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REVIEW
Study on Electrostatic Pesticide Spraying System for Low-Concentration, High-Volume Applications

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Abstract
We have developed an electrostatic pesticide spraying system for low-concentration, high-volume applications to reduce vegetable production costs through savings in agricultural chemical usage and working hours for pest control. The electrostatic spray charging device (ESCD) has an outer annular induction charging electrode around a hydraulic nozzle with a high flow rate. The charge-to-mass ratio of spray droplets was -0.30 to -0.45 mC/kg at +4 kV, using a hollow-cone nozzle with a high flow rate delivering 1.0 to 2.6 L/min. No discharge or electric leakage occurred from the electrode. Using this device, we developed two types of sprayers. One type was an electrostatic boom-type sprayer for cabbage vegetables. Field tests showed that this boom-type sprayer reduced the amount of required pesticide application by 30% as compared to the conventional method.
The other type was a spraying robot for greenhouse melons. There was no significant difference in the control of insect pests between robot spraying and the conventional manual spraying method. The effective field capacity of the robot was 3.8 a/h.

Discipline: Agricultural machinery
Additional key words: sprayer, vegetable

Introduction

To ensure the stability of food supplies, it is essential to protect vegetable crops from destructive pests. In Japan, pesticides in the form of wettable and water-soluble powders, suspensions, and emulsions are commonly used for vegetable production in fields and greenhouses. Sprayed pesticides are applied with 500- to 5,000-fold dilution in water, according to relevant agricultural chemical regulations. The diluted pesticides are sprayed through nozzles using powered pumping equipment. The volume application rate of pesticide is generally large in Japan, in contrast with Western countries where low and ultra-low volume spraying are commonly used. Farmers need access to spray equipment that will allow them to reduce the volume application rate of pesticides by enhancing the adherence performance of the spray droplets.

One of the advanced technologies available to reduce application doses is electrostatic spraying (Law, S.E. 2001). Electrostatic spraying, however, does not deliver good droplet adherence performance in high-volume applications due to the difficulties in charging the droplets. Almost all types of widespread electrostatic sprayers used in Europe and the USA are applied to low and ultra-low volume applications (Law, S.E. and Bowen, H.D. 1966, Marchant, J.A. and Green, R. 1982).

To address these problems, we developed an electrostatic spray charging device that will deliver high adherence performance for low-concentration, high-volume applications. Using this device, we developed two types of sprayers: a boom-type field sprayer for cabbages and a greenhouse spraying robot for melons.

This review describes the development and advantages of electrostatic pesticide spraying systems intended to reduce the volume of pesticide application, as well as to improve working conditions.

Development of electrostatic spraying equipment for high-volume application (Yamane, S. and Miyazaki, M. 2008)

An electrostatic spray charging device (ESCD) was

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designed for high-volume application, and it incorporated an outer annular induction charging electrode around a hydraulic nozzle with a high flow rate (Fig. 1). Efficient induction charging was achieved at low voltage in a high humidity and dusty environment. The open section on the side of the ESCD generated an air stream via suctioning at the nozzle tip. This air stream protected the electrode against adhesion by spray droplets that could cause undesirable corona discharge.

In order to evaluate the charging performance of the ESCD, we measured the charge-to-mass ratio (CMR) of spray droplets. When the voltage applied to the electrode was gradually increased to +4 kV, the CMR of spray droplets increased without discharge or electric leakage from the electrode. Conversely, the CMR decreased when the applied voltage exceeded +6 to 8.5 kV. The CMR was constantly higher when using hollow-cone spray nozzles instead of flat-fan spray nozzles (Fig. 2). The CMR decreased by 13

