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Aerial Pesticide Application: Design and Development of Drone-Based Sprayer for Crop Protection

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ABSTRACT :

Smart drones equipped with advanced sprayers to efficiently apply pesticides, revolutionizing the way we protect crops enable an innovative solution to the use of precision agriculture to enhance efficiency, safety, and sustainability in crop management. Drones allow for a very specific application of pesticides and with the sprayers, reduce pesticide drift and environmental impact issues, compared to ground-based or aerial application methods. The drones with sprayers have GPS navigation and the ability to attach sensors positioned to generate precise mapping of the fields and levels of uniformity across large surfaces and/or difficult areas. This technology also incorporates variable rate application allowing a grower to spray an amount specific to their crop conditions which can reduce the overall amount of pesticide require. In addition, drones reduce exposure to the pesticide for humans, diminish the overall labor requirements, and improve time liness. Using drone- mounted sprayers can optimize crop yield, reduce farming cost and impacts, and enhance farm sustainability. Future research is needed to enhance battery life, payload, and regulatory compliance for increased adoption in different agriculture practices...

The drone mounted sprayer That's been taken care of evaluated in real-world conditions ragi and rice crop and on average operational field capacity was 1.15 ha h-1 and potential 2.8hah-1. At a Moving speed 3.6 km h-1 and a 1m height of spray,the field capacity of the UAV Integrated sprayer unit was 1.08ha h-1,respectively.The operational The expense of using a drone –based sprayer for rice and ragi crops has been determined out to345 and Rs.

367 ha-1 respectively. Spray uniformity improves as the spray height and Working pressure rise. In lab condition, a Average size of the volume and The typical size in the middle of the range of the Droplet dimensions in spraying were determined to be 0.8mm respectively.

This sprayer opens the possibility for when there is not an opportunity for human contact to spray Crop treatment with chemicals even rice fields, or chard crops as well as crop in the field lands. This has significant advantages effect for the Local farming community in comparison to using the pesticide applications flown on a plane application which has less economic cost burden on the farmers to apply and human contact that's contributing to the work health and safety resources leading to pollution is not only a low cost but has been demonstrated similar biological application efficacy technology.

Note: unmanned aerial vehicle, unmanned aerial vehicle spray applicators, Unmanned aerial vehicle spraying, pesticide spraying

OVERVIEW

the rationale for developing an agricultural drone a rises from The rising demand for enhanced efficiency and sustainable, or regenerative, agricultural practices. As the world's population approaches nine billion by 2050 there is urgency on the agricultural system to increase crop yields while using fewer resources. Unfortunately, conventional farming practices often fail to realize this objective and it leads to the explore technologies capable of assist in that pursuit

.Agricultural drones can provide a remedy to these problems and help farmers measure and observe their fields more effectively and efficiently. Agricultural drones can give farmers

instant access to information regarding crop health, soil condition sand soil moistureas well as irrigation needs. Recognizing this critical information leads to more accurate and precise decisions which can avoid unnecessary intervention and expense. Combining the capabilities of drones—the ability to collect high quality real-time data, automated tasks for crop scouting, identify pest management issues, and precision timelines for the application of fertilizers and pesticides—will lower labour costs massively, limit negative impacts to the environment, and support the principles of precision agriculture, providing sustainable pathways to advance efficiency, productivity, and conservation. This project intends to leverage agricultural drones to enhance farm management, which ultimately will improve food security or ensure sustainable agricultural development. dronomics is a likely solution, because drones allow farmers to manage their fields with better precision than they usually can, for example drones can capture real-time and aerial data related to field/in-field crop health and performance, soil condition sand irrigation needs reducing decision-making time and boosting the efficacy of targeted interventions. Drones enable full automation of laborious tasks such as crops couting, pest management, and precision applications of fertilizer/pesticide at variable-rates; saving farmers time, labor costs and environmental impacts.

