Mobile robot based electrostatic spray system for controlling pests on cotton plants in Iraq

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Mobile robot based electrostatic spray system for controlling pests on cotton plants in Iraq

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Abstract: A mobile robot based electrostatic spray system was developed to combat pest infestation on cotton plants in Iraq. The system consists of a charged spray nozzle, a CCD camera, a mobile robot (vehicle and arm) and Arduino microcontroller. Arduino microcontroller is used to control the spray nozzle and the robot. Matlab is used to process the image from the CCD camera and to generate the appropriate control signals to the robot and the spray nozzle. COMSOL multi-physics FEM software was used to design the induction electrodes to achieve maximum charge transfer onto the fan spray liquid film resulting in achieving the desired charge/mass ratio of the spray. The charged spray nozzle was operated on short duration pulsed spray mode. Image analysis was employed to investigate the spray deposition on improvised insect targets on an artificial plant.

1. Introduction

Due to Iraq's arable land and unique location in Asia continent, and having two grand rivers named Tigris and Euphrates, wide lands can be cultivated. These factors created agricultural diversity in whole of the Iraq. However, a number of pests find suitable places in the plants and damage them badly. Among of these plants, the cotton plant is grown in many parts of Iraq (northern, central and southern) due to appropriate climatic conditions during the summer season. Insect on the cotton leaf known as **'*spodoptera littorals*'** is prominent insects affecting plants production [1]. The purpose of this project is to introduce intelligent robot based electrospray system and to design a new induction charging electrospray nozzle (IESN). The system is designed to achieve at the efficient use of pesticide with minimal drift. The mini-robot will scan the plant to identify the insect location using the CCD camera. Once the target is located the short duration pulsed spray will be activated to spray over the target location. Section 2 explains how a new electrospray nozzle was designed using commercially available hydraulic fan spray nozzle. COMSOL based FEM model was developed and used to design appropriate spray charging electrodes to achieve the desired charge/mass ratio for this application. Section 3 presents the experimental set-up used in the project to validate the performance of the electro spray nozzle. Set-of preliminary experimental results are presented in Section 4. Finally, conclusions drawn are presented in the Section 5.

2. Design of IESN

A new IESN was developed to generate pulsed spray and to be used in conjunction with a micro robot capable of traversing the plant canopy. The charged spray will make efficient use of pesticides in terms of deposition on the target locations cited on the plant and help to reduce the spray drift; thus saving money and time. The design of IESN was implemented in two stages: The first one was to determine spray properties (dimensions of the liquid film spray plume and drop size distribution) of the chosen commercial fan spray nozzle (FSN) and the second one is the design of induction electrodes to impart appropriate charge level onto the spar droplets. Commercial FSN used in this project work was TEEjet -TO80015E, which operates at the pressure between 3 and 4 bars and has spraying capacity of 0.59 l/min. Figure 1 shows the experimental set-up used and the spray film obtained under the operating conditions of 40% relative humidity and 20 ^{0}C. As in the figure 1(b), the spray forms a diverging thin film which has a diverging semi cone of 21.30. This diverging spray helps the spray liquid to spread and hence efficiently deposited onto the plant. The induction charging electrodes were designed to achieve maximum charge transfer from the electrodes to the liquid film so that when the film breaks up to form droplets, each droplet will acquire maximum charge. As shown in the figure 1(b), it is a planer liquid film and hence it requires induction electrode placement on both sides of the film to achieve maximum charge transfer. The electrode dimensions were optimized using COMSOL FEM model. Thin film coating of insulating material was used to cover the outer surfaces of both electrodes to minimize the surface wetting by the fine spray and to avoid electrical break down [2]. Sharp edges were also avoided to minimize electric discharge. The shape of plastic cover was designed using solid work software and made using a 3D printer. 'Image J' software was used to measure the liquid film dimensions. In this case, the dimensions of the thin film are shown in the figure 1(b).

