Agri. & Biosys. Eng. Vol. 3(1):29-34(2002)

Evaluation of the Induction and Ionized Field Charging Methods for Electrostatic Nozzles of Orchard Sprayer

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Abstract: Two charging methods of electrostatic nozzle, i.e. induction and ionized field corona charging, were designed and evaluated for orchard sprayer application. An artificial (metallic) target was constructed and used in this experiment. The charge-to-mass ratio for the induction electrode was measured by using the Faraday cage. Two conventional pressure-swirl nozzles have been employed with different orifice diameters under the same experimental operating conditions. A commercial pressure-swirl nozzle with orifice diameter of 1.0 was used for the conventional spray. The diameter of the electrostatic was 0.59 mm. The experiment was carried out for individual nozzle sprays at 0°, 20° and 50° oriented angles and three nozzles, sprayed simultaneously at a distance of 1.0 and 2.0 m from the nozzle tip to the target. The nozzles were mounted on a carriage with constant speed of 1.26 km/h with a blower attached. The weighing method was employed to evaluate for the spray deposition, ground loss and estimated drift. The results show more promising for the induction charging method, especially at 20° oriented angle at a distance of 1.0 m from the target for a single nozzle and when all three nozzles were operated simultaneously for spray deposition. The results of the induction charging method show promising with the developed electrostatic technique.

Keywords: Agriculture, Charging method, Electrostatic, Evaluation, Orchard sprayer

Introduction

Applications of electrostatic atomization and spray in the field of agricultural spray have been studied (Splinter, 1968; Peter Castle and Inculet, 1983; Law et al, 1985; Law and cooper, 1987; Law and Cooper, 1988; Law, 2001). In agricultural spray, there have been some attempts to exploit this technology (Law, 2001). However, the difficulties involved in order to efficiently disperse and deposit the charged droplet onto target areas had not yet been successfully addressed. The major objectives of this application is to get the great benefits such as reduction of toxic active ingredients entering the environment, deposition reliability and even coverage upon complex targets and under-leaf parts where the conventional method found them impossible to reach.

Methods of charging in agricultural sprays include, induction charging, air-assisted induction charging, ionized field (-corona) charging, direct (contact) charging and combined induction charging with ionized field charging. The selection of the charging method depends upon the electrical properties of the pesticide. Most chemicals used in agricultural fields are classified as water-based (aqueous) emulsions or wettable suspensions, having their electrical resistivities in the ranges of 10^{1} to 10^{4} Ωm. Most studies on the electrostatic sprays for agricultural application focused on the twin-fluid nozzle Law, 1978; flat fan, Marchant et al. 1985 and spinning disc, Gupta and Duc 1996. Although, studies have been done on different nozzles, still there remain some difficulties to apply spray on tall trees in orchard. One of the main factors that have been considered in electrostatic sprays is the transportation of the charged droplet to reach to the plant canopy.

Recently, Laryea et al, (2001) and Laryea and No (2001) have studied the spray characteristics of a pressure-swirl nozzle and evaluated the charged spray deposition to apple trees as target in the laboratory by employing the induction charging method. The charged spray from the experiment gave a promising data due to high rate of deposition at the underside of the

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leaves where most insects reside.

The objective of the study was to evaluate the induction and ionized field charging methods for selecting a suitable electrostatic nozzle for an orchard sprayer.

Materials and Methods

Tap water without surfactant was used as a test liquid and its physical and electrical properties are shown in Table 1. The liquid was discharged from a 3-plunger reciprocating pump through a pressure-swirl nozzle. Two charging methods, the induction and ionized field corona were used in this study.

Table 1 Physical and electrical properties of the tested liquid at 25℃

Electrical conductivity (S/m)	4.5×10^{5}
Electrical permittivity (C^2/Nm^2)	7.08×10^{-10}
Surface tension (N/m)	74×10^{3}
Dynamic viscosity (kg/m s)	91×10^{-3}
Density (kg/m^3)	998

The two definitions used for measuring spray charges are the charge-to-mass ratio (Machowski et al., 1997), and the specific charge (Jahannama et al., 1999). The definitions are characterized by the mass and volumetric flow rate respectively.

$$q/m = i / Qm \qquad (1)$$

where (q/m) – charge-to-mass ratio (mC/kg),
i – spray current (A),
Q_m – mass flow rate (kg/s).

