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Development of Agricultural Spraying Drones Prototype for Coconut Beetle Weevil Control

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Abstract

Coconut is an important cash crop of the southern provinces and coastal areas of Thailand, with an area of more than 160,000 hectares and an increase of 85% every year. The total annual output is more than 500,000 tons for domestic consumption, and almost half exported. Part a decade, the coconut growers have suffered from quantity and quality yields decrease. Some coconut trees are destroyed and eventually die by insect pests, especially coconut rhinoceros beetle, black-headed caterpillar and hispine weevils. The difficulty of preventing and eliminating is the nature of the tall coconut plants. The level of wind speed in the coastal areas affects high labour costs. The chemical applied quantities and the risk of the chemical hazards that impact health costs. This research develops the agricultural spraying drones' prototype for coconut beetle weevil control by spraying directly to the coconut shoots, mainly focusing on the development of spraying systems to get closer to the tops of the coconuts and cover the leaves area as much as possible. The methods mentioned above aimed to reduce the wastage of chemicals and nutrients sprayed where conventional manual labour methods cannot reach a critical part of the coconut shoot, the coconut Inflorescence, which will develop into a part of the coconut fruit. The results research developed drone based on the idea the real-time video data in combination with high-quality IP cameras to determine the location of the coconut Inflorescence, installed a 6-arm, 12-propeller, with not over 40 litres load capacity, four high-pressure pumps, 8-nozzles. The research team designed the autopilot system, allowing the drone to learn and recognize its operation in an identical area. The resulting test showed that it can spray 4.5-5.2 litres of water/min, spray radius width 0.5 – 1.2 meters in the case of fixed spraying and 6.5-8 meters wide spray in case of general spraying. An anti-collision system works all the time precisely on a battery 14S size 22,000 mAh. This prototype can spray up to 13-18 rais (2.08-2.88 hectares), fly continuously for 22 minutes in the case of using a single battery, and when compared to spraying using conventional drones. It found that this innovation saved 20-25% of the chemicals applied.

Index Terms—Agricultural Spraying, Drones, Coconut Beetle Weevil Control.

I. INTRODUCTION

The botanical name of the coconut palm is Cocos nucifera; it is currently believed to have originated in the coastal areas of Southeast Asia and Melanesia. Present, the coconut palm is found throughout the tropics. In the Pacific region, it continues to be an essential economic and subsistence crop. Almost every part of the coconut palm is a significant food, oil, fibre, and wood source. [1] Coconut is a small-holder palm which environment-friendly to the tropical zone, covering 12.28 million hectares in 90 countries with an annual production of 64.3 billion nuts. Coconut provides USD$ 7.73 billion per annum to global coconut small-holders. The first four ranking of the worldwide country produced coconut are the Philippines, Indonesia, India and Thailand [2]. In Thailand, there are more than 1.6 hundred thousand hectares of coconut plantations and increasing every year in the southern provinces and coastal around the Gulf of Thailand, The nature of the tree is a strait, large and tall. The total annual yield is more than 500,000 tons. From January – May 2021 and 132,251 tonnes of coconuts have been exported, valued at US$110.25 million [3][4].

The quality and quantity of mature coconut yield have been greatly affected due to the disease that affects the coconut inflorescence is a disease of top rot and fruit drop caused by fungi. The rhinoceros beetles and the coconut beetles destroy young shoots, resulting in a fan-shaped cleavage,

and the coconut will die off and become the decapitated coconut shoot. It is difficult to spray chemicals to prevent diseases and pests due to the large and tall nature of the coconut tree.

Several research studies have suggested the development of sprayers capable of altering the spraying rate by using image processing methods for disease and pest-infested coconut plantations. This sprayer is designed with a remote monitoring system, the traverse and crane control system; once the target is confirmed, the nozzle is moved to the target area. Then the pump sprays to the target at the specified rate. This result is recommended for coconut trees 5-9 m tall, including the distance between nozzle and destination (1 m), pressure (1.5 bar), spring rate (2.712 l/min), maximum travel speed (1.5 km/h), fuel consumption (0.58 L/h) and working capacity (0.056 ha/h). The researcher attempted to develop an innovation based on remote control installed with drones to spray coconut shoots [5]-[11]. They were principally focusing on developing spraying systems to get closer to the tops of the coconuts and cover as much area as possible. Nevertheless, the previously mentioned techniques also resulted in chemicals wastage, including the substances and nutrients injected that do not reach the coconut shoots' vital part.

