their skin directly exposed to pesticides or inhale pesticide

[1] Department of Applied Biology, College of Agriculture and Life Sciences, Chungnam National University, Daejon 305–764, Korea

[2] Department of Bio Environmental Chemistry, College of Agricultural Biology and Life Sciences, Chungnam National University, Daejeon, 305–764, Korea

* Joint corresponding authors (E–mail: ymyu@cnu.ac.kr and yasunaga@grt.kyushu–u.ac.jp)

fumes. Thus far, the development of unmanned controllers for safe use of pesticides and efficient pest control in facilities has been attempted. Since unmanned controllers can reduce the risk of users' exposure to pesticides while enhancing control efficiency and reducing the number of times of control and the amount of pesticide used, standardized development of unmanned controllers is urgently needed (Kang *et al.*, 2014).

In the present study, the characteristics of pesticide spraying using Air Fog, an unmanned control system, were analyzed in comparison with high–pressure sprayers generally used in protected paprika cultivation facilities; furthermore, we checked whether or not the pesticides were uniformly sprayed in the field using water–sensitive papers and the optimum pest control effects; finally, the quantities of active components of pesticides used at safe use dilution rates were analyzed.

MATERIALS AND METHODS

Test chemicals

The applied pesticides used in the tests were Pyrifluquinazon 6.5% SC (brand name: Fanfare S), an insecticide registered as a control agent for *Bemisia tabaci* and *Aphis gossypii* occurring in paprika, and Fluopyram 40% SC (brand name: Mercury), a germicide used as a control agent for *Leveillula taurica* diluted to safe use dilution rates (Table 1). As sprayers, Air Fog (unmanned control system made through the joint technology development by Kyong Nong Co., Ltd. and Gyeonggido Agricultural Research & Extension Services) was used.

Test crop and places

The test crop paprika (varieties: Nagano, Jorrit, and Orange Glory, plant length: 3 m 30 cm – 4 m) was the crop being cultivated in a glass greenhouse farm located in Dogok–myeon, Hwasun–gun, Jeonnam. The test field was 140 m long and 96 m wide (13,500 m^2) in which nine test plots (consisting of three repetitions of three different chemical treatments) were arranged with 10 paprika plants per test plot. Pests *B. tabaci* and *A. gossypii* and a plant disease *L. taurica*, major targets of pest control, occurred in the test field.

Principle and characteristics of spraying equipment

The equipment used in the test was an Air Fog installed in the facility greenhouse, which uses low pressure type ultra–fine particle spray nozzles so that minute particles can be sprayed even at low pressure. Existing high pressure spraying systems have several shortcomings, such as frequent nozzle clogging, impossibility of easy repair when ruptured due to deterioration, and water drop issues (Nam *et al.*, 2012). The Air Fog was made to supplement such shortcomings by using the diameter of nozzle throat of 0.8 mm, which is approximately 16 times larger as compared to high–pressure types, so that nozzles are hardly clogged, regardless of the kinds of chemicals used. It sprays chemicals in the form of fine particles with the diameters in the range of

Table 1. Types of sprayers and pesticides for target diseases and pests

Sprayers type	Pesticide type	Target disease and pest	Component
Automatic control system (Airfog)	Fungicide	*L. taurica*	Fluopyram 40% SC
	Insecticide	*B. tabaci* *A. gossypii*	Pyrifluquinazon 6.5% SC