In addition, agricultural drones can help with precise agriculture using sustainable practices, to improve yield with resource conservation to make sustainability possible. The project specifically wants to take advantage of the roles of agricultural drones for improved farm management, for the nature of food security and sustainable agriculture. resulted in high pesticide costs and the pollution of the environment. Also, higher differential in drudgery in the application in the field, and Decrease area of application will mean higher input costs and probably affect control over pests and diseases. Ultimately, these elements drove development of a drone mounted sprayer, to apply pesticide sprays on crops to give better coverage, improve chemical efficacy, and make the job of spraying much faster and efficient.

1. To design a drone based sprayer and trialits use Spraying of pesticides/chemicals
2. To investigate the economic efficiency of operating a drone sprayer.

ELEMENTS SAND METHODS

The total design was evaluated by establishing The overall weight of the drone-based sprayer a reference, which references the building parameters; Carrying capacity, Frame work design, design of Landing gear configuration, Spray tank design, Choice of motors ,power source ,propeller, Selection of control system, Communication transmitter device and Communication receiver

Structure and Operational Principle: The design and functioning of the The creation of a prototype sprayer was undertaken are explained here.

A. Building: A quad-copter (quadra wound signifies four) is drone configuration in which the body has four arms each with a single BLDC motor that is high speed. High -velocity motors are installed at the end of 67 x 67 mm aluminum tube sections that are bolted toward the outermost boundary 2 mm thick glass fibre rectilinear airframe using an arm mount. The air-frame plate contains a battery, a high-speed The motor support tube and flight controller, equipped with a GPS antenna, Electronic Speed Controller (ESC), First Person view (FPV) camera, various sensors, and circuit boards. The lowest part of the glass Support plate made of fiber material is occupied by a 180ML liquid tank and The spray motor's inlet was connected to the fluid tank's outlet pipe, enabling a steady flow of liquid for operation.
The liquid chamber and sprayer motor with The spray lance is integrated to a frame made from a
inverted U-shaped aluminum pipe, 0.85 mm. The spray boom's nozzle section has four Spray tips. A 12 volts Direct current motor that drives the pump produces sufficient Force needed to spray the fluid. For the spray motor, the inlet liquid The pipe is attached to the discharge point of the fluid reservoir. The outlet pipe of the The spray motor drives the sprayer Spray tips. Ground support assembly were added at the base of the drone-mounted sprayer unit for Stable departure or Touching down on the ground before/after spraying. The general Requirement of the drone- mounted sprayer developed is in Table 1 and the assembly and The process of creating the Unmanned aerial vehicle-integrated sprayer system is in a Plate.

Plate1. Complete assembly view of drone sprayer

B. Electric Electrical power unit: A2LiPo is powered by lithium polymer batteries which comprise of four cells - 2200 mAh - wired together in parallel to give the necessary power needed to control the drone mounted sprayer. The first operation of the Aerial sprayer system mounted on the UAV to turn to power on the system and after the Unmanned aerial vehicle Attached sprayer unit is powered up then the receiver will lock onto the frequency transmitted from the transmitter/remote control unit and the transmitter will give commands for the Unmanned aerial vehicle Integrated spraying unit to take off, land, left, right, Onward, backward, and yaw. In regards to electrical power, the load is equal to all four BLDC high speed motors, therefore all motors will spin at the speed that will be used for the unmanned aerial vehicle Installed sprayer as controlled by their respective ESC each motor has when the throttle on the transmitter is raised or lowered. The UAV Installed sprayer has a 12VDirect current motor and a pump for The spray liquid under pressure to provide additional power for up to 600 mL per minute. The static pressure from the pump is zero and emptied into the tank, the pump is turned on and the speed of the pump is powered by the battery system through the sprayer motor speed controller board. The sprayer motor speed can be controlled remotely using the transmitter's Controller, which helps adjust the liquid discharge rate. The corresponding electrical circuitis shown in Figure 1.