Development of Unmanned Aerial Vehicles (UAVs) for spraying pesticides to eliminate coconut pests by increasing removal accuracy, replacing human labour, reducing the use of the chemicals, and promoting the chemicals used safety through lowering direct exposure pesticides on agricultural workers. Simultaneously, improving yield quality and reducing the impact of the chemical residue on the environment. The survey of the epidemic coconut pests' problems in target areas of Prachuap Khiri Khan Province, Thailand found three main pests: coconut rhinoceros beetle, black-headed caterpillar and hispine weevils. The chemical spraying around the coconut crownshaft, leaves, and inflorescences are tricky, mainly in the case of using man labour. Therefore, the coconut farmers desire some equipment to help their work. Nowadays, drones are prevalent, so the trend of applying drones by the coconut farmer is higher than usual. However, the most common problem with drone use is the chemical waste, pesticide residues on production and the environment. The only drone sprayed chemicals by remote control are still inaccessible and do not cover some critical parts, especially coconut inflorescences around the crownshaft.

In this research, the flight control system was designed to be more autopilot, including the Digital Image Processing method is applied for a position indicator of the spray to reduce restrictions of such drones.

II. Operation System Design

The proposed drone is designed to be a 6-axis, 12-propeller, capable of carrying liquids up to 40 litres in volume, has an ultrasonic bumper sensor (6 sensors), equipped with an IP camera in the front able to control the tilt angle of 90 degrees vertically when pulling the plane parallel to the ground. Central operation control with ECU type Adriano Mega. Flight control is designed into two systems: 1) Manual control using remote control type Radio Master Link, controlled via radio frequency at 2.4 GHz. The control scheme has 16 channels that contain both the flight system and the liquid spray. 2) Auto-Pilot control based on the drone's flight position from GPS-Spectrum AR12120, which uses decision data from all eight satellite connections, as well as avionics control based on video camera image data. It works by tracking objects classified according to the characteristics of coconut leaves, coconut palms, coconut palms, and fruit. Coconut Propeller rotation control uses 6 Brushless Motors, two propellers each, controlling both speed and flight direction through CC3D Revolution, a highly efficient flight control technology commonly used today. There are four Atomizing Pressure Pumps and eight spraying tanks in the chemical spraying part, with a block diagram working as shown in Figure 1.

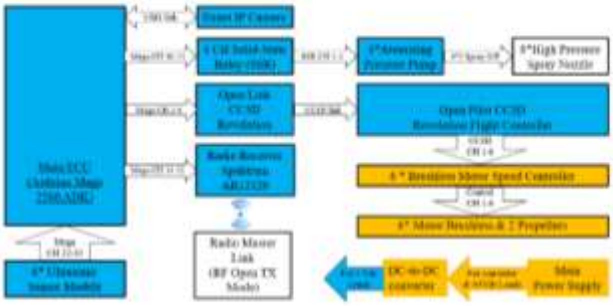


Figure 1. Block diagram of operation system.

There are two main spraying methods: 1) spraying from the top of the coconut tree by spraying from eight nozzles simultaneously. The distance from the nozzle to the top of the coconut is about 1-2 meters. Eight nozzles which this spray pattern It is a standard chemical spray that is commonly used in general. 2) Spraying from the side to make a plane with the coconut tree is positional spraying of the coconut derrick by the Tracking method. The object designed specifically for this research is to be sprayed from two nozzles on either side that corresponds to the location of the coconut gannet. The distance from the nozzle to the coconut leaf is about 1-2 meters. The spray is made at a wide angle of 30 degrees measured from the centre of the Sobal image. Operator and then spread the spraying angle to the left and right 15 degrees. The Block diagram of the whole system operation is shown in Figure 2.

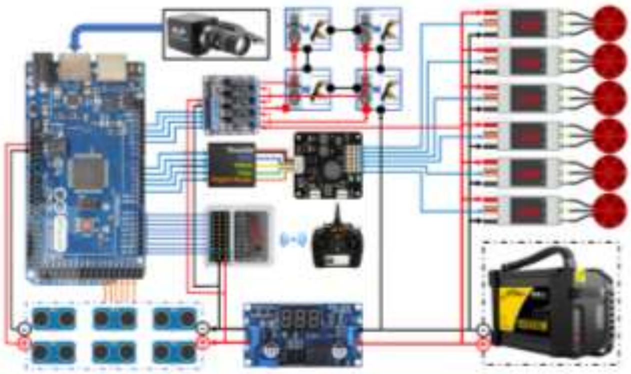


Figure 2. Hardware connection system.

