KEYNOTE ADDRESS

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Electrostatic Spray for Pest Control in Agriculture in Sri Lanka

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INTRODUCTION

In Sri Lanka, the agriculture sector contribution is approximately 8 % to the national GDP and over 30 % of Sri Lankans are employed in the sector (Sri Lanka Country Commercial Guide, 2017). Sri Lanka is a fertile tropical land with the potential for the cultivation and processing of a variety of crops. Pest is a common problem in any agriculture field and Sri Lanka is not an exception (Mobottige *et al.*, 2002). However, pesticides are chemical and poisonous and uncontrolled use can have number of negative impacts. Pesticide pollution can also significantly impact negatively on human health and environments (contamination of soil and water) (Al-Mamury *et al.*, 2016).

In this paper, electrostatic spray based technology to effectively apply pesticide with a number of benefits is discussed. Firstly, the amount of pesticides wasted can be reduced significantly by only applying the pesticide to plant in targeted manner. This can lead to a cost effective pest control in terms of materials and labour.

Since the pesticides are only applied to plants in a targeted manner using electrostatic charging principle, the amount of pesticide usage will be minimal and hence minimise environmental drift and operator contamination. Efficient use of pesticides means, high coverage area, high deposition and low drift. **Fig. 1** shows a set of typical electrostatic sprayers used in large agriculture plants in USA in late 1990/early 2000. As can be seen, they are very massive manned vehicles, uses large volume of pesticides and cannot necessarily be inexpensive. In Sri Lanka, agriculture is still locally owned and hence fields are relatively small. In this paper, it is aimed to address an alternative un-manned way of using electrostatic sprays instead of manned vehicles. Liquid form of pesticide can be atomised and electrically charged using induction electrostatic hydraulic nozzle and sprayed to the plants which are at ground potential and hence space and image charge forces will play a part in achieving the stated benefits above (Edward, 2002). This approach can deliver the pesticide droplets not only to the top part of the leaves but also to the underside of the leaves where pest normally reside. Preliminary, lab based results with artificial leaves and computer simulation findings will be discussed in the presentation of this work.

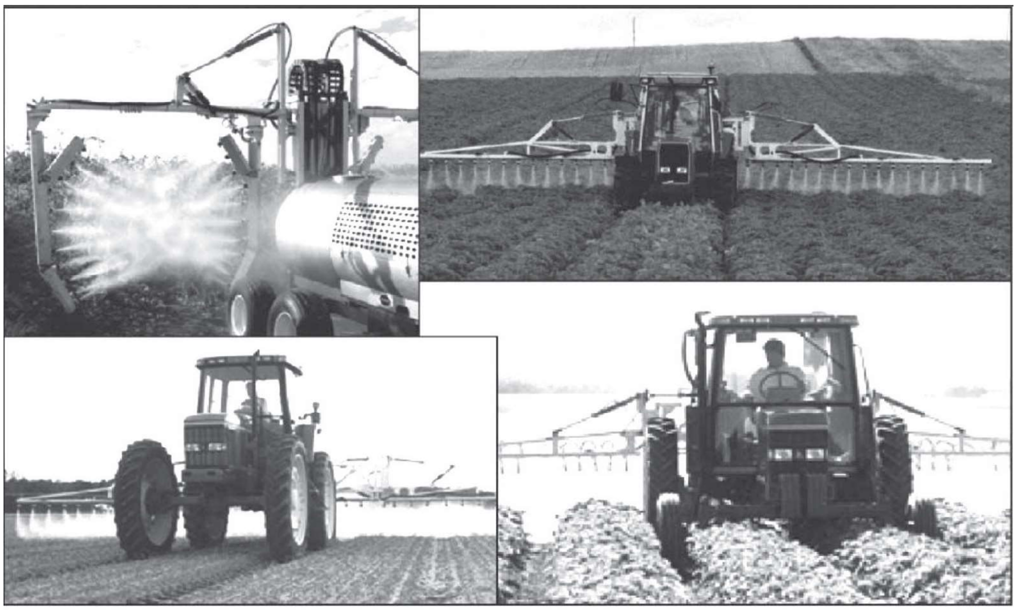

Figure 1: Electrostatic pesticide sprayer used in agricultural field (photos courtesy of Electrostatic Spraying Systems, Inc.