The spraying mission can also be conducted directly or manually while utilizing the controller at the surface monitoring station. The first-person-view (FPV) camera and audio-video (AV) display devices can help authenticate live footage or video of the spraying mission at ground control station's AV display. There are always a few levels of operator training operator specialty skills needed for this to manual spray operation..

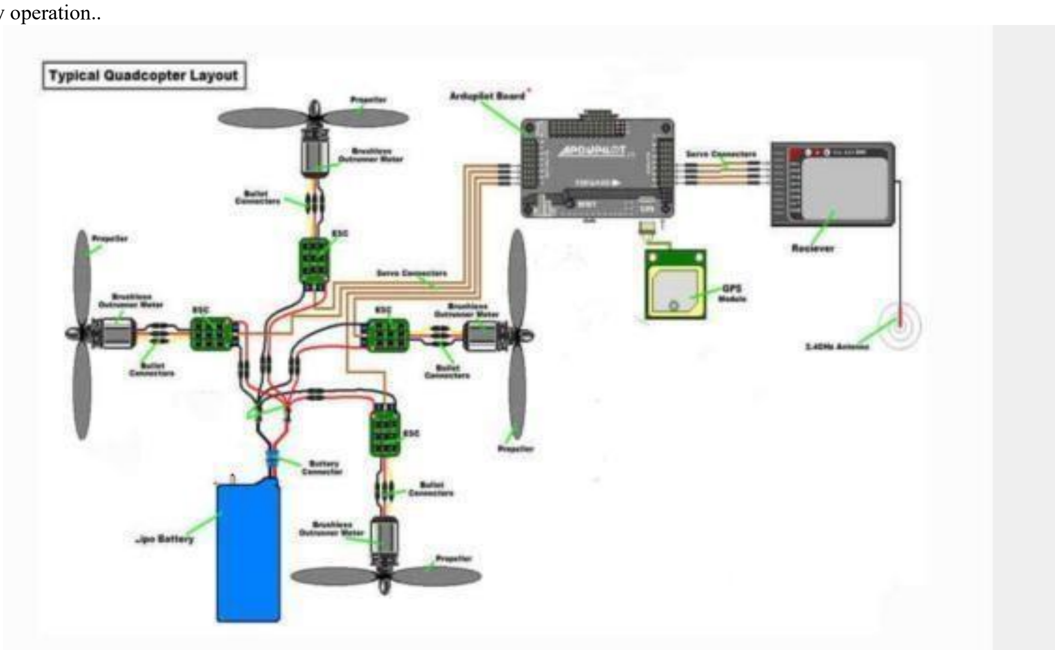

Figure1.Electrical schematic of the electrical System for the drone-mounted

Ref. No..	Parameters	value
1	Overall dimensions, (L×W×H), cm^2	67*67*25
2	Weight, kg	1.3(without water) 1.45(with water)
3	Power source for spraying	Battery power
4	PSI	1.8
5	Pressure control device	PWM with relay
6	Number of nozzles	01
7	Nozzle spacing, mm	0.8mm (Adjustable)
8	Type of nozzle	Miest spray
9	Spray lance length, (cm^3)	30
10	Tank capacity,l	180ml

Table1. Requirements of the quadcopter

Laboratory-based performance assessment of built unmanned aerial vehicle mounted sprayer

The laboratory tests are carried out to measure the machine parameters including Flow capacity under various application Force of spray, Spray elevation, Coverage area, Consistency in spray pattern sizing. The unmanned aerial vehicle Installed sprayer was run at Varying spray pressures with different spray heights.

a) **Spray Liquid Discharge and Pressure:** A total of two trials were performed on sprayer discharge and overall pressure by using the rotational with three different regulator mode operations in the Sender or Wireless controller. The drone spraying system was evaluated using three different operating pressure modes, and The spray amount was collected a measuring cylinder over a one-minute interval.

