Hexacopter Drones for Fertilizer Sowing in the Agricultural Sector Using the Global Positioning System (GPS)

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Abstract

Indonesian agricultural products are one of the highest-yielding agricultural commodities in Asia. Farmers are still reliant on the manual method of agricultural land care and management, one of which is the application of fertilizer to the agricultural land. As a result, with the help of an unmanned aerial vehicle (UAV) or a robot flying drone, a system or fertilizer sowing equipment is utilized on plants. The results of this research lead to the creation of a hexacopter drone equipped with fertilizer-based sensors and GPS. Hexacopter refers to a quadcopter having only four rotors. Drone rides are paired with tank-shaped sower actuators and fertilizer spraying as a container and fertilizer sowing method. Using GPS sensor block m8n, which serves as a satellite signal receiver and is converted to a position point in the form of longitude and latitude values, the vehicle can commute to fertilize by following the route of the coordinate point that has been identified in the agricultural land region. The Pixhawk 2.4.8 flight control system, which uses automatic or autonomous controls, can run smoothly, allowing the ride to automatically seed the track. The Lippo 2300mAh 4s battery has a maximum ride load lifting capability of 500 grams of fertilizer and a fertilizing height of three meters.

Keywords: Hexacopter, Agriculture, GPS, Pixhawk, Fertilizer Spraying.

I. INTRODUCTION

Robot technology in the modern era of industry 4.0 brings many changes in the human activity and life because the application of this robot can help and ease certain tasks [1]. Robots can carry out physical tasks, both using supervision and control or being controlled by humans [2]. For example, in an application of technology in agricultural sector, flying robots or drones are used to carry out heavy tasks, such as spraying and mapping pesticides on a very wide plants area or doing the aerial photography to observe the contours of the land which extends to hectares [3]. Robots have different types and functions according to the needs that will be needed, but the thing that distinguishes one robot from another is the functional part and the application of the robot itself. One type of robot currently being developed is a flying robot with the type of UAV (Unmanned Aerial Vehicle). One of these types is a quadcopter. The quadcopter is a type of drone that has four propellers which are arranged symmetrically [4].

Drones can be used to help the farmers in their work in agriculture. One of the uses of drones is that they can be used to spread fertilizers in the fields, this can be one way to maximize the process of fertilizing plants to increase crop production yields [5], [6]. Traditional farming patterns still use the very simple equipment and have the low agricultural productivity [7]. Traditional techniques are techniques that still use human power which requires a lot of time and energy to finish a large area of land so it is considered as inefficient in the work process. Apart from it, fertilization often do not distributed well on each plant because the limited time for fertilizing, it causes the farmer to return to the edge of the field or garden to take the fertilizer to be sown again. It can cause farmers to sometimes forget which areas have been fertilized and which have not been given, since the area being worked on is quite large, and the uneven fertilization will have an impact on the quality of the plant's growth. In addition, looking at the aspect of occupational health, in the process of providing fertilizer farmers work continuously due to pursuing the targets to meet plant needs. Therefore, it hurts the occupational health of the farmers due to the heavy load carried during the fertilization process. In addition, the negligence of the farmers who do not pay attention to health and work safety by using gloves, masks, and shoes to prevent toxic contamination that could have a bad effect on the farmers' bodies.

The use of drones to spread fertilizers can be one way to maximize the process of fertilizing plants so that they can increase production yields [6]. The use of drones in agriculture can also reduce agricultural costs while supporting the concept of smart farming [8]. Drones are unmanned aircraft that are controlled by the control and equipped with GPS for navigation and for locking position [9]. Technological advances in Indonesia have influenced many things in the life of modern society today, with the development of research and innovation of Unmanned Aerial Vehicles (UAVs) which have the significant progress.

A design is needed to be an alternative solution to increase the agricultural yields. The solution is in the form of using an Unmanned Aerial Vehicle (UAV) which is a Multicopter drone that can assist the process of sowing plant fertilizers so that farmers do not spend a lot of energy and an efficient fertilization process and get an even sowing result.

II. RESEARCH METHODS

The object this research is a Hexarotor drone to sow plant fertilizers using the global positioning system (GPS). The focus of the research is on the development of Hexarotor Drones that are capable of carrying and sprinkling fertilizers on arenas whose locations have been determined based on data from GPS. This research was conducted in five stages, namely problem analysis, identification of system requirements, architectural design, and also system and product implementation with the steps as shown in Fig. 1.