III. Hardware Connection

A. Development of flight controllers

For this research, the original structure of an unmanned vehicle agricultural (drone) with a carrying capacity of 40 litres, 6-arms, 12- propellers is maintained for this research. 1) Main power supply kit, Lipo 145 battery type 44 V. 22000 mAh. 2) Magnetic type Brushless Motor with torque 1500 Nm, speed 2200 RPM, and 3) 30 Amp Brushless Motor speed control unit. The newly designed and developed part is the flight controller and spray control unit.

The flight controller consists of a dc-to-dc converter to adjust the voltage and current from the main power supply to 5 VDC; the electric current 3000 mA allows continuous control of the control system, though the main power supply has a low operating current. The main ECU uses Arduino Mega 2560 ADK, then programming with Arduino IDE and C++, which is easy to design system control software. The input and output ports of the system consist of 1) 2-megapixel (1080P) video camera, the recorded image size is 1920x1080 pixels, and the frame rate is 30 FPS, which supports vibration for sharp images and simplifies the process of image processing toward specifying the desired object location. 2) The flight protection equipment consists of six ultrasonic sensors to prevent collisions in all six directions: top, bottom, left, right, front, and rear. The flight distance has been set to three levels (50 cm, 80 cm, and 100 cm) designed to allow the software to make automated decisions based on object density conditions or the number of trees and coconut leaves. 3) Remote control can be controlled by two systems: manual control using the commander's decision and automatic control Pilot, which relies on the machine's original recognition and flight data to compare the original GPS position of each flight area. Including the processing of flight patterns and flight directions based on the distance measurement data of the Ultrasonic Sensor and the processing of video images from the built-in camera. 4) CC3D Revolution & Fight Control is a flight controller designed to work with the Auto Pilot flight model. The work will mainly refer to the GPS coordinates of the drone and then compare the data from the coordinates from the satellite at least eight to prevent the deviation of the GPS within a distance of not more than +/- 10 cm. 5) Control unit for high-pressure injection pump and pressure tank set. The design allows the spray angle to be adjusted vertically and horizontally to accommodate the vertical coverage spray pattern and the exact positional spraying of the coconut leaf needed from the horizontal. Figure 3 shows the hardware connections of the entire system.

B. An Unmanned Aerial Vehicle (UAV) Sprayer

The proposed drone operation begins when the power is turned on and connects between the ground control station and the UAV. The UAV will process the operation commands received from the control station until all sides are ready and wait for the following commands. Command to start when the UAV begins to take off, the order will be processed again in which form to fly. In other words, it will receive commands from the remote control or in Auto Pilot format. Only the pilot is that the drone will begin to check the GPS coordinates from the data of the eight satellites and the current coordinates of the drone to select the operative area. Once a working area has been selected, the system will monitor the liquid level inside the tank and begin a recorded programmed flight until the fluid level warning system informs the tank emptiness of the preset threshold. When an alarm is triggered, the drone will return to its original location to fulfil the tank repeatedly. The operation will continue to loop until a callback command is received and terminated—the UAV sprayer operating details can be illustrated in a schematic diagram in Figure 3.

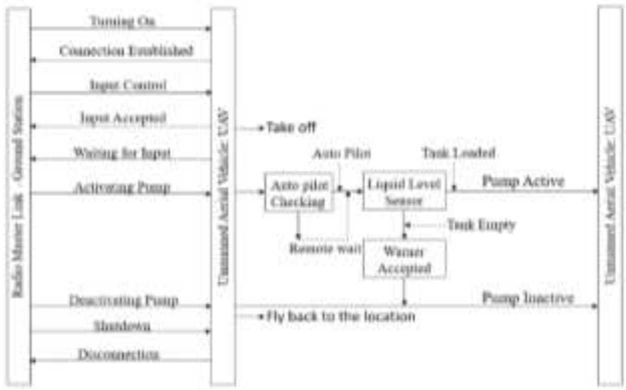


Figure 3. The UAV Sprayer Schematic Diagram.

IV. Identifying Coconut Inflorescence Location

The process of determining the location of coconut inflorescence by Digital Image Processing method consists of 4 steps are as follows.

