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A Review of Electrostatic Spraying for Agricultural Applications

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Abstract: Pesticides are toxic chemicals designed to control certain pests, diseases or weeds. They can easily contaminate the air, ground, water sources, wild animals, birds and aquatic life when they run-off from fields. For these aspects the application of pesticide must be done accurately. One of the most important factors that affecting the success of application is choosing the right equipment. New technologies on sensor and image analyzing process promoted the success of application technique. Besides electrostatic spraying is a new trend to apply pesticides with less drift potential. In recent years electrostatic spraying has been used in many other applications such as painting, ink printing etc. Researches have indicated electrostatic spraying achieves better coverage of difficult targets than conventional spraying. Water consumption of that kind of sprayers is up to 10 times less than conventional spraying. On the other hand this method has some difficulties and disadvantages. In this study, electrostatic spraying in agricultural application was evaluated. Tractor mounted and mobile knapsack electrostatic sprayers were explained and some experimental results of them were discussed.
Key words: Electrostatic fields, ULV, plant-protection treatments, coverage, drift

INTRODUCTION

Pesticide application technique is very important to be success on biological efficacy. There are many subjects that affect the success of the application. These are weather conditions, spray pressure, nozzle type, travel speed, boom height, and etc. (Ozkan 2016; Wolf 2009; Deveau, 2009) Both safety and effectiveness of pesticide use are related with the spray equipment.

Pesticides are applied by using various water amount and application rates take different names according to this applied amount like high volume, low volume and etc. In high volume spraying, application rate is >400 Lha^{-1}, droplet sizes vary from 300 to 500 µm and gun sprayers are used. In this type of application biological efficacy is poor, amount of chemical waste and environmental pollution are high. During low volume spraying, application rate is 50 to 400 Lha^{-1} and droplet sizes vary 125 to 250 µm. Generally air-assisted sprayers are used. In this kind of application biological efficacy is moderate, chemical waste and spray drift is predominant. During ultra-low volume spraying, application rate is <5 Lha^{-1} and droplet sizes vary from 5 to 50 µm. Generally mist blowers, ULV sprayers and electrostatic sprayers are used. In this type of application biological efficacy is better with less chemical waste and drift. Water requirements may be reduced from 20 - 30 gallons per acre used with most conventional herbicide sprayers to one gallon or less per acre with CDA (Controlled Droplet Application). Other advantages of CDA include time and fuel savings, along with less soil compaction (Anonymous, 2016a; 2016b; 2016c).

The electrostatic painting operation is based on one basics principle that opposite electrical charges attract each other. The result is a more uniform coat of paint, less waste and reduced material costs. While the electrostatic painting process was invented for many fields it is still today's technology for coating (Anonymous, 2016d).

Electrostatic spray technology was invented in the early 1930's and the aim was to improve spray deposition on the canopy. Harold Ransburg developed the first electrostatic application system in 1940 (Anonymous, 2016e, 2016f).

By the 1940's, the automobile manufacturers took this technology and improved it for efficient method of painting automobiles. After early 1980's electrostatic spraying equipment were worked on for the agricultural community. Preliminary tests were performed on cotton crops (Anonymous, 2016g). Electrostatic spraying has been used in inland fish farms, conveyor belts, meat processing and packing factories, poultry farms and slaughterhouses, processing for the food industry, food and post-harvest products, wood storage and processing, healthcare in details and also agriculture (Anonymous, 2016h).

MATERIAL and METHODS

There are 3 types of charging method for electrostatic spraying. These are induction charging, ionized field charging and direct charging.

Induction Charging: "When a high-voltage electrode, positioned close to where spray liquid emitted from a nozzle, is positively charged, a conductive water-based pesticide spray at earth potential, has a negative charge induced on its surface by the attraction of electrons." (Law, 1978).