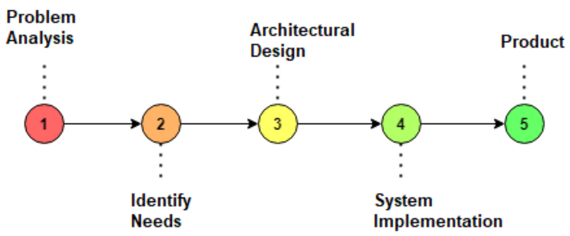


Figure 1. Research Methods

The research begins by analyzing the problem with formulates a problem related to the design of a hexacopter drone for sowing fertilizers based on a global positioning system (GPS) in the agricultural sector. The drone system must be able to lift the fertilizer, to sprinkle the fertilizer, to know where the fertilizer will be sown, and to communicate with GCS as shown in Fig. 2.

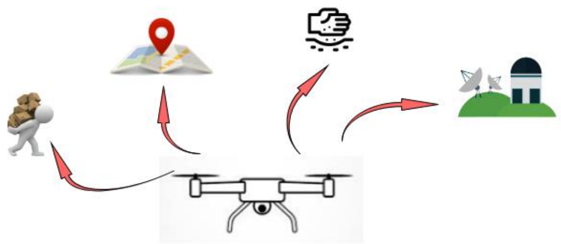


Figure 2. Problem analysis

The next stage is to identify the functional requirements for the drone such as autopilot, motor, actuator, battery, and other equipments. The devices used are shown in Table 1.

TABLE I. TOOLS AND MATERIALS

No	Component	Specifications	Mount
1	Autopilot	Pixhawk 2.4.8	1
2	Sorftware	Mission planner	1
3	Actuator	Servo 9g	1
4	Sensor GPS	GPS NEO M8N	1
5	Telemetry	3DR 500mW 900Mhz	1 Pair
6	Hexacopter Frame	DJI F550	1 Set
7	Motor	Brushless DJI920KV	7
8	Motor Controller	ESC 30A	7
9	Battery	Lipo 4S 2300 Mah	1
10	Propeller	10.45 Inch	3 Pairs

The design of architecture system is a description of how the system will be built. All elements are integrated to form a system that functions to sprinkle fertilizer plants with the hexacopter drone vehicle automatically and in precise locations with longitude-latitude coordinates on the GPS so that it can sprinkle fertilizer evenly and according to waypoint orders (flight missions). The system block diagram can be seen in Fig. 3.

The workflow of the drone begins by starting and then the process of activating the transmitter, GCS system, and hexacopter system. Next, the drone will initialize the PWM signal received from the receiver and then process the gyroscope calibration. The drone will continue the telemetry initialization process for the GCS as well as initialize the location from the GPS sensor to obtain its location. After obtaining the location point, the drone is ready to arm and read the mode command from the transmitter, if the received mode is the manual mode, the drone must be flown and run the sowing system manually by the pilot and if the mode command is automatic, the drone will fly and sprinkle fertilizer automatically based on pre-set flight parameter data. This flow chart is shown in Fig. 4.