A. Image Enhancement Process

An image enhancement is a process to improve the sharpness of images by using a spatial domain process and the result is in the spatial domain as well by using $g(x, y) = T[f(x, y)]$,when $f(x, y)$ is the original image, $g(x, y)$ is the resulting image, and $T[\ ]$ is the function $h(r_k) = r_k$ which adjusts the brightness and histogram values of the image in the neighbour point (*x,y*).

(a) (b)

Figure 4. Spatial domain Enhancement (a) Original image (b) After enhancement.

B. Image Filters

In this case, the second derivative is used to create an Isotropic Filter [12]. That means no matter which direction the image data rotates when processed with an Isotropic Filter, the result will be the same. The second-order partial derivative implemented is the Laplacian method, which is the most straightforward second-order partial derivative operator used to create an undirected filter. The Laplacian operator of a two-variable image f(x,y), defined as $\nabla^2 f = \frac{\partial^2 f}{\partial x^2} + \frac{\partial^2 f}{\partial y^2}$,when Laplacian is used to improve discrete data images. The derivative solving must be calculated using nearby data when taking the sum of the partial derivatives along the axis x and y of the images are written together to form the partial derivatives$\nabla^2 f = [f(x - 1, y) + f(x + 1, y) + f(x, y - 1)]$. Then sharpen the image again with Laplacian.

$$g(x, y) = \begin{cases} f(x, y) - \nabla^2 f(x, y), x < 0, Lamplacian\ is\ negative \\ f(x, y) + \nabla^2 f(x, y), x \geq 0, Lamplacian\ is\ positive \end{cases}$$

(a) $g(x,y) = f(x,y) - f(x,y) * w4$

(b) $g(x,y) = f(x,y) - f(x,y) * w8$

Figure 5. An example of sharpening the image signal with the Laplacian method.

C. Image Registrations

Image registration is the automatic overlaying of images. This process defines the key points that match the two images by selecting from the feature edges position and corners of the image or the image characteristics corresponding to the default template. The next step is translation, rotation, and scaling along the lines (*x,y*). This technique calls "Matching Correlation", that is, $X = xscos\theta - yssin\theta + h$, and $Y = xssin\theta - yscos\theta + k$, which do along the x-axis in h-pixels and along the y-axis in ratio s-times and rotates along the angle θ.

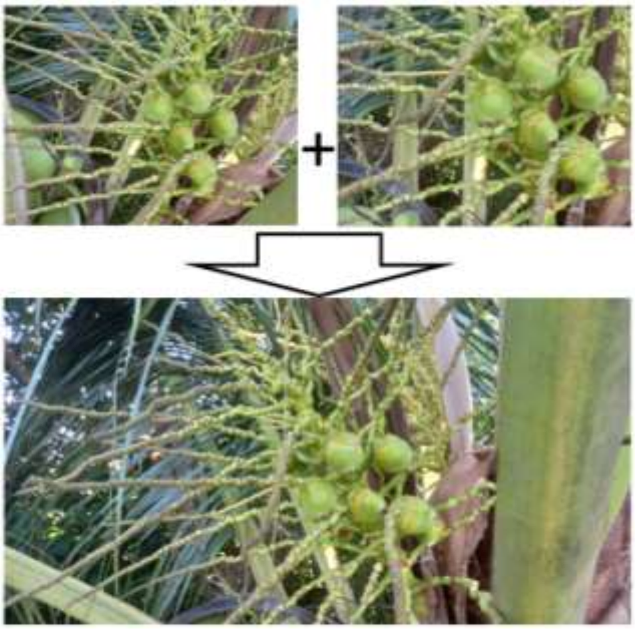


Figure 6. Image Registration Process.

D. Image Segmentation and Edge Detections

The image obtained through the entire process is a segmentation image to be compared before the location of the Edge Detections feature image is determined. In this study, the Gradient method was derived from the gray level difference of pixels around the x and y-axis, which 2D-Gradient, I(x,y) described as vector $VI = \begin{bmatrix} \mathrm{Gx} \\ \mathrm{Gy} \end{bmatrix} = \begin{bmatrix} \frac{\partial \mathrm{I}}{\partial \mathrm{y}} \\ \frac{\partial \mathrm{I}}{\partial \mathrm{y}} \end{bmatrix}$ Since an image is digital, its pixels are considered discrete. Hence, the gray level difference between I(x,y) and surrounding pixels have been found as $Gx =$