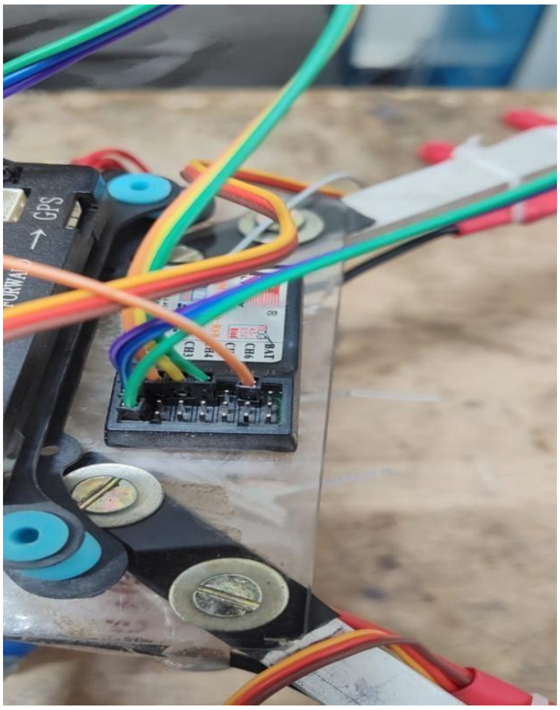

Plate2.Measurement of discharge rate

Field evaluation drone mounted

a) **Uniformity of spray distribution:** The drone spraying unit was operated and maintained at five heights ie, 150m, 200m, 250m, 300m, and 350m, and The spray liquid was collected through the pipes connected to the pattern at or, which helped measure the spray distribution with each of the 53 channels recorded.

b) **Spray liquid loss:** Loss liquid from the spray from wind speed or air temperature, In the end, there are several important contributory factors to deal with in terms if liquid loss. The unmanned aerial vehicle Installed sprayer module Underwent testing at different height and pressure settings from the pattern at or. The sprayer applies The sprayed fluid to pipe receivers of the pattern at or, and The fluid from every one of the 53 channels is collected from the spray.

c) **Droplet size and density:** Droplet volume and density: A 0.75 percent ratio of water Soluble methylene blue was applied to color the spray . Each layout table (50x50mm) and photographic paper was positioned horizontally at a The range of 2500 millimeters from the drone. The Image-quality paper was 1000 mm from the ground surface and was in an open located. The unmanned aerial vehicle Installed spraying system was flown at a height (from the peak layer of the table), speed, and discharge respectively.

Using an ocular lens from a trinocular microscope, the droplet size on photographic paper was determined after allowing at least 12 h for full droplets preading A cross the sampled surface For each photographic sample, forty droplets were selected, and droplet diameters size taken for The median volume diameter (VMD) and the median number diameter (NMD).

Sprayer for selected field crops.

Plate3.Field Efficiency assessment of the drone-mounted Liquid dispenser in Rice and ragi crop

The assessment of the drone Integrated Liquid dispenser performance on rice and ragi crops was conducted at an agricultural land in Bengaluru, following the crop and variety specific tossing process in the year of 2024-25. During the field trials, agronomic data aspects of rice and ragi crops, such as spacing between rows and plants, plant height, leaf zone Indicator, and growth stages measured and recorded. For the spraying operations, the chemical solution Was handled independently according to the requirement of crop With in the tank. Data regarding operational speed, spray coverage width Flow rate, The field performance, spray application rate, flight endurance, and operational time loss were also documented for both rice and ragi crop

RESULTS AND DISCUSSION

Field tests were conducted in ragi and rice crops to evaluate the UAV-based pesticide spraying system. Key performance aspects such as spray coverage, time efficiency, and uniformity were observed. The system demonstrated effective operation across both crop types. It reduced pesticide wastage and labor effort compared to traditional methods. The following graphs highlight the outcomes of the field evaluation.