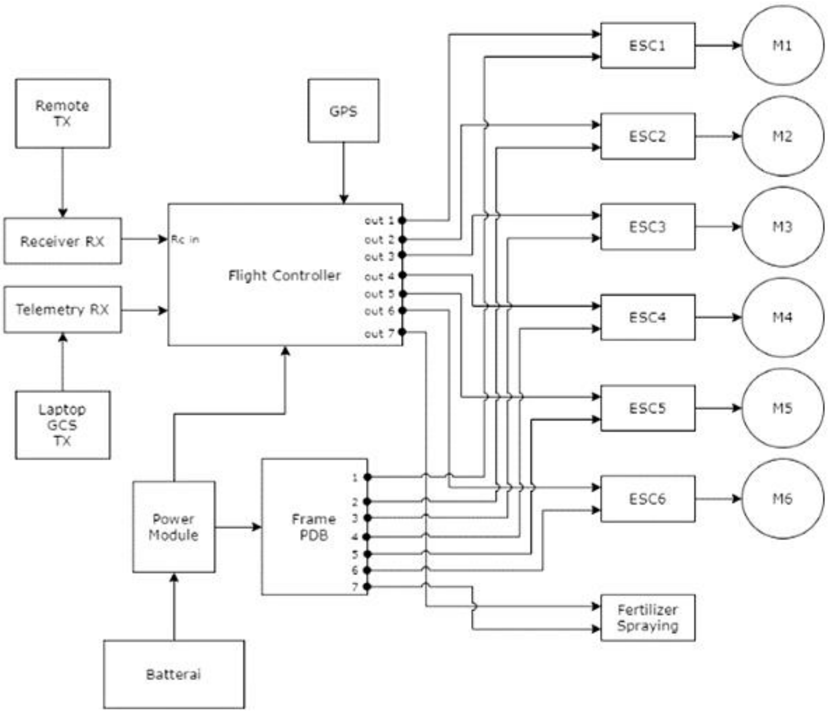


Figure 3. Flight control diagram block

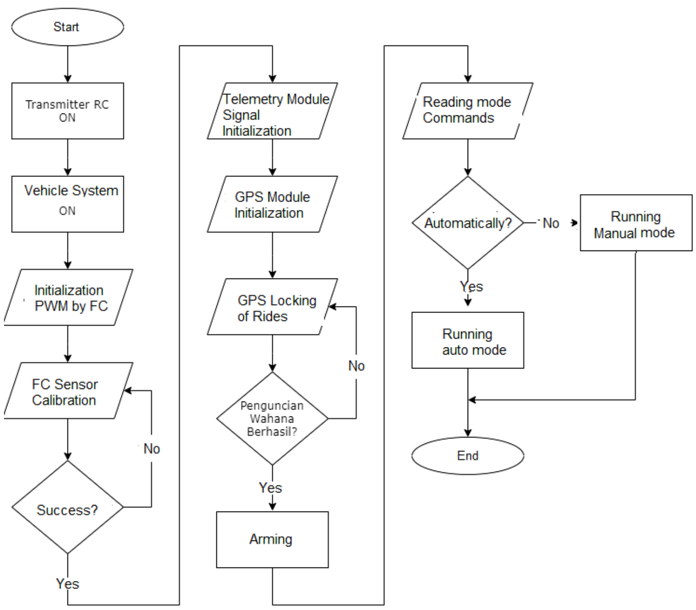
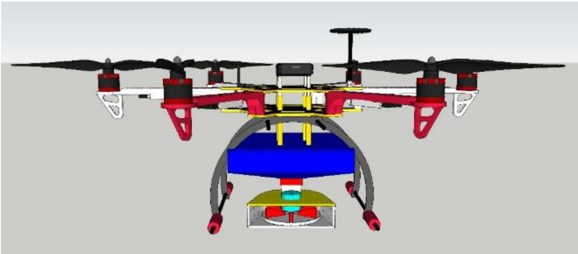


Figure 4. Flowchart of source code

The mechanical design of the hexacopter drone for sowing the plant fertilizers in the form of mechanics from the hexacopter drone and mechanics for sowing fertilizers. The image of the mechanical design (see Fig. 5) is a design for the process of making the research vehicle that will be carried out in this research. This design consists of a body frame that functions as a laying part for components used on the vehicle, such as brushless motors, flight controllers, and fertilizer sowing equipment.



The plant fertilizer sowing equipment that will be used on the hexacopter drone consists of a tank, fertilizer sprayer, and actuator (electronic components). The tool is designed as mentioned so that when the sowing tool is attached to the vehicle, it does not interfere the flight process and stability. Fertilizer spraying is a tool design whose work function is rotating. In this rotation, definitelly there are electronic components such as mechanical power (actuators) to drive fertilizer spraying. The electronic components are a brushless DC motor and electronic speed controller (ESC) which are connected to the flight controller. The design of the fertilizer sowing device can be seen in Fig. 6.

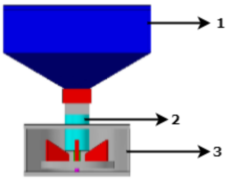


Figure 5. Mechanical design

System implementation is the stage of making drones and making electric sowing systems. The manufacture of drones is carried out by assembling a hexacopter frame, installing motors and electronic equipment, wiring, making the sowing system consisting of creating the fertilizer tanks, making the sowing mechanism, and installing the electronic system. This manufacturing process is shown in Fig. 7.

Figure 6. The process of making drone and sowing system

In the configuration of the PIXHAWK 2.4.8 flight controller, in order it can be used according to the function and form of the research vehicle, first the firmware is installed. Connect the flight controller to the computer using a USB cable, wait until it finishes booting on the flight controller (note the LED flash sign) enter the "SETUP" display menu, select the appropriate firmware type and the type of drone used in the research vehicle, namely the "X" frame configuration hexacopter (see in Fig. 8). When the firmware installation process is complete, then it reboots the flight controller which is still connected to the computer by removing the connected USB cable, the flight controller can enter the sensor calibration stage.