$\frac{\partial \mathrm{I(x,y)}}{\partial \mathrm{x}} = \lim_{\Delta x \to 0} \frac{\mathrm{I(x+\Delta x,y)-I(x,y)}}{\Delta \mathrm{x}}$

and $Gy = \frac{\partial \mathrm{I(x,y)}}{\partial \mathrm{y}} = \lim_{\Delta y \to 0} \frac{\mathrm{I(x,\Delta,y)-I(x,y)}}{\Delta \mathrm{y}}$ This result is called a mask; this mask can use to create an edge detection by referring to the direction of the Gradients Vector is $\Phi(u,y) = tan^{-1}(\frac{\mathrm{Gy}}{\mathrm{Gx}})$ and refer to the size of Gardient Vector $E(u,y) = \sqrt{Gx^2 + Gy^2}$. The last process is searching the location of the image captured by the camera. This study chose the method of the Sobel operator because it focuses on the centre line of the point of interest, making the edges of the object are clear. According to the program design, the filter mask of the Sobel operator of the x-axis is $H_x^S = \begin{vmatrix} -1 & 0 & 1 \\ -2 & 0 & 2 \\ -1 & 0 & 1 \end{vmatrix}$ and Sobel operator of y-axis is $H_y^S = \begin{vmatrix} -1 & -2 & -1 \\ 0 & 0 & 0 \\ 1 & 2 & 1 \end{vmatrix}$

Matching correlation Gray scale Sobel operator

Figure 7. The Sobel operator filter mask applies for locating the position of an image.

V. EXPERIMENTS AND RESULTS

A. Experiment

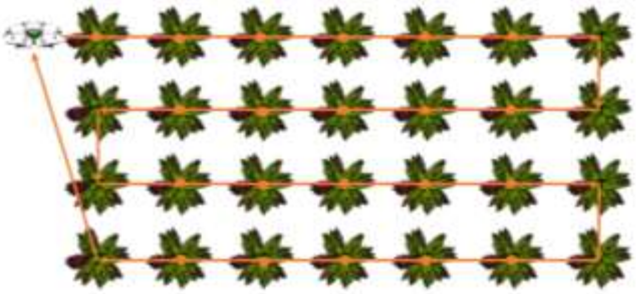
The proposed drone performance testing is divided into two approaches are as follow:

1. A comprehensive spraying test

A drone hovers over the top of a coconut tree before reading the coconut canopy diameter by Tracking Object of the video footage. Later, when the drone flies to a vertical coordinate at an angle 90-degree, corresponding to the centre of the canopy, then the ECU analyzes the size of the top. The coconut canopy is divided into three sizes in this research: S, the canopy is no larger than 7 m in diameter. Size M is 7-7.5 meters, and L- size is more extensive than 7.5 meters up. Then the ECU commands the injector pump and spray chemicals to the target object. On the condition of spraying is complete, the drone will operate to the next coordinate being in a straight line, continuously work until the tank is empty. Eventually, the drone was turned to initial coordinates to refuel and resumed operations at its final coordinates before recalling in figure 8 (a).

2. Spraying drone by locating coconut inflorescences

This is done by piloting the drone in a horizontal plane with the coconut crownshaft in a circular motion and then facing it; while moving, the system will do a Tracking Object the inflorescences simultaneously. The drone will command to stop, spray liquid to the centre of the inflorescence and fly in a complete circle (360 degrees) if the coconut inflorescences detect. After that, it moves to the following crownshaft. The flight paths of this approach are illustrated in figure 8 (b).



(a) Drone flight paths for comprehensive spraying.

(b) Drone flight paths for spraying inflorescences located detection.

Figure 8. Two approaches of drone flight paths to performance testing.

B. Results

The results of the drone test in two spraying patterns are shown in Tables 1–2 as follows.

Tree No.	Canopy Size	Spray radius (m)	Liquid volume (litre)	Spray time (sec)
1	S	6.780	1.780	21.360
8	S	6.580	1.580	18.960
15	S	6.890	1.890	22.680
21	S	6.860	1.860	22.320
		Average	**1.78**	**21.33**
2	M	7.440	2.440	29.280
3	M	7.490	2.490	29.880
4	M	7.380	2.380	28.560
6	M	7.440	2.440	29.280
9	M	7.410	2.410	28.920
12	M	7.260	2.260	27.120
13	M	7.380	2.380	28.560
17	M	7.360	2.360	28.320
18	M	7.490	2.490	29.880
19	M	7.500	2.500	30.000
22	M	7.230	2.230	26.760
23	M	7.340	2.340	28.080