The charge-to-mass ratio for the induction type was measured by using the Faraday cage and Keithley electrometer similar to as described by Laryea et al. (2001). For the conventional spray, pressure-swirl nozzle with orifice diameter of 1.0 mm was used while nozzle with orifice diameter of 0.59 mm was selected for the electrostatic application. The small orifice diameter was used for the electrostatic nozzle in order to reduce the liquid flow rate and also to obtain an optimum charge on the droplet.

The operating pressure of 2.0 MPa was selected as the normal operating pressure used by the orchard sprayer (speed sprayer) that is much familiar in Korea and Japan as stated by Park et al., 1997. An experimental boom sprayer was driven on a carriage (with a traverse span of 3.5m) at a constant velocity of 1.26km/h. The nozzle was oriented individually at angles; 0°, 20°, 50° for each application and all the three nozzles were applied simultaneously. The experiment was performed at a temperature between 28~36℃ and humidity in the range of 50~86%.

4 kV was applied to two experimental methods with different polarities (positive for the induction type and negative to the ionized field corona type) while the liquid and target grounded. The distance from the center of the sprayer to the center of the tree is 1.7 m, therefore a distance of 1.0 and 2.0m from the tip of the nozzle to the target was used for the experiment.

Figs 1 and 2 show the developed induction and ionized field corona charging type electrodes with a pressure-swirl nozzle (orifice diameter of 0.59 mm). inserted. The fixed operating pressure of 2.0 MPa was applied mostly to the orchard sprayer. The weighing technique used by Laryea et al. (2001) was employed to evaluate the deposition, the ground loss and the estimated drift. The target stem was covered with a water-resistance material to allow non-target sprays to drop on the spray tray thus considered as ground loss. The spray deposition on the target was weighed directly by an electronic scale while the ground loss was collected in the spray tray also on another weighing scale with a 1g resolution. The drift was

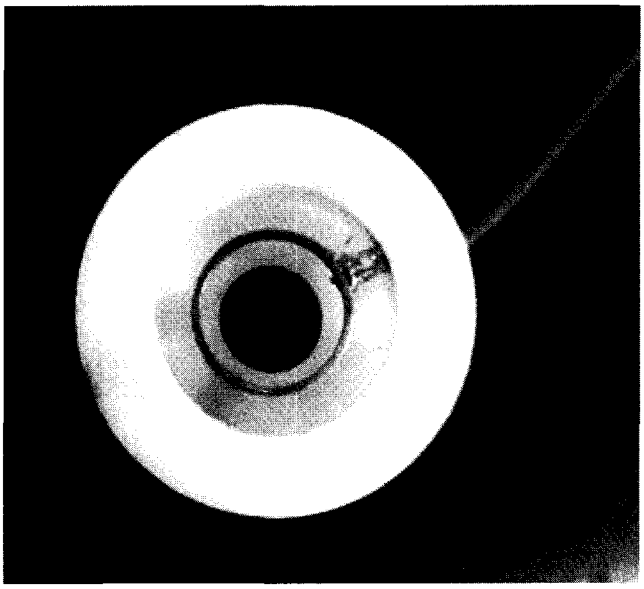

Fig. 1 View of the induction charge electrode.

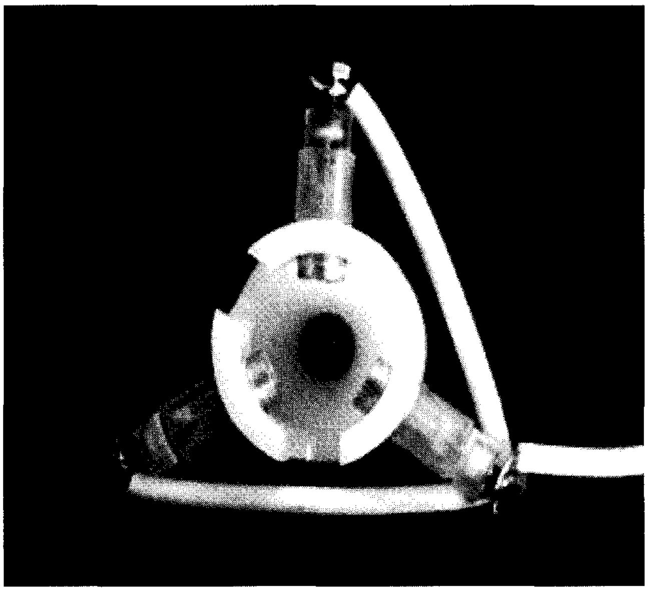

Fig. 2 View of the ionized field corona charge electrode.

assumed to be the difference between the summation of the target deposition and ground loss to the total mass sprayed liquid.