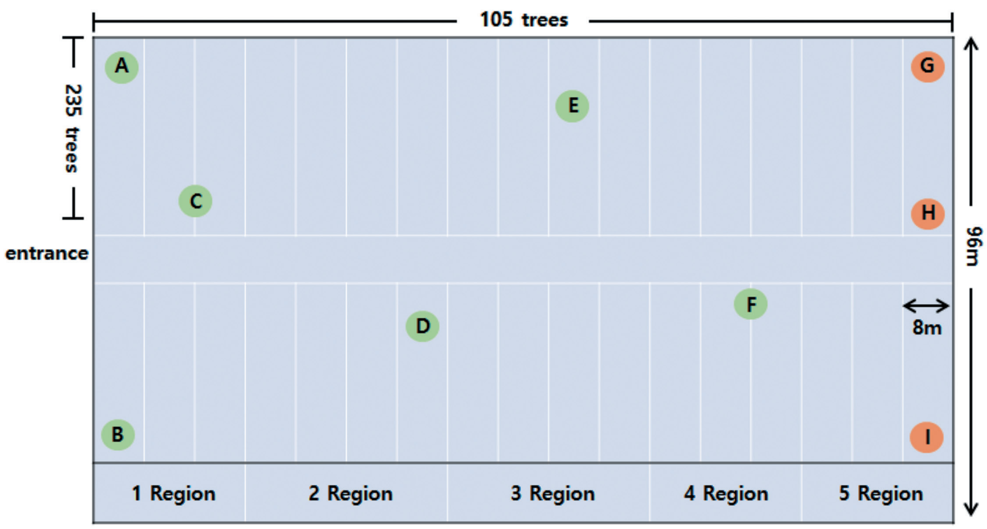

Fig. 1. Experiment section of the occurrence region of *L. taurica* (A–F), *B. tabaci* and *A. gossypii* (G–I).

20–60 μm at the low water pressure of 2–6 kg f/cm^2 so that the ground is hardly wetted and it has an advantage of enabling repairs by farms, as its nozzles can be easily replaced.

Examination of pesticide deposit degrees and quantities of active components according to spraying equipment units

To examine the pesticide deposit degrees and quantities of active components, the test field was divided into experimental sections according to the occurring pests (Fig. 1) and Air Fog conditions were set for all experimental sections. Before spraying the chemicals, water–sensitive papers (52 × 76 mm, TeeJet Tech. Switzerland) and α–cellulose patches (Whatman 17CHR, 46 × 57 cm, Cat. No.3017–915) were installed (Table 2, Fig. 2). Paprika trees were arbitrarily divided into upper, middle, and lower parts and the water–sensitive papers were attached to the front and rear of leaves in each part so that to judge whether or not the pesticides were deposited according to the degree of coating of the water–sensitive papers after pesticide spraying. The α–cellulose patches for examination of quantities of active components of pesticides were cut to 10cm–sized patches and fixed into previously prepared aluminum foils. The patches were collected when the chemicals had been completely sprayed and stored at −20°C until they were analyzed. The analysis was conducted by the Department of Bio Environmental Chemistry, Chungnam National University, using the following analysis instruments: HPLC Hewlet Packard 1090 (USA) and LC/MS Shimadzu 2020 (Japan).

Examination of pest control effects

To examine *B. tabaci* and *A. gossypii* control effects, the densities of these pests were examined through visual examinations before chemical treatments. Pyrifluquinazon 6.5% SC (brand name: Fanfare S) was diluted to the concentration recommended by the pesticide use Guidelines of the Rural Development Administration (2016) and was sprayed as a diluted spray solution that meets the safe use standard. The degree of occurrence of at least 50 pests per repetition before the chemical treatment and live pest counts were examined before the chemical treatment, as well as 24 hours and 72 hours after the chemical treatment to calculate control

Table 2. Airfog and experiment conditions of paprika cultivation

Region	Block	Area (pyeong)	Nozzle No.	Application dose (L/min)	Spraying time (min/10 a)	Total application dose (L/10 a)	WSPNo.※	α–cellulose patch No.
1	3	720	240	32	15	480	54	54
2	4	960	320	43	15	640	18	18
3	4	960	320	43	15	640	18	18
4	3	720	240	32	15	480	18	18
5	3	720	240	32	15	480	54	54
Total	17	4,080	1,360	181	75	2,720	162	162

※ Water–Sensitive Paper (WSP) results were randomly divided into good, fair, and poor according to wet the pesticide dose.

Fig. 2. Test preparation on the application potential of Airfog in paprika cultivation.

values. The chemical treatment against *L. taurica* was conducted by spraying the chemicals to foliage three times at the intervals of 10 days while covering the crops in the untreated plots using vinyl to prevent chemical deposit. Fluopyram 40% SC (brand name: Mercury) was diluted to the concentration recommended by the pesticide use Guidelines of the Rural Development Administration (2016) and was sprayed as a diluted spray solution that meets the safe use standard. The *L. taurica* diseased leaf rate of the untreated plots was 52.2%, indicating that the chemicals had sufficient effects and the diseased leaf rates of paprika per repetition were examined to calculate the control values.

