Development and evaluation of drone mounted sprayer for pesticide applications to crops

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DEVELOPMENT AND EVALUATION OF DRONE MOUNTED SPRAYER FOR PESTICIDE APPLICATIONS TO CROPS

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ABSTRACT

Application of crop protection materials is one of the crucial operations in agriculture to meet ever demanding food production. The drone mounted sprayer mainly consists of BLDC motors, LiPo (Lithium polymer) batteries, peticide tank, pump, and supporting frame. Six BLDC motors were mounted to hexa-copter frame to lift of 5 kg payload capacity. Two LiPo batteries of 6 cells - 8000mAh were used to supply the necessary current required for the propulsion system. A 5 liter capacity conical-square shaped fluid tank was used to hold the pesticide solution. A 12 V DC motor coupled with pump was used to pressurize spray liquid and then to atomize in to fine spray droplets by means of four nozzles. A suitable aluminium supporting frame was used to mount the spray liquid tank, sprayer motor, spray and supporting legs (landing gears) for safe take-off and landing. The entire drone mounted sprayer operation controlling with the help of transmitter at ground level, HD FPV camera also provide at front down side of drone sprayer unit to monitoring the live spaying operation.

The developed drone mounted sprayer was evaluated for its field performance in groundnut and paddy crop and the average field capacity was found to be 1.15 ha h^{-1} and 1.08 ha h^{-1}, respectively at a forward speed of 3.6 km h^{-1} and 1m height of spray. The cost of operation for groundnut and paddy crops using drone mounted sprayer has been worked out 345 and Rs. 367 Rs ha^{-1} respectively. The spray uniformity was increased with increase in height of spray and operating pressure. A VMD and NMD of spray droplet size were measured and it was found to be 345 and 270 µm, respectively in lab condition.

This sprayer is very useful where human interventions are not possible for spraying of chemicals on crops including rice fields and orchard crops as well as crops under terrain lands. This technology greatly helpful for small farming community in reducing cost of pesticide application and environmental pollution but also biological efficacy of application technology.

Key words: Drone, Drone mounted sprayer, UAV spraying, Pesticide spraying

INTRODUCTION

In India, Agriculture is a major sector of our economy but still it is far short of western countries when it comes to adapting latest technologies for better farm output. Farmers in developed world have started using agricultural drones equipped with cameras to improve the process of crop treatment.

Kale et al. (2015) used agriculture drone for spraying fertilizer and pesticides. Architecture based on unmanned aerial vehicles (UAVs) which can be employed to implement a control loop for agricultural applications where UAVs are responsible for spraying chemicals on crops. The process of applying the chemicals is controlled by wireless sensor network (WSN) deployed on the crop field.

Huang *et al.* (2015) developed a low volume sprayer for an unmanned helicopter. The helicopter has a main rotor diameter of 3 m and a maximum payload of 22.7 kg. The helicopter used one gallon of gas for every 45 minutes. The method, system and analytical results from this study provide an extendable prototype that could be used in developing UAV aerial application systems for crop production management with higher target rate and larger VMD droplet size.

Xue et al. (2016) developed an unmanned aerial vehicle based automatic aerial spraying system. The system used a highly integrated and ultra-low power MSP430 single-chip micro-computer with an independent functional module. This allowed route planning software to direct the UAV to the desired spray area.

Dongyan *et al.* (2015) evaluated effective swath width and droplet distribution of aerial spraying systems on M-18B and Thrush 510G airplanes. In this study they evaluated the effective swath width and uniformity of droplet distribution of two agricultural airplanes, M-18B and Thrush 510G, which flew at 5 m and 4 m height, respectively. They concluded that flight height leads to the difference in swath width for M-18B Thrush 510G.

At present in India, conventional methods of pesticide spray application leads to excessive application of chemicals, lower spray uniformity, deposition, and coverage; resulting higher cost of pesticide as well as environmental pollution. Apart from these, there will be increased drudgery in field application and reduced area coverage, leading to increased cost of inputs as well as reduced effectiveness in controlling the pests and diseases.

Keeping in view of these facts, a drone mounted sprayer was developed for application of pesticide sprays on to crops which improves coverage, boosts chemical effectiveness and makes spraying job easier and faster.