A blower with an air flow rate of $1m^3$/min and air velocity of 8.5m/s was used in the experiment in order to accelerate the transportation of the droplet onto the target. Three-level aluminum targets modeled as a prototype was used to evaluate the deposition coverage for the induction and ionized field charging methods. The aluminum sheets used as leaves were copied from original apple tree from the Apple Research Center, Taegu, Korea. They were of five different sizes and evenly distributed on all the three level (top, middle and bottom) of the branches of the target. The experiment for the measurement of spray deposition was repeated ten times. A schematic diagram of the experimental apparatus is shown in fig. 3.

An analysis of variance (ANOVA) was performed to determine significant difference within and among the means. Spray deposition, ground loss and estimated drift were analyzed and standard deviation calculated.

Results and Discussion

1. Charge-to-mass ratio

It is clear from fig. 4 that the charge-to-mass ratio increases to a peak (critical applied voltage) and then begins to decline as applied voltage was increased. This explains the occurrence of corona discharge causing the spray to become less chargeable. At this point, further increase in the applied voltage becomes useless.

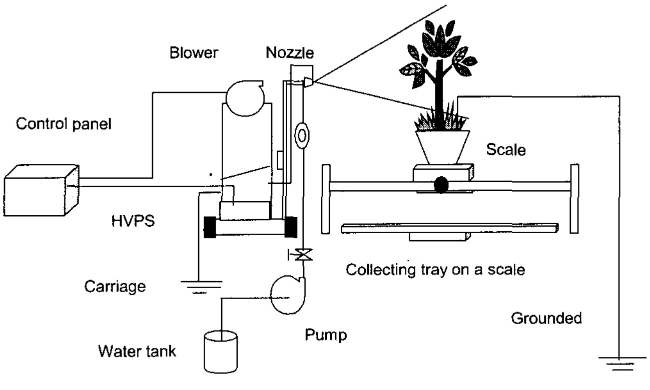

Fig. 3 A schematic diagram of the experimental apparatus.

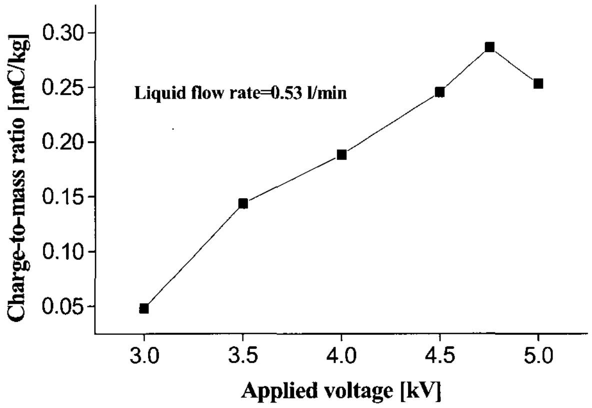

Fig. 4 Charge-to-mass ratio versus applied voltage.

2. Spray deposition (%)

With individual spray nozzle at a distance of 1.0 m from the target, the induction charge nozzle at 20° orientation showed the highest deposition rate. At a distance of 2.0 m from the target, the same charging nozzle at the same 20° orientated angle yielded a higher deposition. The distance effect on the deposition was reduced by 30% for the induction charge method as compared with 5% reduction for the ionized field corona charge method.

When all three nozzles were operated, the induction charge nozzle at 1.0 m gave a higher spray deposition than the ionized field corona type. An efficient deposition was collected for the induction charge type at oriented angle of 20° at a spraying distance of 1.0

Table 2 Spray coverage [%] at 0° orientated angle

Distance (m)	Method of Application	Deposition		Ground loss		Estimated drift		Total
		Rate (%)	Std.	Rate (%)	Std.	Rate (%)	Std.	(%)
1.0	Conv, 1mm	34.42	0.91	45.35	0.83	20.23	1.30	100
1.0	Induction	32.30	0.44	33.08	0.96	34.62	1.18	100
1.0	Corona	27.69	0.90	27.69	0.75	44.62	1.16	100
2.0	Conv. 1mm	20.93	1.61	35.35	1.39	43.72	2.48	100
2.0	Induction	16.15	0.55	50.00	1.11	33.85	1.09	100
2.0	Corona	18.46	0.49	50.00	0.89	31.54	0.86	100

Table 3 Spray coverage [%] at 20° orientated angle

Distance (m)	Method of Application	Deposition		Ground loss		Estimated drift		Total
		Rate (%)	Std.	Rate (%)	Std.	Rate (%)	Std.	(%)
1.0	Conv, 1mm	32.09	0.91	30.23	0.98	37.68	1.08	100
1.0	Induction	37.69	0.44	26.15	0.80	36.16	0.97	100
1.0	Corona	26.15	0.90	26.92	0.70	46.93	1.00	100
2.0	Conv. 1mm	23.72	0.60	37.91	0.59	38.37	1.05	100
2.0	Induction	26.15	0.94	32.31	0.40	41.54	1.23	100
2.0	Corona	24.62	0.86	39.23	0.68	36.15	0.79	100

m from the tip of the nozzle. This shows the effect of induction charge on conductive liquids. The high yield of deposition may be due to the increased in spray angle caused on the charged spray by the induction electrode and a slight wrap-around effect.