α–cellulose patch analysis condition

To analyze the effectiveness of the pesticides, Pyrifluquinazon 6.5% SC and Fluopyram 40% SC attached to the patches were extracted. The aluminum foils and pockets enclosing the cellulose patches were removed and the weights of patches were measured. Thereafter, individual patches were quickly put into 500 ml volume glass jars containing acetonitrile including 40 ml of 0.1% formic acid, sealed with Teflon cover, and shaken for 1 hour in a shaker maintained at 10°C. For further analysis, the solution was filtered through 0.45 μm PTFE syringe filters before being used as analysis samples. Hewlett Packard SeriesII 1090 (USA) and Shimadzu LC/MS–2020 (Japan) were used as analysis instruments; the detailed analysis conditions are shown in Table 3.

RESULTS AND DISCUSSION

Pesticides used to control pests in crops are widely used for diverse purposes, such as quality enhancement and harvest storage. However, if appropriate quantities of the pesticides do not come into contact with pests, biological effects cannot be expected. Improper pesticide use and control methods promote the expression of pests' resistance. In recent years, crops such as paprika, cucumber, strawberry, tomato, and melon have started to be repeatedly cultivated all year round in protected cultivation facilities in South Korea. Therefore, pest developments increase day by day. In particular, pests are prolific, since they can repeat their life cycles all year round, leading to severe damage. To remove these pests, diverse kinds of sprayers, including high pressure type sprayers and mobile sprayers, are used in cultivation facilities. In addition, it is well known that the numbers of diverse minute pests have been recently increasing due to the subtropical climate and cultivation under structure environments. These minute pests avoid pesticides by hiding themselves in flowers or the rear of the leaves where pesticides cannot reach them and develop their resistance against pesticides. Therefore, pesticides should be evenly sprayed, including the habitats of pests, such as the inside of flowers, the rear of leaves, and high crops, so that the pests die completely at once to prevent the pests from developing into resistant pests. Therefore, since unmanned fogging machines ensure that the same quantities of pesticides are deposited anywhere in the areas of cultivation under structure, tests were conducted to satisfy the necessary and sufficient condi-

Table 3. The HPLC and LC/MS conditions for the analysis of Pyrifluquinazon and Fluopyram

HPLC	Instrument	Hewlett Packard SeriesⅡ 1090 (USA)
	Column	Phenomenex, Kinetex 2.6 μm C18 100A, (100 mm × 4.6 mm)
	Oven Temp.	30°C
	Injection Volume	10 μl
	Run time	5 min
	Flow rate	0.7 ml/min
	Mobile phase	Acetonitrile with 0.1% formic acid : 0.1% formic acid Water/ 60:40 (v/v)
MS	Instrument	Shimadzu LC/MS–2020, Japan
	Tuning Mode	Auto
	Acquisition Mode	SIM (Positive)
		Ion Monitored; Pyrifluquinazon: 465 m/z, Fluopyram: 397 m/z
		Retention time: Pyrifluquinazon: 1.96 min, Fluopyram: 3.48 min
	MS–ESI	Interface ESI
		Detector Voltage 1.30 kv
		Interface Voltage 4.50 kv
		DL temp. 250°C
		Heat block Temp. 200°C
		Nebulizing gas 1.5 l/min
		Drying gas 15 l/min

tions. In the tests, we checked whether or not pesticides were deposited at different locations along the plant lengths of the target crops following spraying by unmanned controllers; furthermore, the quantities of active components of the deposited pesticides and the resultant pest control effects were reviewed.

Spraying by unmanned controllers and degrees of deposit on water–sensitive papers

The high–pressure type sprayers generally used in protected cultivation facilities have several shortcomings, such as large particles that make the chemicals flow along leaves so that the traces of chemicals gathered at the ends of leaves are found and no deposit on the rear of leaves so that no control effect would appear. By contrast, unmanned controllers have the advantages of using ultra–fine particle spraying methods to save chemicals and enhance the degrees of deposit of chemicals in all parts of crops, thereby reducing the rate of loss to the ground. To measure the degrees of deposit following unmanned controller's pesticide spraying, water–sensitive papers were attached to the front and rear of leaves in all parts of paprika trees divided into the upper, middle, and lower parts; after spraying, all water–sensitive papers turned blue (Table 4). Water–sensitive papers in the treated plots showed a degree of deposit of 100% and all pesticides were efficiently deposited in the plots treated with the unmanned controller.