Ionized field charging: "A high voltage applied to pinpoint can create an intense electric field around it that sufficed molecules of the surrounding air. A positively charged conductor will repel the positive ions created, while the electrons that are released in the ionization process will be attracted to the conductor and neutralize some of its charge." (Arnold and Pye, 1980).

Direct charging: "When a semi conductive spray liquid, with an electrical resistivity in the range 104-106 ohm m, is exposed to a high voltage (15-40 kV) as the liquid emerges through a narrow slit, mutual repulsion between different portions of the liquid overcomes surface tension and ligament are formed. These ligaments break up into droplets due to axisymmetric instabilities. The level of charge on the droplets represents the maximum that can be attained and is called the Rayleigh limit" (Rayleigh, 1882).

According to Coulomb's Law "If the two charges have the same sign, the electrostatic force between them is repulsive; if they have different signs; the force between them is attractive". This is the basic principle on electrostatic spraying. As the droplets leave the nozzle, they are exposed to a negative charge. These charged droplets are attracted to the positively charged leaf surface (Anonymous, 2016i).

In agriculture, electrostatic spraying is not a new technique but development in technology of production and environmental concerns are promoted to work on electrostatic spraying technique. Giles and Blewett (1991) announced that, use of a reduced-volume, charged-spray application system was found to significantly increase the initial deposition and the decay time of captan dislodgeable foliar residue as compared to those of a conventional spray application system. Patel et al. (2015) designed an air-assisted electrostatic nozzle based on induction-charging. According to the researches that nozzle was light weight, highly efficient, reduces pesticide use and human health risks, and eco-friendly. The deposition of liquid was enhanced 2-3 fold with electrostatic application under the same conditions while using non-electrostatic nozzle.

Unlike conventional spray droplets, which contain an equal number of positively charged protons and negatively charged electrons, spray droplets emitted through an electrostatic system receive a positive or negative charge from electrodes surrounding each nozzle. As the charged spray droplets reach the target, they induce an opposite charge on the plant, thus activating electrostatic forces and attracting the charged droplets to both the upper and under leaf surfaces (Anonymous, 2016j).

In this study, two types of sprayer which were manufactured by Electrostatic Spraying Systems Company (USA) were tested. Flow rates of nozzles, working pressures, fuel consumption, temperatures of air flow and basic specifications were evaluated.

RESULTS and DISCUSSION

Petrol engine-driven mobile sprayer and PTO driven mounted type orchard-row crops sprayer are tested and the results were given below.

Petrol engine-driven mobile sprayer

This sprayer mainly consists of petrol engine, air compressor, spray tank and spraying unit (Figure 1).

Figure 1. General view of petrol engine-driven mobile sprayer

Air compressor is driven by petrol engine. Air mixes with spray liquid in the spray gun and atomization as well as charging of liquid occurs in spray gun. Parts of the spray gun are shown below (Figure 2). For operator's safety, spray gun is powered by a low-voltage power supply. The rechargeable 9 V batteries are in the handle of the spray gun. The electrostatic charge imparted to the spray is not strong enough to harm people. Charging time for the battery is minimum 12 hours. The spray gun was used 13 to 15 hours of operation on a charge.

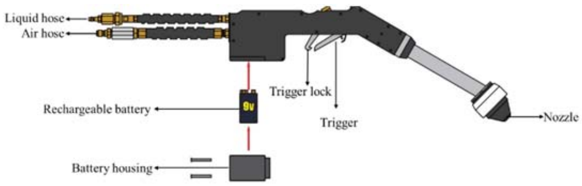

Figure 2. Parts of the spray gun

Basic specifications of sprayer are shown below (Table 1 and 2). During the gasoline consumption tests the engine consumed 0.600 L h^{-1}. Because of the safety reason when the slope exceeded 9-10°, the engine stopped automatically.