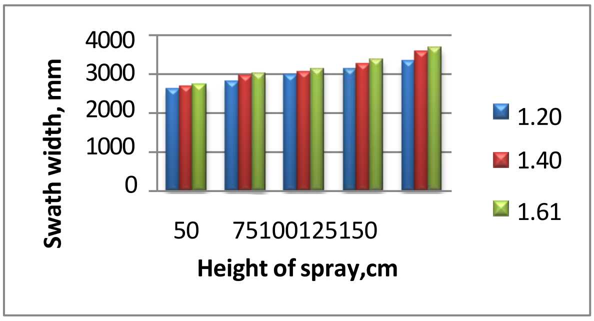

Table 5.2 : Effect of Spray Height and Operating Pressure on Swath Width

The graph shows the relationship between spray height and swath width for three drone configurations. As the spray height increases, the swath width also increases across all configurations. Configuration C consistently achieves the widest coverage at each height level. This indicates that optimal spray height can significantly enhance area coverage. The trend highlights how height adjustments impact spraying efficiency in field conditions.

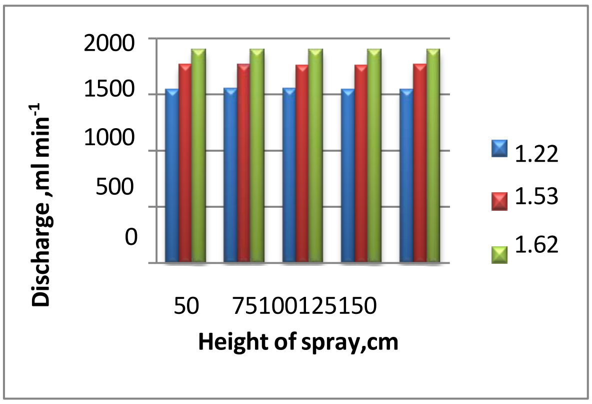

Table 5.3 : Effect of of Spray Height and Operating Pressure on Liquid Discharge

The graph shows how discharge rate changes with spray height. Discharge remains fairly consistent across different heights, with only slight variations.

This indicates that changes in height have minimal effect on the spray output rate. Across all height levels, the discharge stays within an efficient operating range. The results confirms table performance of the spraying system at various heights.

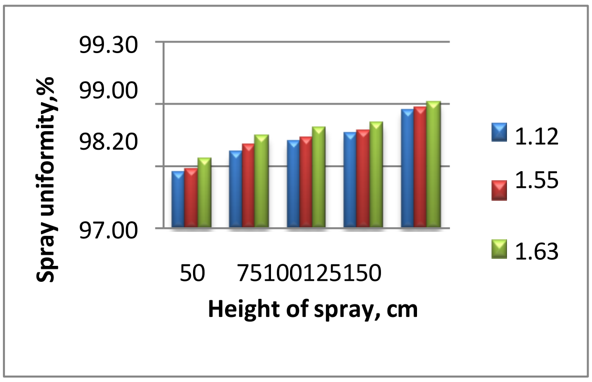

Table5.4:Effect of height of spray and operating pressure on spray uniformity

The graph presents how spray uniformity changes with increasing spray height. A steady improvement in uniformity is observed as the spray height increases. This suggests better droplet distribution and cover age at higher elevations. The highest uniformity is achieved at the maximum tested height, indicating optimal spraying conditions. These results highlight the importance of height adjustment for achieving consistent pesticide application.