Pest control effects of pesticide spraying

The pest control effects of pesticide spraying using an unmanned controller were examined by spraying Pyrifluquinazon 6.5% SC in the sections where *B. tabaci* and *A. gossypii* occurred and the control effects were examined. When all experimental sections showed the degree of pesticide deposit of 100%, *B. tabaci* control effects were shown to be ca. 77.5% in 24 hours later and ca. 96.4% in 72 hours (Table 5). *A. gossypii* control effects were shown to be ca. 77.56% in 24 hours and ca. 97.3% in 72 hours (Table 6). Therefore, our results suggest that, even if pesticides are not sprayed to the extent that they flow down using high pressure type controllers, high control effects can be obtained if pesticides are sufficiently deposited on crops using unmanned controllers.

***Leveillula taurica* control effects of pesticide spraying**

L. taurica that occurs in paprika is the most problematic disease of crops in protected cultivation facilities and is, unlike other *Leveillula taurica* bacteria, endoparasitic. Since *L. taurica* cannot be diagnosed with the naked eye, as it occurs on the rear of leaves at the beginning, appropriate time for control can be easily missed and it can be controlled only when pesticides reach the rear of leaves. The *L. taurica* control effects of pesticide spraying using an unmanned controller were examined by spraying Fluopyram 40% SC in sections A–F and analyzing diseased leaf rates by plot 7 days after the final pesticide spraying. Whereas as the diseased leaf rate of the untreated plots was 52.2%, the diseased leaf rate of the treated plots was 8.8%, indicating that the control value was at least 83.2% (Table 7).

Table 4. Water–Sensitive Paper (WSP) assay for the section of the automatic control system (Airfog)

Pesticide type	Component	Section	Change of WSP (good, fair, and poor)
Fungicide	Fluopyram 40% SC	All	good 
Insecticide	Pyrifluquinazon 6.5% SC		

Table 5. Mortalities of *B. tabaci* in each section of the automatic control system (Airfog)

Pesticide type	Component	Target pest	Section	Mortality (%)	
				24 hr	72 hr
Insecticide	Pyrifluquinazon 6.5% SC	*B. tabaci*	A	79.1	95.3
			B	85.3	95.7
			C	75.3	94.6
			D	61.0	93.5
			E	63.7	96.7
			F	71.7	97.6
			G	81.2	97.4
			H	91.4	100
			I	88.4	96.3

Table 6. Mortalities of *A. gossypii* in each section of the automatic control system (Airfog)

Pesticide type	Component	Target pest	Section	Mortality (%)	
				24 hr	72 hr
Insecticide	PPyrifluquinazon 6.5% SC	*A. gossypii*	A	80.6	100
			B	87.8	97.8
			C	62.9	96.1
			D	77.2	93.9
			E	73.8	95.2
			F	75.5	100
			G	80.1	97
			H	84.3	100
			I	75.8	95.8

Table 7. Diseased leaf and control value of *L. taurica* in each section of the automatic control system (Airfog)

Pesticide type	Component	Target disease	Section	Diseased leaf (%)	Control value (%)
Fungicide	Fluopyram 40% SC	*L. taurica*	A	8.7	83.4
			B	12.7	75.7
			C	9.3	82.1
			D	7.3	86
			E	5.3	89.8
			F	9.3	82.1
			Con	52.2	0.0

Table 8. Attached amounts of Fluopyram 40% SC and Pyrifluquinazon 6.5% SC on paprika in accordance with the spray water volume

Component	Position of leaf	Amount of compound (μg/50 cm^2 patch)			Average (μg/50 cm^2)
		High	Middle	Low	
Fluopyram 40% SC	Front	1.27	1.31	1.32	1.30
	Back	2.54	0.26	0.34	1.05
Pyrifluquinazon 6.5% SC	Front	0.57	0.65	0.65	0.62
	Back	1.30	0.07	0.11	0.49

The quantities of active components of pesticides following spraying using an unmanned controller

Since the degree of deposit of pesticides on crops in the sections where pesticides were sprayed using unmanned controllers can greatly affect pest control, the quantities of active components were examined using patches made of α–cellulose paper. According to the results, chemical effects persisted when the quantities of active components on the front and rear of the leaves were on average 1.30 (μg/50 cm^2) and 1.05 (μg/50 cm^2), respectively, in the case of spraying of Fluopyram 40% SC and when the quantities of active components on the front and rear of the leaves were on average 0.62 (μg/50 cm^2), 0.49 (μg/50 cm^2), respectively, in the case of spraying of Pyrifluquinazon 6.5% SC; the overall deposit amounts on the front and rear were not considerably different (Table 8). Therefore, both pesticides were evenly sprayed on the front and rear of leaves and the chemical effects persisted resulting in high pest control values. Since the development of unmanned controllers for safe use of pesticides and efficient pest control in facilities can enhance control efficiency and reduce the number of times of control, as well as the amount of used pesticide and residual pesticides, further research is needed for the standardized development of unmanned controllers.