		Average	**2.39**	**28.72**
5	L	7.880	2.880	34.560
7	L	7.960	2.960	35.520
10	L	7.640	2.640	31.680
11	L	7.740	2.740	32.880
14	L	7.920	2.920	35.040
16	L	7.630	2.630	31.560
20	L	7.880	2.880	34.560
24	L	7.820	2.820	33.840
25	L	7.960	2.960	35.520
		Average	**2.83**	**33.91**
Overall Average			**2.450**	**29.405**

Table 1. Drone testing results for comprehensive spraying based on the tree canopy.

The results from Table 1 illustrated that the comprehensive spraying based on the coconut tree canopy consumed the liquid 2.450 litres by average—the bushes size S spray about 1.78 litres of liquid. M-size sprays about 2.39 litres, and L-sized bushes spray fluid about 2.83 litres. Considering spraying time spent regarding the S-sized canopy diameter takes the shortest spraying time, followed by L-sized and M-sized, respectively.

Table 2. Drone testing results for spraying detected inflorescences location.

Tree No.	**Inflorescences /Spray radius (m)**					**Liquid volume (litre)**	**Spray time (sec)**	**Remarks**
	Inf. 1	**Inf. 2**	**Inf. 3**	**Inf. 4**	**Inf. 5**			
1	1.050	0.754	0.682			2.490	29.880	
2	0.960	0.680	0.540			2.272	27.258	
3	0.653	0.720	0.997	1.150		3.228	38.739	
4	0.840	0.584	0.651			2.197	26.359	
5	0.557	0.685				1.602	19.221	
6	1.140	0.512	0.863			2.511	30.129	
7	0.523	1.150	0.548	1.145	0.521	3.490	41.884	
8	0.851	0.654	0.945			2.464	29.572	
9	0.684	0.662	0.950			2.354	28.252	
10	1.100	0.645	0.682	0.488		2.796	33.556	
11	0.850	0.815	0.658			2.374	28.483	
12	0.760	0.682				1.745	20.935	
13	1.020	0.820	0.610	0.547		2.855	34.258	
14	0.598	0.525	0.992			2.225	26.701	
15	0.845	0.680	0.460			2.132	25.587	
16	0.997	0.523	1.140	0.692	0.710	3.615	43.383	*refilled the liquid.
17	0.756	0.589	0.654	1.250	0.562	3.436	41.233	
18	0.689	0.599	0.570	1.320		2.984	35.809	
19	0.520	0.580	0.932			2.166	25.990	
20	0.910	0.581	0.821	0.544		2.754	33.050	
21	0.660	1.200				2.043	24.516	

22	0.921	1.180	0.511	0.834		3.175	38.105
23	0.570	0.821	0.685			2.197	26.367
24	0.680	0.942	0.640			2.330	27.961
25	0.693	0.680	1.220	0.750		3.102	37.223
Average	**0.793**	**0.731**	**0.761**	**0.872**	**0.598**	**2.582**	**30.978**

The Drone testing results for spraying detected inflorescences location in Table 2 reflected the less efficiency of this approach observed from the liquid volumes used 2.58 litres by average higher than the first approach around 0.132 litres. Similarly to the spraying time, a comprehensive spraying approach is preferred because of a shorter spraying time.

CONCLUSION

In this study, standard digital image processing has been applied to enhance the potential of the proposed UAV, which aims to support the tough jobs of the coconut farmers. Moreover, due to the coconut trees physically characterized are relatively large and tall. These are the barrier for them on insect pests management. The coconut inflorescence, which will finally develop into the coconut fruits, is the significant factor affecting their income. So, they need equipment and tools like sprayers that can replace labour, decrease the directly touching chemicals, increase the efficiency of eliminating and controlling pests (precise method).

This research developed a prototype agricultural spraying drone to control coconut insect pests by spraying directly on the tops of coconuts, focusing on developing spraying systems close to the coconut crownshaft. As a result of this research, the sprayer reduces the quantity of chemicals used, means decreased cost, reduces the risk of direct chemical exposure, and increases the efficiency of coconut pest control.

Nevertheless, the effectiveness of coconut pest protection and control still has to consider other factors besides the efficiency of the equipment brought in to help farmers, drones. Since the research study in this section has not measured the effectiveness of spraying that directly affects the elimination of coconut insect pests.

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