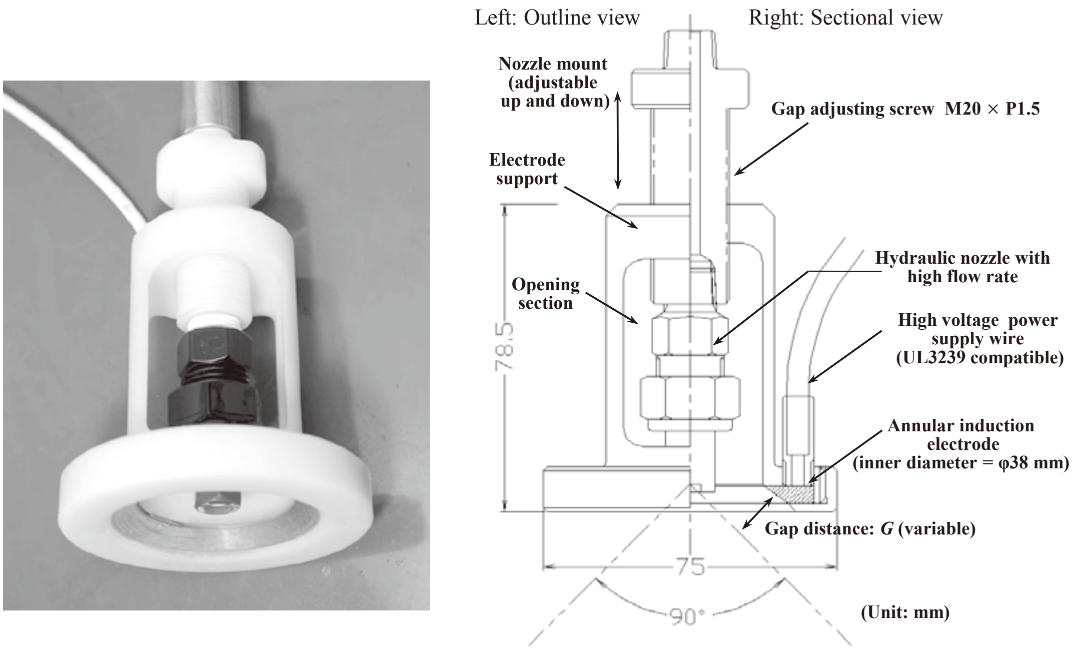

Fig. 1. Electrostatic spray charging device (ESCD)

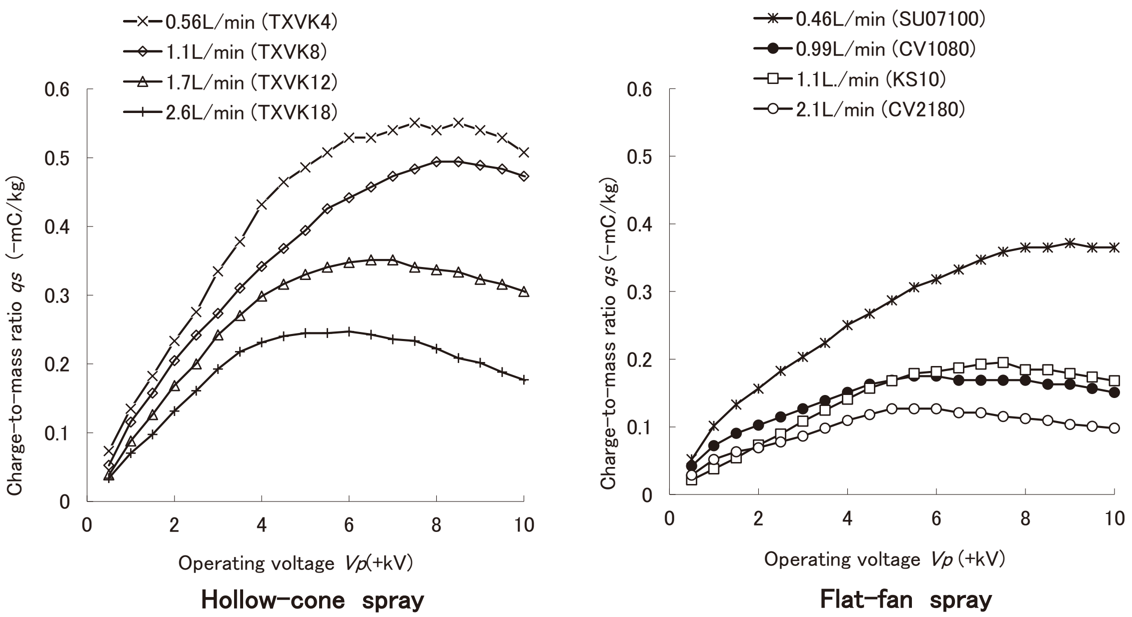

Fig. 2. Relationship between operating voltage and charge-to-mass ratio (Nozzle operating pressure: 1.5 MPa)