Figure 7. Installing flight controller firmware

III. RESULTS

The product of the hexacopter drone design for sowing fertilizers based on the global positioning system (GPS) in the agricultural sector is a hexacopter drone that can sow solid fertilizer in the form of seeds in agricultural fields, either with commands which are given manually or automatically. The vehicle can work well and the product results are shown in Fig. 9 and Fig. 10.

Figure 8. Front side

Figure 9. Right side

The hexacopter drone managed to fly and do the sowing with autonomous control (see Fig. 11), the pilot only need to activate the arm switch button on the vehicle and also on the remote control then taking off with the throttle stick facing upwards (up throttle) after the successfully taking off and then activates the auto mode using the mode switch on the remote control. in this way this the vehicle will fly towards the coordinates of the waypoint by carrying out the mission according to the created flight device. When the hexacopter drone is at the second coordinate point, the actuator commands will be active, they are the servo motor and fertilizer spraying. The sower will rotate according to the command made and the motor attached to the tank connection path with fertilizer spraying being open and then the fertilizer will flow down to sprinkle. After the pilot knows the vehicle is halfway through the waypoint mission, the vehicle will be given an RTL command input to return to the take-off point to land, replace the battery and then the vehicle will fly back to continue the sowing mission until it is finishes and enters the last command, namely the automatic RTL. The hexacopter drone will automatically land on the predetermined coordinate point.

Figure 10. Sprinkle powder

IV. DISCUSSIONS

A. *Vehicle Communication Test*

The vehicle communication test aims to determine the maximum range of the vehicle with the ground control station (GCS) which can communicate in one direction, this needs to be done to continue to know the visual data of the vehicle and to monitor the vehicle in real-time on the GCS, to find out how much the vehicle's ability to achieve each target (waypoint point) entered with a radius range from the input point to the the vehicle's position in its actual state. The vehicle communication test is carried out vertically by making a straight line as far as 110 meters with 10 meters distance from one waypoint to another (see Fig. 12).

Figure 11. Flight plane communication test

The communication testing process is carried out by flying the vehicle to each waypoint away from the point where the GCS is located to determine the signal strength every 10 meters. The results obtained can be seen in Table 2.

TABLE II. RESULTS OF COMMUNICATIONS TESTS

No	Distance (meters)	Signal strength (%)
1	1 meter	100 %
2	2 meters	100 %
3	3 meters	100 %
4	4 meters	98 %
5	5 meters	98 %
6	6 meters	98 %
7	7 meters	70 %
8	8 meters	70 %
9	9 meters	70 %
10	10 meters	66 %
11	20 meters	66 %
12	30 meters	66 %
13	40 meters	66 %
14	50 meters	65 %
15	60 meters	65 %
16	70 meters	65 %
17	80 meters	65 %
18	90 meters	50 %
19	100 meters	50 %
20	110 meters	50 %

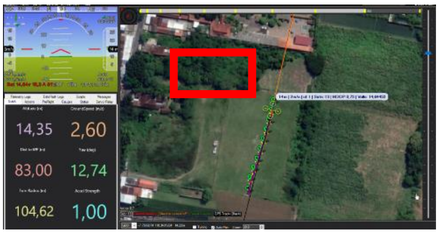


Figure 12. Testing process of vehicle communications

The results of the signal strength testing process can be seen on the GCS Mission Planner visual display screen (see Fig. 13) which is marked by a red square, the movement or displacement of the vehicle is showed by the purple line in the image above. The results of testing the communication system for the hexacopter drone sowing fertilizer can be concluded that the research vehicle can still communicate well as far as 110 meters away from the GCS location point, and this the vehicle can be monitored in real-time when carrying out autonomous missions. The hexacopter drone used in this research is equipped by an additional security system (fail-safe GCS) when there is a disconnection of the vehicle signal connection from the the GCS, the vehicle will read a fail-safe GCS command. This safe GCS failure refers to the condition that if there is no connection between the vehicle and the GCS, the flight controller will order the vehicle to return home or smart RTL (Return To Launch) automatically by relying on the GPS module which has provided the initial location lock to take off so that the vehicle will not disappear or crash when the connection is lost.