3. Ground loss (%)

The ground loss was evaluated and means were presented in Table 3. At horizontal position of the nozzle (i.e. 0° oriented angle), the electrostatic nozzles showed a higher ground loss. This was due to the drop sizes issued from the nozzles and thus the effect of the blower. For single nozzles application at a distance of 1.0 m from the nozzle tip, the highest ground loss occurred with the conventional nozzle with orifice diameter 1.0 mm at 50° oriented angle. At a distance of 2.0m the same nozzle at the same angle of orientation had the higher ground loss than the other nozzles. This may be attributed to force of gravity acting on the larger droplets size issued by the nozzles and preventing them to reach the target. When all the three nozzles were in operation, there is no significant difference in the spray loss for all techniques applied.

4. Estimated drift (%)

The term estimated drift is used here since it is impossible to measure or calculate actual value of drift in spray. It was estimate as the difference between the volume of spray and the summation of the deposition and ground loss expressed as percent (%). The calculated values are present in Table 4. The volume median diameter (VMD) dispersed from the conventional nozzle with orifice diameter of 1.0 mm was 180 μm and the electrostatic nozzle was 116 μm. This confirms that smaller droplet sizes are being carried away by the wind when aerodynamic acts on them.

Conclusions

The charge performance of the developed nozzle gives a clearer understanding of the charge sprays. The

Table 4 Spray coverage [%] at 50° orientated angle

Distance (m)	Method of Application	Deposition		Ground loss		Estimated drift		Total
		Rate (%)	Std.	Rate (%)	Std.	Rate (%)	Std.	(%)
1.0	Conv, 1mm	28.06	0.40	48.14	1.39	23.26	1.60	100
1.0	Induction	26.92	0.85	31.54	0.53	41.54	1.08	100
1.0	Corona	13.85	0.79	25.38	1.06	60.77	1.43	100
2.0	Conv. 1mm	15.12	0.82	54.40	0.50	30.48	0.93	100
2.0	Induction	20.77	0.78	33.85	0.56	45.38	0.75	100
2.0	Corona	12.31	0.64	38.46	0.59	49.23	0.92	100

Table 5 Spray coverage [%] at 0°, 20°, 50° orientated angles (3 nozzles)

Distance (m)	Method of Application	Deposition		Ground loss		Estimated drift		Total
		Rate (%)	Std.	Rate (%)	Std.	Rate (%)	Std.	(%)
1.0	Conv, 1mm	27.98	0.45	33.64	1.16	38.38	1.30	100
1.0	Induction	30.00	0.72	29.74	0.72	40.26	0.97	100
1.0	Corona	23.08	1.08	30.77	1.32	46.15	0.71	100
2.0	Conv. 1mm	23.57	0.88	38.29	0.94	38.14	1.35	100
2.0	Induction	21.02	0.91	31.28	1.27	47.70	1.87	100
2.0	Corona	18.72	0.89	36.15	0.71	45.13	1.38	100

optimum charge on the droplet was obtained but was not used for the experiment, due to sparks that appears around the induction charge electrode at voltage above 4 kV.

A high deposition was collected for the induction charge type at oriented angle of 20° at a spraying distance of 1.0 m from the tip of the nozzle, when applied individually or when all three nozzles were operated.

When all the three nozzles are in operation, there is no significant difference in the spray loss for all techniques. The least spray loss to the ground was obtained when the developed electrostatic induction nozzle was operated at orientation angle of 20°.

The estimated drift was found be less with the conventional nozzle with orifice diameter of 1.0 mm at orientation angle of 0°.

Efforts to improve the deposition on the plant canopy and under side of the target has not been very effective, this may be due to the insufficient charge on the droplet. From the experiment, it can be observed that the nozzle orientation could be a factor to be considered in order to obtain a higher spray deposition on plants.

The statistical analysis (ANOVA) of the mean values and the standard deviations are presented in Table 2 to Table 5.

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