Table 1. Basic specifications of petrol engine-driven mobile sprayer (Part 1)

Width (cm)	Length (cm)	Height (cm)	Empty weight (kg)	Size of wheels (cm)
49	90	116	77.6	40

Table 2. Basic specifications of petrol engine-driven mobile sprayer (Part 2)

Power (kW)	Petrol tank capacity (L)	Spray tank capacity (L)	Air hose length (m)	Liquid hose length (m)
2.6	2	15	30	1

The flow rate can be controlled by the flow disk (Figure 3). The flow disk sizes are No. 39 and No. 59. The flow rate was changed from 150 ml min^{-1} to 240 ml min^{-1}. Working pressure was about 4 bar when the gas throttle was fully opened. When it is half and idling the pressures are respectively 2 and 1 bar. The flow rate was affected by working pressure. For this reason, according to the experiments recommended working pressure for the sprayer is 4 bar. During the test the strainer was cleaned several times in case of blocking the nozzle.

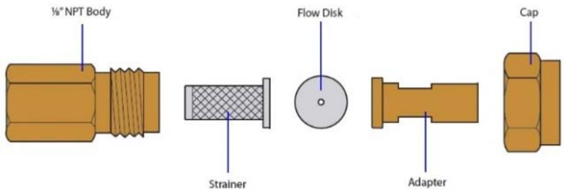

Figure 3. Place of the flow disk and strainer

There are different types of spray gun (Figure 4). Because of narrow working width, longer spray gun with double nozzle may be used in various plant heights.

Figure 4. Types of the spray gun

PTO driven mounted type orchard-row crops sprayer

This type of sprayer can be used in both orchards and row crows (Figure 5). Sprayer has spray tank, supercharger, pump, hand wash tank, boom and filters.

The boom of the sprayer can be adjusted either perpendicular or horizontal to the ground by hand. The charging unit should be attached to the tractor's battery via conducting wire. This sprayer has a supercharger instead of blower. Basic specifications of sprayer are shown below (Table 3).

Figure 5. PTO driven mounted type orchard-row crops sprayer

Table 3. Basic specifications of petrol engine-driven mobile sprayer

Width (cm)	313
Length (cm)	92
Height (cm)	187
Nozzle no.	20
Nozzle distance (cm)	13
Working width (cm)	278
Spray tank capacity (L)	132

Flow rates of both sides of the sprayer can be controlled by the flow disk. The flow disk size is No. 59, whereas the flow rate was 225 ml min^{-1}. The nozzle orientation can be done easy without any hand tool. Nozzle can be adjusted for wide range of row distances. Also for different forward speeds, the nozzles' direction can be adjusted all directions.

During the tests the operator practiced the sprayer for one hour. After one hour working time, the temperature of the nozzle outlet and supercharger was measured (Figure 6). In front of the nozzle outlet the average temperature was 30 °C, whereas the average temperature on the supercharger was 105 °C. For this reason special cooling system was developed by the manufacturer to cool the airflow. The cooling liquid for the system is oil.

Figure 6. Measuring the temperature of the nozzle outlet and supercharger

CONCLUSIONS

The secret of efficient spraying lies in even and targeted liquid distribution. Uneven coverage of the target area is wasteful, costs money and results in unwanted and unnecessary contamination of the environment.

This type of sprayers produced "Extremely fine or very fine" droplets (ANSI/ASAE S572.1). For a conventional sprayer it is not easy to lead the droplets to the target. With the help of gentle air flow charged fine droplets reach to the target with electrostatic spraying technique. There are many types of conventional sprayers that can be used in pesticide application. On these sprayers, new technologies are introduced every year. Electrostatic spraying has been not only a new technique but also a new topic of conversation in recent years.

Electrostatic sprayers save time, water, labor, fuel and pesticide. Because of the size of the droplets produced by electrostatically, the coverage on tops and undersides of plants is better than conventional spraying. On the other hand electrostatic sprayers' acquisition costs are still expensive and in same cases the droplets cannot reach to the tops of the high trees. Calibration of the sprayer should be done always precisely and keeping eye on the weather conditions is vital during the electrostatic spraying process.

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