Optimization of parameters of designed and developed handheld electrostatic sprayer and its performance evaluation for herbal pesticides

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Abstract- Electrostatic force field has been exploited in the design and development of a handheld air-assisted electrostatic sprayer for herbal pesticides. Electrostatic spraying is a novel approach for agricultural pesticides applications to increase the mass transfer efficiency, pesticide bio-efficacy, uniform deposition, maximum canopy coverage and liquid pest to reach the hidden areas and underside of the target by reducing the drift of active ingredients of pesticides from the target. A new air-assisted electrostatic sprayer has been designed and developed for small scale farms with a specific focus on rural developing economies. In this work, experiments were carried out with four types of herbal pesticides and one chemical pesticide to evaluate and compare the performance of developed electrostatic sprayer. The results are characterized in terms of depended variable i.e. charge-to-mass ratio by varying independent variables such as applied voltage, air pressure, conductivity and density of liquid. The droplets are charged more than 8 mC/kg with an applied voltage of 1.5 kV at a flow rate of 110 ml/min and air pressure of 40 psi which is more than desirable to achieve the wraparound effect. This nozzle is light weight, highly efficient, reduces pesticide use and human health risks, and eco-friendly.

1. Introduction

In the process of sustainable agricultural development, pesticides have become as a plant protection agent from many dreadful diseases and insects, for boosting food production to fulfil the basic human need [1]. Pesticides can be chemical, herbal, bio-pesticides etc. However, excessive usage of chemical pesticides has raised a very serious concern over the time as pesticide residues on food commodities, human health risks and environment pollution [2]. Several methods of pesticides spraying such as hand pressure based sprayers, pedestal-mounted sprayers, motorised sprayers, high pressure spray guns etc. are available. However, these spraying technologies are not efficient and effective to reduce the vertical and horizontal losses of active ingredients of pesticides [3, 4].

The electrostatic spraying technology to agricultural applications is one of the most promising methods to apply the protective liquid based sprays onto the biological surfaces of crops and orchards [5, 6]. It reduces the pesticides consumption, off-target losses and environmental pollution and increase the deposition efficiency and bio-efficacy. The available literature shows that the designed and developed electrostatic sprayer was optimised and characterized for chemical pesticides, however, no work has been carried on characterization of herbal pesticides and
optimization of parameters of electrostatic nozzle suitable for herbal pesticides [7, 8]. In this paper, the performance of developed electrostatic nozzle has been evaluated by using four types of herbal pesticides and one chemical pesticide. Various parameters such as applied voltage, liquid flow rate, air pressure, liquid conductivity, density, charge-to-mass ratio etc. were optimized in respect of herbal pesticides. The experimental results show that the charge-to-mass ratio is in desired range and the developed nozzle can be used for spraying of herbal pesticides as a protective agent for dreadful diseases and insects.

2. Material and methods

The designed and developed nozzle is an internal mixing, air induced air-assisted nozzle with a concentric positioned nickel annular ring electrode of appropriate dimensions. In the experiment(s), four herbal pesticides and one chemical pesticide were used to optimise the various parameters and checked the suitability of developed electrostatic nozzle for herbal pesticides. The herbal pesticides were procured from SRISTI, Ahmedabad. Various properties such as rheology, conductivity, density, surface tension and particle size has been given in table 1.

| S. No. | Pesticide        | Conductivity (mS/cm) | Viscosity (mPa.s) | Density (g/cm$^3$) | Surface tension (mN/m) | Particle size ($D_{50}$, μm) |
|--------|------------------|----------------------|------------------|--------------------|------------------------|-----------------------------|
| 1.     | SRISTI Sarvatra  | 18.91                | 23.91            | 1.0080             | 32.87                  | 124.0                       |
| 2.     | SRISTI Suraksha  | 26.9                 | 1.958            | 1.0116             | 29.68                  | 1.40                        |
| 3.     | SRISTI Shastra   | 12.09                | 1.834            | 1.0051             | 55.87                  | 4.59                        |
| 4.     | SRISTI Shakti    | 7.01                 | 3.049            | 0.9944             | 49.63                  | 48.7                        |

An induction charging based method has been used for the charging of liquid sprays which is a well proven and satisfactory method particularly in the case of agricultural applications. The Faraday Cage method had been used for measuring the charge-to-mass ratio (CMR). The charge-to-mass ratio was calculated from the relation [9].