to 18% when the gap between the spray cone and electrode was increased by 1.6 mm. The CMR obtained by this system was -0.20 to -0.45 mC/kg at +4 kV with the hollow-cone nozzle having a high flow rate of 0.56 to 2.6 L/min.

Effects of electrostatic spraying system for high-volume application

1. Effect on pest control for cabbage in fields (Yamane et al. 2010a)

(1) Electrostatic boom-type sprayer

In Japan, pesticide spray can be applied up to seven times in cabbage production during the growing period from autumn to winter, with an application rate as high as 200 L/10a. Farmers need an application-efficient sprayer to minimize environmental impact and reduce pesticide costs. Therefore, we designed an electrostatic boom-type sprayer with the ESCD that could replace the original nozzle (Fig. 3).

(2) Advantages for cabbage production in the field

Laboratory experiments were conducted to confirm the adherence performance of the spray generated using the ESCD on cabbages compared with that of the original nozzle; however, the influence of wind in the field was not considered. The adherence properties were investigated using water-sensitive paper placed on an artificial cabbage crop.

The electrostatic spraying method showed the increased adherence of fine-grain droplets (Fig. 4). The coverage rates obtained for different parts of artificial cabbage crops were examined. On the side of cabbage heads, the electrostatic method delivered up to 50.4% coverage as compared with 30.5% from a non-electrostatic spraying method at the same application rate of 140 L/10a. More-

Fig. 3. Boom-type electrostatic sprayer
7.4 kW gasoline engine, Nozzle span: 300 mm, Spraying width: 15 m, Nozzle operating pressure: 1.5 MPa, Nozzle flow rate:1.7 L/min., Hollow-cone spray:VMD 112 µm

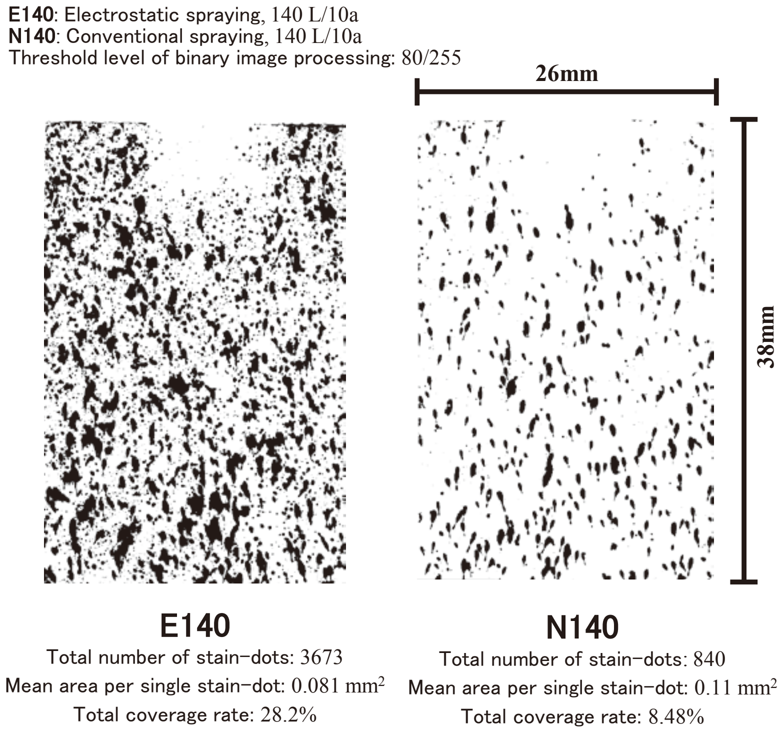

Fig. 4. Distribution of stain-dots on water-sensitive paper attached to vertical surface of an artificial cabbage head

over, the electrostatic method showed a smaller coefficient of variation for the coverage rate, and pesticide deposition was also more uniform.