B. *GPS Sensor Testing*

Testing the GPS sensor is done by readings the GPS sensor on the vehicle by looking at the longitude and latitude data on the GCS Mission Planner visual display, then comparing it with the reading data from the Check Satellite application using a smartphone. The results of the GPS test of the fertilizer sowing hexacopter drone are demonstrated in Table 3 and Table 4.

Testing and data retrieval are carried out in open locations and under the normal weather conditions (not raining), by walking and moving to a location point by bringing the GPS on the vehicle (not in flying condition) and the smartphone to the same location to find out the results of the survey. Here is the obtained longitude and latitude data.

TABLE III. GPS LATTITUDE TEST

No	LATTITUDE		
	Vehicle	**Measuring instrument**	**Error**
1	-7.748892	-7.748848	0.000044
2	-7.748874	-7.748846	0.000028
3	-7.748957	-7.748946	0.000011
4	-7.749001	-7.749007	0.000006
5	-7.749026	-7.749023	0.000003
6	-7.749094	-7.749081	0.000013
7	-7.749171	-7.749135	0.000036
8	-7.749177	-7.749164	0.000013
9	-7.749180	-7.749170	0.000010
10	-7.749061	-7.749062	0.000001
11	-7.751184	-7.751116	0.000006
12	-7.751273	-7.751061	0.000007
13	-7.751023	-7.751022	0.000007
14	-7.751013	-7.751002	0.000010
15	-7.750907	-7.750919	0.000003
16	-7.750918	-7.750930	0.000002
17	-7.750963	-7.750966	0.000004
18	-7.750969	-7.750061	0.000080
19	-7.750874	-7.750877	0.000008
20	-7.750762	-7.750766	0.000010
Average Error			0.000016

TABLE IV. GPS LONGITUDE TEST

No	LONGITUDE		
	Vehicle	**Measuring instrument**	**Error**
1	110.355704	110.355731	0.000027
2	110.355555	110.355579	0.000024
3	110.355557	110.355583	0.000026
4	110.355686	110.355692	0.000006
5	110.355765	110.355752	0.000013
6	110.355723	110.355731	0.000008
7	110.355725	110.355742	0.000017
8	110.355611	110.355618	0.000007
9	110.355518	110.355511	0.000007
10	110.355476	110.355469	0.000007
11	110.349208	110.349213	0.000005
12	110.349096	110.349102	0.000022
13	110.348960	110.348958	0.000014
14	110.348808	110.348800	0.000016
15	110.348680	110.348680	0.000000
16	110.348840	110.348836	0.000004
17	110.348040	110.349038	0.000006
18	110.349232	110.349255	0.000031
19	110.349096	110.349097	0.000023
20	110.349688	110.348702	0.000018
Average Error			0.000002

The accuracy of data from GPS sensor readings is very influential when the hexacopter drone flies using the autonomous mode that relies on a GPS-based navigation system, where the test results of measuring data from the GPS sensor show that there is a difference in the results of the obtained data between sensors and measuring instruments so that the average value is obtained. The average error at latitude is 0.000016 and the longitude is 0.000002.

C. *Hexacopter Vehicle Lifting Test*

The trial includes testing the sowing tank which determines the overall capacity of the tank, determines the performance of the vehicle and whether it can lift the total mass of fertilizer weight which varies during the test. The conducted test aims to weigh the corn to determine the total weight of the corn using a sitting digital scale, then put them in the tank (see Figure 5.8). The total weight test of the corn is divided into several weighing scales, they are 100g, 300g, 500g, 700, 900g, and up to 1200g. Each weight variation is put into the tank and tested to determine the vehicle's attitude and the load which can be carried ina flight.

The test results show the varied findings and the maximum mass that can be accommodated in the tank is 2000 grams and the lift that can be lifted by the vehicle is only 1200 grams. In flying tests with a load of 500 grams, the hexacopter drone vehicle can fly at a throttle position of 50%. The devices are also able to fly higher if the throttle is increased to 100%. The test results of the lifting power of the vehicle with different load masses show that the mass of the 500gram load is a relatively good mass to be lifted by the vehicle. It is proved from several tests with 500grams of weight, that the result or flight control of the vehicle is still quite stable and easy to control. In testing with a load of

700gram to 1200gram, the movement of the device is less stable because the load being carried is too heavy. The results of this test are shown in Table 5.