1. To develop a drone mounted sprayer and evaluate its performance for application of chemicals/pesticides.
2. To work out the economics of operating with drone mounted sprayer.

MATERIALS AND METHODS

The complete design was calculated by considering the total weight of the drone mounted sprayer as reference and these consideration parameters are payload capacity, design of supporting frame, landing gear, design of fluid tank, selection motors, battery, propeller, flight controller, transmitter and receiver. Development and pre-testing work has been carried out with the assistance of Maavan Aeronautics Pvt Ltd, Chennai, Tamil Nadu, India.

Performance trials were conducted in the Research Farm of University of Agricultural Sciences, Raichur, Karnataka, India. The evaluation techniques used to find the performance of the drone mounted sprayer for the field conditions for the selected field crops viz., paddy and groundnut crops.

I. Construction and working mechanism

The process of construction and mechanism involved in the operation of developed prototype sprayer are discussed here.

a. Construction: As its prefix implies, a hexa-copter ("hexa" = six) is a type of drone setup in which there are six arms and each arm is connected to a single high-speed BLDC motor, These high speed motors are mounted at the outer end of aluminium tubes (500 x 25mm) which in turn are fixed to the outer edge of the glass fibre airframe (2mm thickness) using the arm mount. Battery, high speed motor support tube, flight controller with GPS antenna, ESC, FPV camera, sensors and other circuit boards are mounted on air frame plate. A 5 l capacity fluid tank is fixed at the bottom of the glass fibre supporting plate and outlet of the fluid tank pipe is connected to the inlet of the spray motor. An aluminium pipe (14x1.5mm) is bent in an inverted U shape for making supporting frame in which fluid tank, sprayer motor and spray lance are mounted. Four nozzles are fixed on 1.3 m length of spray boom with 45 cm spacing between two nozzles. A 12 volts DC motor with pump is used to generate enough pressure to spray the liquid. Inlet liquid pipe of spray motor is connected to the outlet of fluid tank and outlet pipe is connected to sprayer nozzles. Landing gears are mounted at the bottom of drone mounted sprayer unit, which helps in safe takeoff and landing on ground surface before and after spraying operation. The overall specification of the developed drone mounted sprayer is presented in Table 1 and the assembling and development of drone mounted sprayer is shown in Plate. 1

Plate 1. Complete view of assembled drone mounted sprayer

b. Electrical power supply system: A 2 LiPo (Lithium polymer) batteries consisting of six cells – 8000 mAh are used and they are connected in parallel system to provide the required power for the operation of drone-mounted sprayer. When the drone mounted sprayer system is switched on, the receiver starts receiving the transmitted frequency from transmitter/remote control. The transmitter gives commands for takeoff and landing as well as left, right, forward, backward and yaw movements. Electrical power is supplied equally to all the 6 BLDC high speed motors and they will start to rotate at specified speed which is controlled by the respective ESC, when the accelerator/throttle is increased or decreased in the transmitter. A 12 volts DC motor with pump is connected to the battery system through sprayer motor speed controller board for generating the pressurized spray liquid and also the outlet discharge rate can be directly controlled by changing the sprayer motor governor in the transmitter. The electrical circuit diagram is shown in Fig 1.

The spraying operation can also be directly controlled manually with the help of transmitter at the ground control station. FPV camera and AV display units are helpful for providing live footage of spraying operation in the AV display at the ground control station. It requires some amount of special operator training skills for the manual spraying operation.

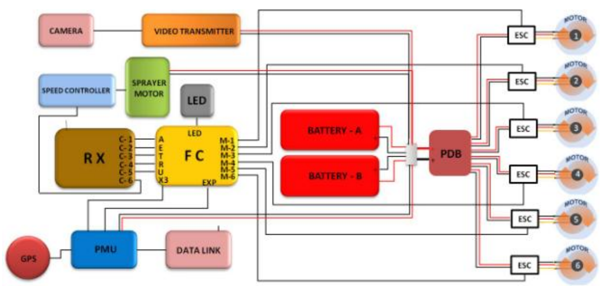


Figure 1. Electrical circuit diagram of drone mounted sprayer

Table 1. Specifications of the drone mounted sprayer

Sl. No.	Parameters	Value
1	Overall dimensions, (L × W × H), mm	420×1300×450
2	Weight, kg	6
3	Power source for spraying	Battery power
4	Pump discharge, l min^{-1}	2.5
5	Pressure control device	Regulator in transmitter
6	Number of nozzles	4
7	Nozzle spacing, mm	450 (Adjustable)
8	Type of nozzle	Flat fan
9	Spray lance length, mm	1300
10	Tank capacity, l	5