A field experiment was conducted to determine the corrected density indexes of insect pests after spraying, as well as the cabbage crop yield and quality compared with a conventional spray. The field experiment was conducted in an actual cabbage field at the Shizuoka Prefectural Research Institute of Agriculture and Forestry from April to December 2007.

The electrostatic method, with an application rate of 140 L/10a, produced no significant difference in the density of insect pests on cabbage compared to the conventional method at 200 L/10a. Therefore, the test could not confirm the superiority of electrostatic spraying on the insect pest control effect. The cabbage crop quality and yield were the same for both spraying methods (Table 1).

2. Effects on pest control for melons in greenhouses (Yamane et al. 2010b)

(1) Electrostatic spraying robot

There has been a recent trend in Japan toward the large-scale production of melons in greenhouses measuring 20 to 30 a. With regard to pest control, power sprayers with long hoses are widely used by hand, but require a large amount of labor and working in enclosed and hot workplaces. Farmers need a robotic sprayer that requires no operator and which delivers higher performance in the adherence of pesticide to crop leaves than that afforded by conventional methods.

We consequently designed an electrostatic spraying robot for large-scale melon greenhouses. The spraying robot was equipped with ESCDs, along with airstream suction at the nozzles to prevent electrical leakage from the electrode and undesirable corona discharge through the adherence of droplets. The robot was equipped with a total of eight electrostatic spraying nozzles (at a per-nozzle discharge rate of 0.56 L/min. and CMR of -0.45 mC/kg), along with a liquid chemical tank having a capacity of 180 L. The robot was an electric vehicle that traveled without an operator along magnetic tape placed on the floor of a greenhouse (Fig. 5).

(2) Advantages for greenhouse melon production

An experiment was conducted to determine the remaining number of “*Thlips palmi* KARNY” insect pests after spraying chemicals, and the yield and quality of melons as compared with non-electrostatic spraying. The experiment was conducted in an actual melon greenhouse at the Shizuoka Prefectural Research Institute of Agriculture and Forestry in 2009.

The spray deposition indexes on the abaxial surface of

Table 1. Yield and quality of cabbage crops (Autumn, 2007)

Sprayin method	Applicaton rate(L/10a)	Yied(g/head)	Salable rate(%)
Electostatic spraying	140	1565	95.0
Conventional spraying	200	1566	96.7
Control	−	1604	16.7

-60 samples per plot


Fig. 5. Electrostatic spraying robot for melon greenhouses
24 VDC battery drive, 1880 (D) ×610 (W) ×1980 (H) mm, Weight: 315 kg, 8 nozzles,
Nozzle operating pressure: 1.5 MPa, Nozzle flow rate: 0.56 L/min., Hollow cone spray, VMD = 96 µm

leaves located in front of the melon crop after electrostatic spraying were twice as high as those for non-electrostatic spraying (Fig. 6). At the back of the melon crop, deposition indexes for the electrostatic method were significantly higher than those for the non-electrostatic method. There was no significant difference in the control of insect pests between the robotic and conventional manual spraying methods (Table 2).

In the field test, the robot could apply pesticide stably without the need for an operator, by being guided on magnetic tape on the greenhouse floor. The effective field capacity of the robot was 3.8 a/h at an application rate of 450 L/10a. This result indicated that the system improved both spray deposition and work efficacy.

Conclusions

We developed an electrostatic pesticide spraying system for low-concentration, high-volume applications with the following features:

(1) An ESCD was developed, featuring an outer annular induction charging electrode around a hydraulic nozzle with a high flow rate. The CMR of spray droplets was -0.30 to -0.45 mC/kg at +4 kV. A hollow-cone nozzle with a high flow rate delivered 1.0 to 2.6 L/min. without discharge or electric leakage from the electrode.