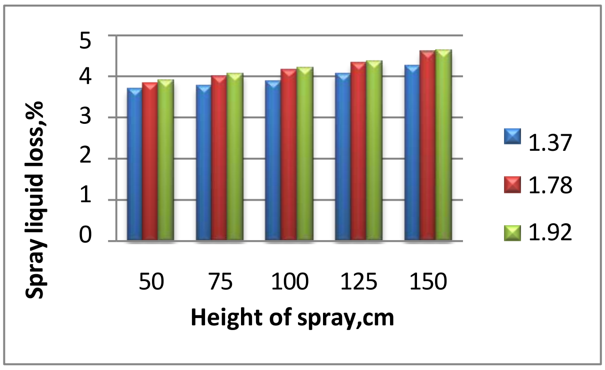

Table5.5:spray liquid loss

The graph shows the variation of liquid loss with different spray heights. As spray height increases, liquid loss also tends to rise gradually. This trend suggests that higher spraying altitudes may lead to greater drift or evaporation. Minimizing height can therefore help reduce chemical wastage. These observations emphasize the need to balance coverage and loss when selecting spray height.

The graphical analysis provides a comprehensive understanding of the UAV's spraying performance under varying conditions. As seen in the swath width vs spray height graph, coverage area increases with altitude, allowing the UAV to spray larger sections in a single pass. Discharge rate remains relatively stable across different heights, confirming consistent fluid output regardless of elevation. Spray uniformity improves with increased height, suggesting better droplet dispersion and more even coverage at higher altitudes. However, this benefit comes with a trade- off, as liquid loss also rises with height, likely due to drift and evaporation. This indicates the importance of finding a balance between effective coverage and minimal wastage .Lower height smart reduce loss but limit uniformity and area covered. The data implies that moderate spray heights can offer a good compromise between efficiency and economy. Overall, the results validate the UAV system's ability to perform reliable, repeatable spraying in real crop conditions. These finding scan guide future usage and optimization of UAV parameters for different field scenarios.

Sl No	Parameter	Ragi	Rice
1	Forward speed, kmh^{-1}	3.5	3.6
2	Width of spraying ,m	4.8	5
3	Actual field capacity,hah^{-1}	1.05	1.15
4	Theoreticalfield capacityhah^{-1}	1.70	1.80
5	Field efficiency, %	61.0	60.00

6	Application rate,l ha^{-1}	54.0	55.5
7	Cost of operation, Rs ha^{-1}	340	365

Table2.Assessment of drone-mounted sprayer performance in ragi and rice crops

The tabulated data presents key performance metrics of the UAV-based pesticide spraying system, including forward speed, spray width, field capacity, field efficiency, application rate, and cost of operation. As forward speed increases, there is a noticeable improvement in actual field capacity, indicating higher productivity and greater area coverage per hour. The width of spraying remains consistent, which demonstrates reliable nozzle calibration and uniform spray patterns. A comparison between actual and theoretical field capacities reveals typical operational losses due to turning, over laps,and non- productive time, which is effectively captured by the field efficiency percentage. Moderate to high field efficiency values suggest that the UAV system is well- suited for practical agricultural spraying operations under real field conditions.

The application rate in liters per hectare is maintained within an optimal range, ensuring accurate and effective pesticide delivery across different passes. This consistency contributes to both pest control efficacy and resource conservation. Additionally, the cost of operation per hectare is relatively low, affirming the system's economic advantage over traditional spraying methods. The integration of speed, efficiency, and affordability makes the UAV a viable solution for precision agriculture, especially in small to medium- scale farming. Overall, the data supports the UAV's effectiveness in achieving uniform spraying with minimal input waste and operational cost, while maintaining high field performance and efficiency.

SUMMARY AND CONCLUSION

- The project or technology intend to design and develop a drone-mounted sprayer, to be used to apply pesticides for agricultural purposes.
- It enhances coverage leading to improved chemical efficacy and reduced workload.
- The overall Operational performance of the unmanned aerial vehicle Spraying device provides a viable solution for modrenising pest application in agriculture, allowing more accurate and non- wasteful spraying.
- The developed drone mounted sprayer has a max takeoff of 5.5 land endurance of 10min but need to be designed for a payload capacity of 15 l and 10 minutes endurance to spray chemicals in field crops. The drone system is scalable and can be implemented to different crop types and field sizes. Upon consideration of muck scale agricultural operations ranging from small to, large in size.

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