TABLE V. ABILITY TEST RESULTS VEHICLE

	Propeller (Inchi)	**Heavy (gram)**	**Throttle (%)**	**Stability**	**Flying ability**
BATTERY 2300 MAH 4S	9.4		25%	US	US
	X	100	50%	S	S
	5.0		100%	S	S
	9.4		25%	US	US
	X	300	50%	S	S
	5.0		100%	S	S
	9.4		25%	US	US
	X	500	50%	S	S
	5.0		100%	S	S
	9.4		25%	US	US
	X	700	50%	US	US
	5.0		100%	S	S
	9.4		25%	US	US
	X	900	50%	US	US
	5.0		100%	S	S
	9.4		25%	US	US
	X	1200	50%	US	US
	5.0		100%	S	S

Note:

US : Unstable

S : Stable

D. Fertilizing Sowing Test

The fertilizer sowing test is a test carried out to see the distribution of sowing the fertilizer which carried out by a prototype hexacopter drone sowing fertilizer based on a global positioning system (GPS). The initial process is to create a flight plan which contains information in the form of coordinate points using the Mission Planner software to command the vehicle to carry out the mission of sowing fertilizer autonomously. Create a point boundary for the location of the land to be fertilized using the Draw Polygon command, limit the area to be sprinkled by forming a rectangle. Next, add a waypoint mode command to the drawn polygon. By using the waypoint mode command, you can create a fertilizer sowing mission path through coordinate points, you can also adjust the path angle, path spacing, start the sowing from above or below, height and speed. After the flight plane creation process has been completed (see Fig. 14) in the Mission Planner software, the data will be sent to the flight controller on the vehicle via a telemetry module that communicates via radio waves.

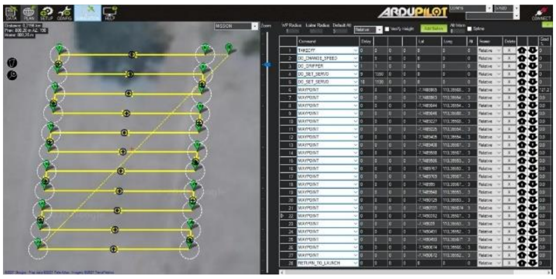


Figure 14. Make a flight plan

The process of collecting data for calculating the distribution of fertilizers sown by the hexacopter drone vehicle uses a media container in the form of five plastic pans which are located at each point in the area to be sprinkled (see Fig. 15). The results of the fertilizer that is put in each plastic pan will be calculated (per item) and the data is taken to calculate the level of distribution of sowing using a hexacopter drone. The vehicle will fly and sprinkle fertilizer according to a predetermined path with a load capacity or fertilizer carried in one flight weighing of 500 grams at a height of 3 meters from the object with a land area of 307 m2 and the fertilizer used is corn media to sow land with an area of approximately 307-m2. The vehicle needs to make two flights for sowing due to insufficient battery capacity to do only in one sow on the land area.

Figure 15. Fertilizer distribution data collection

Observation of the results of the sowing process by looking at the fertilizer which have been successfully sown by the hexacopter drone in the sowing area that corresponds to the flight lane and recording the fertilizer that fell into the plastic tray media container placed in the fertilization area (see Fig. 16).

Figure 16. Result of fertilizer sowing

From the data from the test results, the corn media that managed to enter this container did not weigh 1 gram, so each container of corn in the container was counted one by one to find out the amount in each container. The results obtained in this equalization test are shown in Table 6.

TABLE VI. THE RESULTS OF THE CALCULATION OF THE EQUALIZATION SAMPLE

Plate	**Heavy (gram)**	**Test**				
		1	**2**	**3**	**4**	**5**
1	500	32	28	30	25	35
2	500	21	24	19	23	25
3	500	17	21	19	25	20
4	500	34	30	26	23	27
5	500	30	31	20	27	22
Total		134	134	114	113	129
Average		26,8	26,8	22,8	22,6	25,8
Average of Deviation		6.24	3.44	4.16	3.04	4.16

V. CONCLUSION

A. Conclusion

The sowing of fertilizers carried out by this drone can be done automatically and fertilizers are sown according to a predetermined path evenly. Drones can also return to land at a specified place because of the use of GPS the drone. The power stability is obtained at a throttle of 50% with a maximum load of 500 grams, while for weights reaching 700 grams to 1,200 grams, it must be with a throttle of 100%.

B. Suggestion

Sowing drone can then use a lidar sensor so that the drone can fly by following the contours of the ground surface. In addition, it is also necessary to design drones so that it can carry more capacity of the fertilize, especially in large planting areas. It is necessary to consider the power of the battery so that it can reach the whole planting area in one flight.

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