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\text{Charge-to-mass ratio} = \frac{i_s}{Q_m} \text{ mC/kg} \tag{1}
\]

Where $i_s$ is the measured spray current (A) and $Q_m$ is the collected mass of the liquid ($kg \cdot s^{-1}$). The flow rate of the nozzle was 110 ml/min at an applied air pressure of 3 bar.

3. Experimental

The experimental set-up consists of an air-assisted electrostatic nozzle, air compressor, high voltage power supply, electrometer, multi-meter, air pressure regulator, air flow meter and water tank as shown in figure 1.

**Figure 1.** Experimental set-up including electrostatic nozzle, high voltage, air and water supply, spray current measuring electrometer and herbal pesticides used for the experiment(s).

The high voltage power supply has been provided to charging electrode with a high voltage module (ULTAVOLT +20 kV, 1.5 mA, 30W) for laboratory experiments. The laboratory experiments were conducted in an open air and at ambient conditions (T= 285±3 K, RH= 90±3%). Tap water of finite
conductivity of 0.442 mS/cm and density of 0.998 g/cm$^3$ was used for the experiment(s). During the spray current measurement, the distance from the nozzle tip to Faraday cage was 130 mm which is one among most important factors affecting the measurement of spray current.

4. Results and discussion

In the experiment(s), various parameters such as applied voltage, charge-to-mass ratio, liquid conductivity, load current, air pressure have been optimised and checked for the suitability of herbal pesticides.

4.1. Charge-to-mass ratio and load current variation with applied voltage

In this experiment, four types of herbal pesticides such as SRISTI Sarvatra, SRISTI Suraksha, SRISTI Shastra, SRISTI Shaktithas and Coragen chemical pesticide have been used. Charge-to-mass ratio has been calculated for all five pesticides and a significant charge-to-mass was found.

![Figure 2](image-url)  
**Figure 2.** Charge-to-mass ratio variation at different air pressure.

Considering the figure 2, it can be concluded that, the nozzle can be used for all type of herbal pesticides without any degradation of performance.

4.2. Charge-to-mass ratio variation with the change in applied air pressure and liquid conductivity

Applied air pressure is one of the most important inputs in air-assisted electrostatic spraying. Optimum air pressure and hence air supply reduces the wetting of charging electrode and increases the chargeability of liquid sprays. There was a minor change in liquid flow with the variation of applied air pressure.

![Figure 3](image-url)  
**Figure 3.** (a) Charge-to-mass ratio at different air pressure (b) Charge-to-mass ratio and load current variation with liquid conductivity.
Considering the figure 3 (a), charge-to-mass ratio has a maximum value at an applied pressure of 3 bar. At an applied air pressure of 2 bar the spray current is less, however, load current is more. Supplied air acts as a dielectric between charging electrode and liquid stream and hence optimum supply of air is desired to avoid breakdown.

In electrostatic spraying, as the conductivity changes, the chargeability of liquid sprays changes. Conductivity affects the charge-to-mass ratio (CMR) and load current (LC) both. The designed nozzle covers a wider range of liquid pesticides which has been shown in figure 3 (b). Most of the liquid pesticides mixed with solvent lies in between $10^{-1}$ to $10^4$ $\Omega$ m resistivity range. It has found that as the conductivity of the liquid increases, the load current increases which shows that induction charging tends to conduction charging and more load current is drawn from the power supply. At optimum conductivity, the charge-to-mass ratio is maximum and hence the chargeability is more.

5. Conclusion

An air-assisted electrostatic sprayer has been designed and developed for agricultural herbal pesticides applications. To check the suitability of electrostatic sprayer for herbal pesticides, four types of herbal pesticides have been used and the performance has been compared with the performance of Coragen (chemical pesticide). Significant charge-to-mass ratio has been achieved for the optimum performance and wraparound effect for the designed electrostatic sprayer. The charge-to-mass ratio of 8mC/kg has been achieved at an optimum applied air pressure of 3 bar and flow rate of 110ml/min. The results are in good agreement with the proposed theory and hypothesis.

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