II. Performance evaluation of the developed drone mounted sprayer under laboratory condition

The laboratory test are conducted to assess the different machine parameters such as discharge rate at different operating pressure, height of spray, swath width, uniformity of the spray and droplet size. The drone mounted sprayer was operated at different heights at different operating pressure.

a. Discharge and Pressure of spay liquid: The discharge and pressure from the sprayer was measured at three levels of operating pressure mode by rotating regulator device in transmitter/remote controller. The drone mounted sprayer unit was tested at three different operating pressure modes and the spray volume was collected in measuring cylinder for one minute duration.

Plate 2. Measurement of discharge rate and spray uniformity in the laboratory

b. Spray uniformity: The drone mounted sprayer unit was kept and operated at five different heights viz., 500 mm, 750 mm, 1000 mm,1250 mm and 1500 mm (Padmanathan *et al.*, 2007) from the patternator and spray liquid at the collecting pipes of the patternator was collected and the quantity of liquid from each of 53 channels was measured.

c. Spray liquid loss: Spray liquid loss may accrue due to effect of wind velocity and air temperature. The developed drone mounted sprayer unit was operated at different heights and pressure from the patternator and spray liquid at the collecting pipes of the patternator was collected and the quantity of liquid from each of 53 channels was measured.

d. Droplet size and density: The spray was coloured with water soluble methylene blue of 0.75 percent concentration used. Photographic paper having size of 50x50 mm was placed on each plan table and at a horizontal distance of 25000 mm. It was placed at 1000 mm height from ground surface in open yard. The drone mounted sprayer was operated at height (from top surface of table), speed and discharge rate of 1000 mm, 6 km h^{-1} and 1.60 l min^{-1} respectively.

The sizes of the water droplets on the photographic paper were determined through trinocular microscope equipped with an ocular after allowing a minimum period of 24 h for complete spreading of droplets on the sampling surface. From the individual photographic sample, sixty water droplets were selected and the droplet diameters were computed for volume median diameter (VMD), number median diameter (NMD) size was noted.

III. Field evaluation drone mounted sprayer for selected field crops.

The performance evaluation of drone mounted sprayer on paddy and groundnut crops has been carried out at Research Farm of University of Agricultural Sciences, Raichur during the year 2016-17. During field trials, the agronomic data pertaining to paddy and groundnut crops such as row to row spacing, plant to plant spacing, height of crop, leaf area index and stage of crop were noted. For spraying operation, the recommended chemical solution as per the plant requirement was prepared separately in the tank. The data on speed of operation, swath width, discharge rate, field efficiency, application rate, flying endurance and time losses were measured and noted for the paddy and groundnut crop.

Plate 3. Performance evaluation of drone mounted sprayer in paddy and groundnut crop

RESULTS AND DISCUSSION

Evaluation of developed drone mounted sprayer under laboratory conditions for discharge rate, droplet size, droplet density, swath width and spray uniformity are analyzed and discussed. Field performance evaluation of the developed drone mounted sprayer in the field condition is also presented. The cost-economic of the unit is found out and salient features are enlightened.

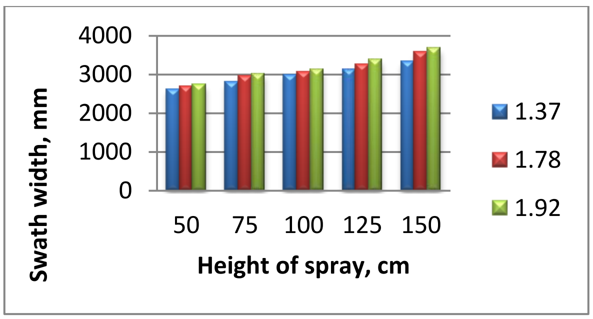


Figure 2. Effect of height of spray and operating pressure on swath width

It was observed that the swath width was increased by increasing the height of spray and operating pressure.