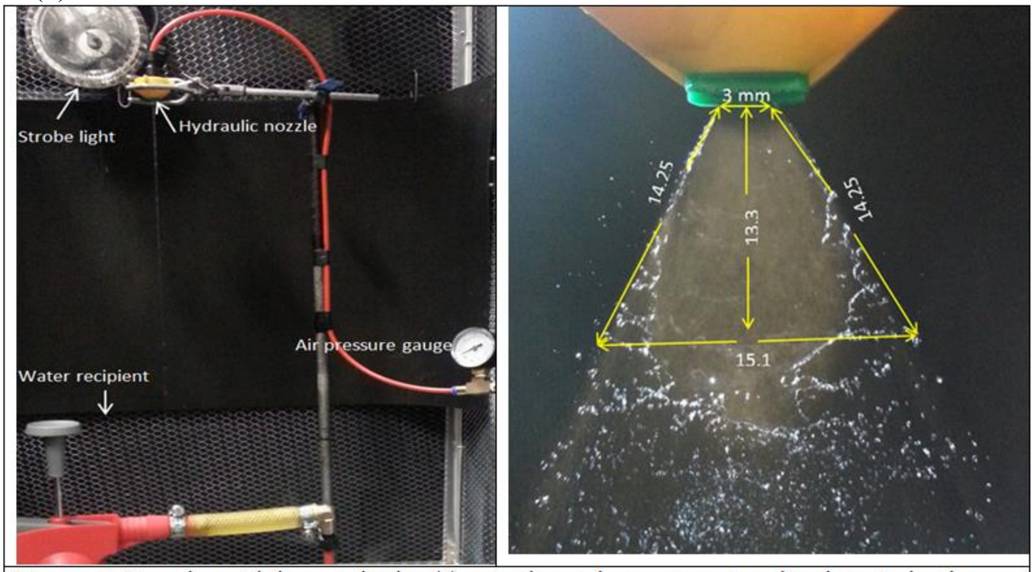

Figure. 1: Experimental characterization (a): experimental arrangement used to characterize the spray and (b) a thin film spray under normal operating condition.

A FEM was developed on COMSOL multi-physics environment and number of simulations was performed for various settings of the electrode parameters. The purpose of this simulation was to determine the parameters of the electro spray nozzle, such as, electrode dimensions, distances between the induction electrodes and nozzle tip, and the value of the high voltage that is required to achieve maximum surface charge density on the liquid film. Figure 2(a) shows a typical COMSOL simulation results which shows electric filed lines between the electrodes and the surface charge density on the surface of the liquid film. The optimum operating condition was found to be 0.5 kV electrodes potential for 10 mm spacing between the electrode and the liquid film. The designed electrodes have the same surface area as the film and of thickness of 1.5 mm. The constructed IESN is shown in figure 2(b).

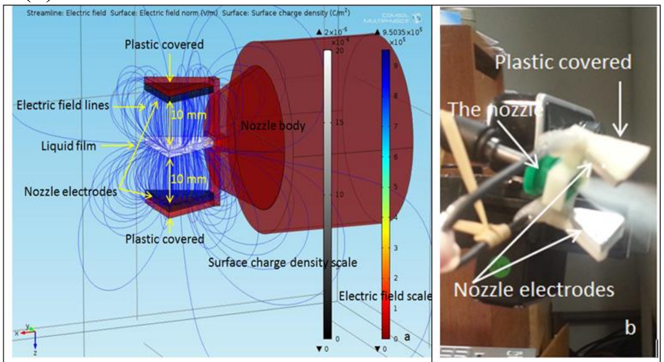

Figure. 2 :Design of Induction Spray Nozzle (a)COMSOL simulation results, electrode voltage 0.5k V, and distance between electrode voltage and thin film spray=10mm (b) Constructed Induction Spray Nozzle.

The surface charge density of the liquid film was calculated in the COMSOL simulation and for the electrodes with separation of 20 mm (as shown in the figure. 2) is 8 $\mu c/m^2$.