AUTHOR CONTRIBUTIONS

You Kyoung Lee designed the study, performed the overall experiments, analyzed the data and wrote the paper. Na Young Jin and Yu Seop Kim performed the Pest control effects of pesticide spraying experiments. Hee Ji Kim and Young A Hur performed the *L. taurica*

control effects of pesticide spraying experiments. Young Shin Kim and Chi Hwan Lim conducted the total active ingredients of pesticides analyses. Young Nam Youn edited the paper. Chisa Yasunaga–Aoki participated in the design of the study and discussed on the experiments and the results. Yong Man Yu supervised the work and wrote the paper. All authors assisted in editing of the manuscript and approved the final version.

ACKNOWLEDGEMENTS

The present study was conducted within the framework of the "Standardization of pesticide spraying devices and methods and grouping of pesticide product containers and formulations" project (No. PJ010043) funded by the Rural Development Administration.

REFERENCES

Jin, N. Y., Y. K. Lee, B. R. Lee, J. H. Jun, Y. S. Kim, M. J. Seo, C. H. Lim, Y. N. Youn and Y. M. Yu 2014 Pest control effect and optimal dose by pesticide dispersion spray method in the paprika cultivation. *Kor. J. Pestic. Sci*. **18**: 350–357

Jin, N. Y., Y. K. Lee, B. R. Lee, Y. S. Kim, H. J. Kim, Y. S. Kim, C. H. Lim, Y. N. Youn, C. Yasunaga–Aoki and Y. M. Yu 2016 Optimum spray method for paprika cultivation sites under structure and pest control effects according to spray water volumes. *J. Fac. Agr., Kyushu Univ*., **61**: 95–101

Kang, T. J., S. J. Kim, D. H. Kim, C. Y. Yang, H. H. Kim and M. R. Cho 2014 A report on the control effects of automatic dry fog sprayer on aphids in greenhouse crops. *Korean J. Appl. Entomol*., **53**: 479–483

Kim, N. K. 2011 Monitoring of neonicotinoid pesticide residues in paprika using UPLC–MS/MS from Gyeongnam region. *Korean J. Pesti. Sci*., **15**: 15–21

Kim, K. D., S. W. Lee, E. H. Kang, Y. G. Shin, J. Y. Jeon, N. Y. Heo and H. S. Lee 2013 The pests survey of paprika export complexes and packing house in Korea. *CNU. J. Agricul. Sci*., **40**: 93–99

Lee, D. Y., Y. J. Kim, S. G. Kim and K. Y. Kang 2013 Residual characteristics of insecticides used for oriental tobacco budworm control of paprika. *Korean J. Environ. Agric*., **32**: 84–93

Lee, J. H., K. S. Han, D. W. Bae, Y. S. Kwon, D. K. Kim, K. Y. Kang and H. K. Kim 2010a Emulsification characters of COY (Cooking Oil and Egg Yolk Mixture) and mixing application with sulfur wettable powder for enhancing the control efficacies against paprika *Leveillula taurica*. *Res. Plant Dis*., **16**: 74–80

Lee, J. Y., W. J. Choe, H. J. Lee, Y. W. Shin, J. A. Do, W. S. Kim, D. M. Choi, K. R. Chae and C. S. Kang 2010b Research on pesticides residue in commercial agricultural products in 2009. *J. Fd Hyg. Safety*., **25**: 192–202

Nam, S. W., Y. S Kim, I. M. Sung and G. H. Ko 2012 Cooling efficiency of low pressure compressed air fogging system in naturally ventilated greenhouses. *Journal of the The Korean Society of Agricultural Engineers*, **54**: 49–55

Seo, M. J., N. Y. Jin, Y. K. Lee, J. H. Jun, Y. S. Kim, B. R. Lee, Y. S. Kim, C. H. Lim, Y. N. Youn, C. Yasunaga–Aoki and Y. M. Yu 2015 Optimal use of pesticides for controlling insect pests in apple orchards. *J. Fac. Agr., Kyushu Univ*., **60**: 363–370