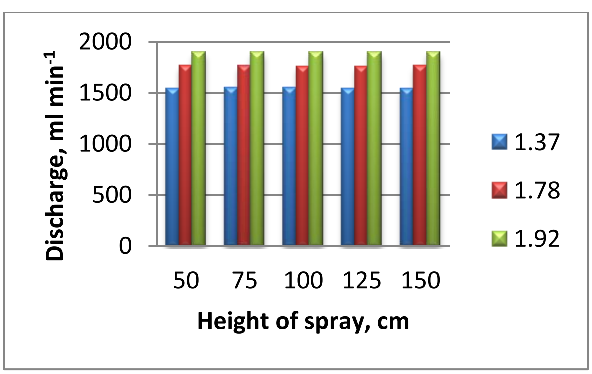


Figure 3. Effect of height of spray and operating pressure on discharge

It was observed that the discharge increased by increasing the operating pressure. The height of spray does not influence the discharge rate during the laboratory trials.

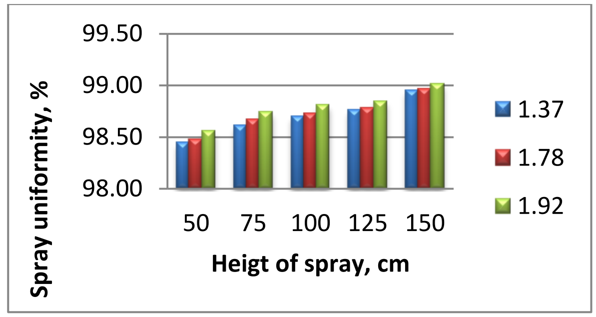
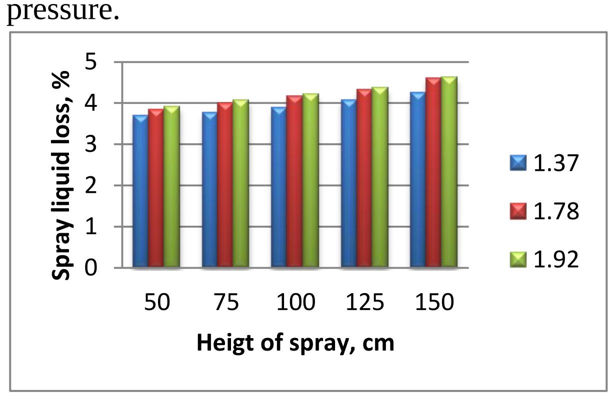


Figure 4. Effect of height of spray and operating pressure on spray uniformity

The spray uniformity increased with increase in height of spray and operating pressure.



It was observed that there was less spray liquid loss due to powerful backspin airflow produced by the propeller during spraying operation in spray patternator.

Table 2 . Performance evaluation of drone mounted sprayer in paddy and groundnut crop

Sl No	Parameter	Groundnut	Paddy
1	Forward speed, km h^{-1}	3.6	3.6
2	Width of spraying, m	5.10	5
3	Actual field capacity, ha h^{-1}	1.15	1.08
4	Theoretical field capacity ha h^{-1}	1.83	1.80
5	Field efficiency, %	62.84	60.00
6	Application rate, l ha^{-1}	55.15	55.5
7	Cost of operation , Rs ha^{-1}	345	367

The developed drone mounted sprayer was evaluated for its field performance in groundnut and paddy crop and the average field capacity was found to be 1.15 ha h^{-1} and 1.08 ha h^{-1}, respectively at a forward speed of 3.6 km h^{-1} and 1m height of spray. The cost of operation for groundnut and paddy crops using drone mounted sprayer has been worked out 345 Rs ha^{-1} and 367 Rs ha^{-1} respectively. The drone mounted sprayer worked satisfactorily for the selected field crops of groundnut and paddy crops for spraying operation and reduced the drudgery involved.

SUMMARY AND CONCLUSION

- This technology is very useful where human interventions are not possible for spraying of chemicals on crops including rice fields and orchard crops as well as crops under terrain lands.
- It helps in improves coverage, boosts chemical effectiveness and makes spraying job easier and faster.
- Developed drone mounted sprayer can takeoff maximum 5.5 l and endurance 16 min. but need to be design 15 l of payload capacity and 30 minutes endurance for chemical spraying in field crops.

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