3. Experimental study

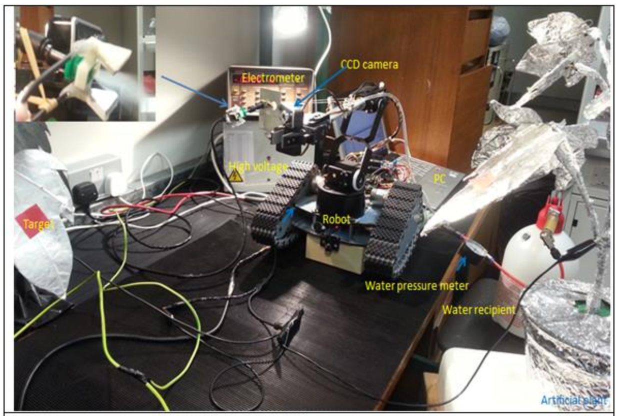

Figure.3:Lab scale experimental set-up of IESN

Experimental set-up used to demonstrate our IESN is shown in figure 3. As shown, a mini-robot with moving arm (AL05D robotic arm and the TTRK-KT tracked electric vehicle from Lynx motion™) is mounted with the newly constructed IESN and the CCD camera, and is connected to a PC. The PC receives images taken by the CCD camera, and then process them to identify and locate the insects (artificial). Finally the PC instructs the mini-robot to move forward or backward and activate IESN to spray the pesticides to the targets (artificial). An advanced imaging processing code was written in MATLAB programming environment to identify the pre-known targets (a various versions of '***spodoptera littorals'***) on the artificial plant. Two artificial cotton plants are made using cardboard and their dimensions are similar to that of actual cotton plant. These plant leaves were covered with aluminum foil to make the leaves electrically conducting to mimic the natural plants which are electrically conductive. Artificial cotton plant insects of various shapes and sizes were also made and used in this study [3]. A number of experiments were carried out using ordinary water as the pesticides to spray over the artificial targets.

4. Results

The IESN was set to operate in pulse mode. In the experiments, a single pulse of varying time periods was applied over a target and the volume of water on the ground (wasted pesticides) was measured. The volume of the applied spray was calculated by multiplying the flow rate of the spray nozzle and the pulse duration. Figure 4 shows the results obtained in the preliminary set-of experiments. This figure 4(a) shows normalized spray volume, normalized drift volume and the ratio between drift volume and total spray volume for the pulse durations of 50, 100, 150, 250, 400, 500, 600 and 700 ms. As can be seen in figure 4, the ratio of waste/applied reduces for longer pulse period and further experiments to be performed to find the optimum pulse duration by considering other factors such as leave coverage along with the waste [4]. Experimentally measured the charge-mass ratio of the induction spray nozzle is plotted in figure. 4(b) as a function of spray pulse duration.

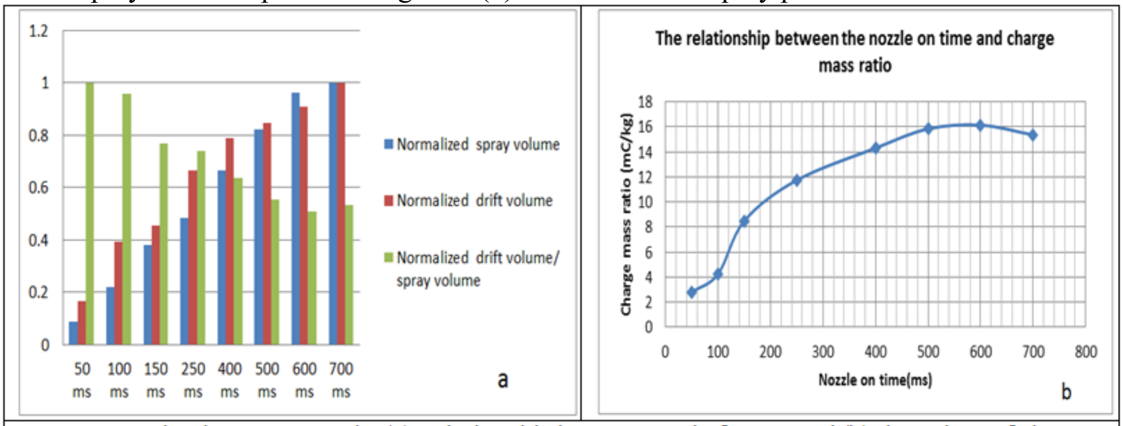

Figure. 4: Induction spray results (a) relationship between study factors and (b) the values of charge mass ratio

5. Conclusions

A mini-robot electrospray system has been designed and preliminary tests have been carried out to evaluate its feasibility. Early experimental results indicate that the system is capable of locating the pests on leaves of a plant canopy and then activate the electrospray for a short duration in an around that location. This minimises the amount of pesticides needed in real operation. Furthermore, this system also helps to minimise ground contamination and spray drift. Further work is being continued to fully evaluate the system under various operating conditions.

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