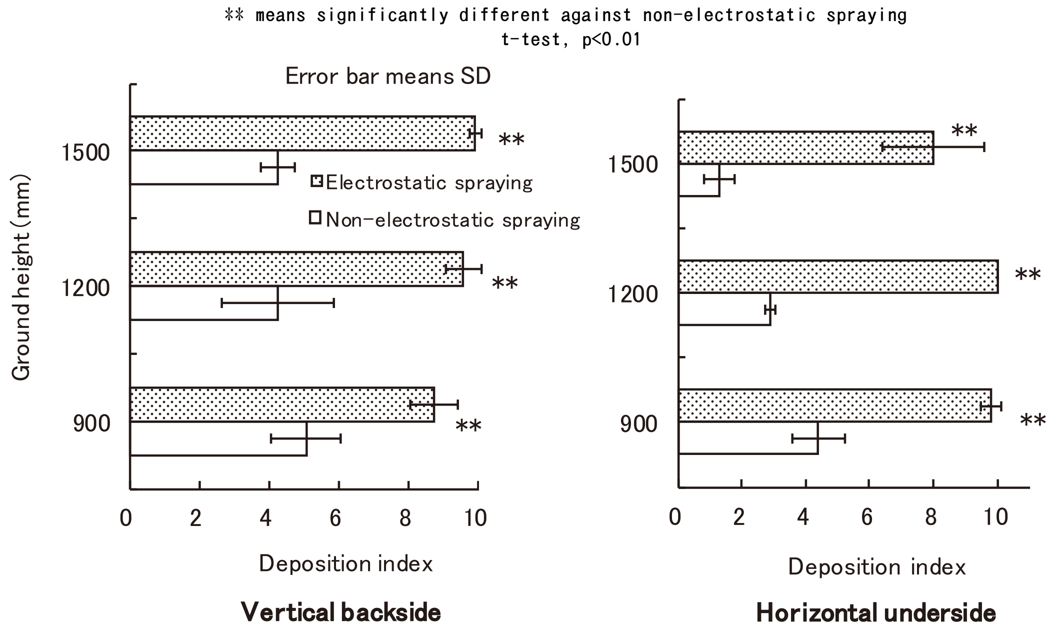

Fig. 6. Measured deposition indexes at various heights in front of melon community
(Spray distance: 310 mm)

Table 2. Control effect of the electrostatic spraying robot on "*Thlips palmi KARNY*" insect pests

Spraying method	The day before		3 days after		6 days after	
	Number of insects heads 1)	SD	Number of insects heads 1)	SD	Number of insects heads 1)	SD
Manually spraying (Conventional)	43.2	15.8	1.5 a	1.2	1.1 a	1.1
Electrostatic spraying (with robot)	45.3	16.6	3.5 a	2.3	3.6 a	3.0
Non electortatic spraying (with robot)	43.7	15.1	8.1 b	5.8	10.0 b	6.7
Control	44.1	13.5	35.7	18.8	32.8	23.5
ANOVA	n.s.		*		**	

1) Total heads of *Thrips palmi* KARNY larva infested on three melon leaves.
* means in each column followed by a common letter are not significantly different, p<0.05, Tukey's method.
** means in each column followed by a common letter are not significantly different, p<0.01, Tukey's method.

(2) An electrostatic boom-type sprayer equipped with the ESCD was developed and tested in cabbage fields. The field tests showed that this boom-type sprayer could reduce the amount of required pesticide application by 30%. There was no significant difference in the density of insect pests on the cabbages between electrostatic spraying and the conventional method. The quality and yield of cabbage crops were the same for both spraying methods.

(3) A spraying robot equipped with the ESCD for greenhouse melons was developed and tested in a melon greenhouse. There was no significant difference in the effect of controlling insect pests between robot spraying and the conventional manual spraying method. The effective field capacity of the robot was 3.8 a/h.

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