Electrostatic Spraying

Though the first understanding of electrostatics force was first established in 1600, the first use of it came after 300 years in electrostatic spray painting. Electrostatic spraying has become very popular for many industrial applications including pest control in in agriculture. In a post Atomization Charging (PAC) based electrostatic spray, the liquid is first made into droplets and then charged; droplets are made atomized by some mechanical or aerodynamic means (Grace, 1994). It is widely used in industrial and commercial applications of which crop spraying is one example. Another method is that the droplets are produced by Electro Hydrodynamics Atomization (EHDA). EHDA depends on liquid conductivity which can be divided three categories: conductive, semi-conductive and insulating according to the charge relaxation time (τ). Atomisation will occur based on conductivity(σ)and electrical permittivity (ε) of the liquid as illustrated in **Table 1** (Al-Mamury *et al.*, 2016).

Table 1: Three types of liquids and their properties for electrostatic spraying

Type of liquid	Insulating	Semiconducting	Conducting
Electrical conductivity (S/m)	$< 10^{-8}$	$10^{-8} < \sigma < 10^{-4}$	$\sigma > 10^{-4}$
Relaxation time	long	moderate	short
Other features	• Cannot be charged by induction due to lack charge carriers • Charge injection atomize by EHDA with Charge injection	• Relaxation time and droplet formation times are comparable. • Ideal for EHDA. • Stable jet obtained as a result of tangential stress and surface charge induced by the (radial) electrostatic field.	• Charge relaxation time must be shorter than the droplet formation time. • Equipotential surface when subjected to an electric field. • Harder to attain EHDA. • Ideal for charging by induction.
Example	Corn oil: $\sigma = 5x10^{-11}$ S/m, $\tau = 4.8$ s, $\varepsilon = 2.7$	Ethylene glycol: $\sigma = 1x10^{-6}$ S/m, $\tau = 0.4$ ms, $\varepsilon = 41$	Tap water: $\sigma = 5x10^{-2}$ S/m, τ =21ns, ε =80

Electrostatic spraying is a process of simultaneous droplet generation and charging; this only happened the electric force is stronger than the surface tension force. Electrostatic spraying also includes conveyance of particles to the target object and target deposition. Liquid coming out from the nozzle at high pressure is subjected to an electric field, with this pressure causing elongation of the meniscus so as to form a spray of droplets. This process allows for the generation of fine droplets of charge of magnitude close to one-half of the Rayleigh limit, which is the magnitude of charge on droplets that overcomes the surface tension force, thereby resulting in their fission. The interactions that happen between charges on the surface of the liquid and the applied electric field give out two results: the first being the acceleration of the liquid and subsequent disruption into droplets, whilst the second is the build-up of the charges on the droplets. There have been a number of ways researched and developed to apply electric field.

One of the early research conducted by Edward Law clearly showed that charged droplets were deposited on the plant many times higher than uncharged (Law, 1983). The results is shown in **Table 2** below. As shown, charged spray has increased by factor of 7 for cabbage and factor of 2 for Broccoli. The ratio varies plant to plant as the geometry of the plant makes the major difference. E.g. “smooth” cabbage heads and “pointed” corn plants.

Table 2: Relative increase in spray deposition onto various agronomic plants and model targets which result with electrostatic spray application

Type Target	Application Comparison	
	Charged Versus Uncharged[1]	Charged Versus Conventional2
Cabbage heads	7.0	2.9
Broccoli plant	1.8	1.9
Cotton plants	2.5	N/A
Corn plants	2.0	4.4
Smooth metal sphere	7.0	7.8
Metal sphere with point	3.5	3.5
Horizontal metal plate	2.5	1.6
Vertical metal plate	3.0	24.0

[1]Sprayed from same pneumatic nozzle at 9.4 1/ha. [2] Conventional sprayed from hydraulic nozzle at 75 1/ha.

The work reported in this paper was aimed at using a commercial spray, but use of robotic arm to see the plants and calculates its distance and apply the charged spray onto it. The some results are presented in the next section.

Materials and Methods

A Novel integrated intelligent induction electrostatic spraying has been demonstrated in a laboratory set-up. The integration of induction electrostatic spray nozzle (IESN) installed on a mobile robotic arm with high resolution camera (HC) for image capturing, a commercial ultra-sonic distance measuring (UDM) device and an integrated intelligent algorithm (IA) installed on a dedicated computer (PC) for the purpose of automated pest identification and targeted pesticides spraying make the system novel. The HC captures the images of the plants and transfer to the PC where the IA processes the image and looks for pests using pattern recognition technique. The locations of the pests are computed with the help of UDM and captured image. A series of instructions are then given to the robotic arms which in turn adjust the IESN position and angle and apply spray of pesticide in a controlled manner; such a way the spray is only targeted to the pests. The control of the spray angle is controlled be the induction voltage. Induction electrostatic spray nozzle was designed and made by having specially designed parallel induction plates on top of the commercial hydraulic spray nozzle. A set of computer simulation was performed using COMSOL Multiphysics to determine the nozzle parameters and operation voltage.

Figure 2: Induction electrostatic spray nozzle (IESN) installed on a mobile robotic arm with artificial plants along the path.

Since the pesticide is only applied to the pests unlike to the whole plant as done in the conventional spray, cost of pesticides will be minimized. The wastage of the pesticides to the soil can also be minimized and hence soil contamination will be minimal too.

Results and Discussions

The proposed intelligent spray was tested in the laboratory with artificial plants and insects, where an excellent set of results was obtained. The typical distance for the spray to apply was 25 cm and this can be increased by having larger robotic arm and higher pressure hydraulic nozzle for the real applications. In the lab-scale demonstration, it was found pesticides can be cut down by 50 % and soil contamination can be reduced by 60 %. A number of computer simulations were also carried out using COMSOL multi-physics software to understand electric field distribution around induction electrostatic spray nozzle and a typical results is shown in **Fig. 3**. This field distribution can be used to determine the velocity of spray at the nozzle and hence the range it can reach in a free air. In COMSOL simulation, it was also possible to change the spray parameters (e.g.: induction voltage and spray dimensions) and identify the best combination for a given application.

Mobile Robotic electrostatics spray can save time, money and very suitable for agriculture land, which is relatively small. A further research should be carried out to identify the type of insects and type of plants in Sri Lankan agriculture land in order to make the spraying with intelligence and hence make the pest control even more economical and environment friendly.

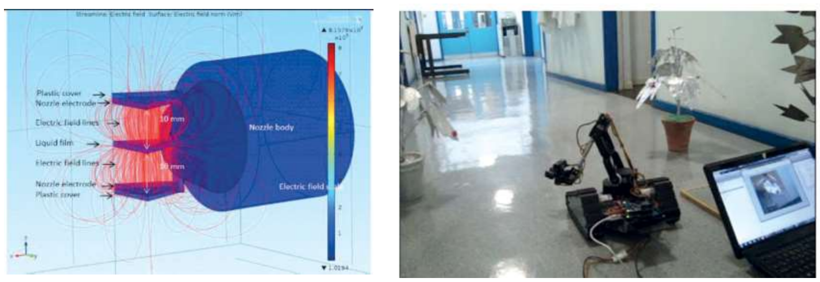

Figure 3: The COMSOL based simulation for designing the induction nozzle (left) and the shape of nozzle built and used in the study.

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