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Study on Field Capacity and UAV Operation Time During Aerial Fertilizer Spraying in Rice Field

Muhammad Nurfaiz Abd. Kharim[1, a)], Aimrun Wayayok[2, 3, b)], Abdul Rashid Mohamed Shariff[2, c)], Ahmad Fikri Abdullah[2, d)], Ezrin Mohd Husin[2,3, e)] and Muhammad Razif Mahadi[2, 3, f)]

[1]Faculty of Agro Based Industry, Universiti Malaysia Kelantan Campus Jeli, 17600 Jeli, Kelantan, Malaysia
[2]Department of Biological and Agricultural Engineering, Faculty of Engineering, Universiti Putra Malaysia, 43400, Serdang, Selangor, Malaysia.
[3]SMART Farming Technology Research Center, Faculty of Engineering, Universiti Putra Malaysia, 43400, Serdang, Selangor, Malaysia.

[a)] Corresponding author: nurfaiz@umk.edu.my
[b)] amirun@upm.edu.my
[c)] rashidpls@upm.edu.my
[d)] ahmadfikri@upm.edu.my
[e)] ezrin@upm.edu.my
[f)] razifman@upm.edu.my

Abstract. Fertilizer spraying to improve rice yield using an Unmanned Aerial Vehicle (UAV) is receiving a lot of interest from rice farmers due to its field operational advantages. However, operators have to rely on their flying experiences and skills to perform an effective aerial spraying over the rice field. This study aims to investigate UAV field capacity and time consumed while performing different rates and types of fertilizer for the aerial spraying operation. The spraying experiments were conducted in fields located in Sungai Besar, Selangor with an area of about 0.6 ha/field. The field capacity, flying time for aerial spraying, frequency of refilling tank, and changing the battery set were recorded and evaluated. The results showed that uniform rate fertilizer consumes most of the flying time for the spraying process thus required a higher number of batteries set and refilling procedure. Activities such as UAV flying time, refilling of the tank, and changing the battery set during the spraying procedure were associated with the volume of liquid sprayed to the field. Treatment of variable rate application (VRA) fertilizer showed faster in terms of time-consuming for the aerial spraying operation, better field capacity, less volume of liquid, and less energy to operate the UAV.

Keywords: variable rate application, aerial fertilizer spraying, precision farming, field capacity, operation time.

INTRODUCTION

Recently, research related to Unmanned Aerial Vehicles (UAV) has become one of the most anticipated technology for agriculture activities [1]. UAV technology has become popular among farmers due to its high capability and efficiency for field activities such as field mapping, liquid spraying, and seeding broadcasting [2]. UAV technology is considered as part of new mechanization technology with very high potential benefits in precision farming [3]. It has even attracted various research interests on the UAV technology such as remote sensing, sensor, multispectral & hyperspectral camera, nozzle microcontrollers, lightweight high-capacity batteries, and advanced connectivity as part of agricultural automation and mechanization for implementation in agricultural activities. The use of UAV has a promising benefit for fertilizer and other inputs spraying. Such as able to cover much larger areas of operation in a short time, protects them from direct exposure to the spraying inputs which is a major concern in safe agricultural practice, and less laborious due to automated process [4]. At the moment, there

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are three critical field operations in a rice field that required utilization of modern mechanization such as fertilization that has agricultural mechanization index of 0.17 followed by spraying and seedling with an index of 0.19 and 0.25, respectively [5]. Therefore, reformation of rice management with the utilization of the latest technology is necessary to improve rice productivity.

In rice cultivation, UAV was mainly used for applying pesticide, herbicide, and fertilizer in the rice field due to its flexibility, and advantages in various field conditions compared to on the ground application. Thus, the various investigation has been conducted on the effects of droplets spraying uniformity, spraying drift, wind airflow in the field, droplet deposition, and types of nozzles for UAV spraying in control wind tunnel & field experimental [6]. Thus, the application of organic liquid fertilizer on rice fields with UAV aerial spraying has also been conducted [7]. Moreover, a detailed study on the field capacity and time of various activities for hormone spraying with UAV in the sugar fields has been conducted [8]. The finding showed that field capacity was dependent on the size and shape of the farm field. While the time for flight planning, fertilizing operation including tank refilling took the longest time for field operation with UAV. However, there is still less detailed study on the field capacity, and time utilization involving fertilizer spraying activities with UAV in rice fields.

Therefore, this study aims to investigate the effect of different types of fertilizer rate application on the field capacity and operation time in completing an aerial liquid fertilizer spraying in rice fields. The results from the study could benefit the development of UAV aerial spraying procedures in rice cultivation and can enhance further the site-specific nutrients management with UAV mechanization.

MATERIALS AND METHODS

Instrument

The model of UAV (AgFarm) used in this spraying test was a remote-control UAV with six multi-rotor propellers as shown in Figure 1. The specification of the UAV is listed in Table 1.

Figure 1. Six multi-rotor propellers UAV used in the spraying experiment

Table 1. Summary of six multi-rotor propellers UAV specification

Type	Specification
Size	1780x660x433 mm
Battery	2 battery, 13,000 amp
Spray Boom Length	3 meters
Rotor	22 in. 8 Rotor
Payload	15 kg
Nozzle	Flat fan, 4 Nozzle, angle 110°, Pressure 5.5 bar
Pump	Diaphragm
Tank Capacity	10 L
Spraying Speed	0 – 3.0 L/min
Flight Speed	1 - 6 m/s
Flight Time	15-20 minutes

Experiment Procedure

The experiment was carried out at Parit 5, Sungai Besar, Selangor, Malaysia (3.683677^{o} N, 101.028650^{o} E), and the System of Rice Intensification (SRI) planting method was performed throughout the experiment period. The experiment area size was 0.6 ha for each of the treatments. In the experiment, the UAV aerial spraying was performed based on two methods of liquid fertilizer applications; uniform and variable rate application (VRA) with two types of fertilizer (organic and inorganic) as shown in Table 2. Uniform rate fertilizer was applied according to the supplier recommendation whilst VRA fertilizer was applied according to the precise requirement of the rice plant during its specific growth stages by performing site-specific aerial mapping procedure.

Table 2. Treatment table for the experiment

Treatment	**Method of fertilizer application**	**15 DAT**	**35 DAT**	**55 DAT**	**65 DAT**	**75 DAT**
		Volume of liquid (fertilizer + water) for aerial spraying (L/field)				
T1	Uniform rate Inorganic	119.38	119.38	119.38	119.38	119.38
T2	Uniform rate Organic	120.73	120.73	120.73	120.73	120.73
T3	VRA Inorganic	16.61	46.36	40.57	16.10	16.10
T4	VRA Organic	54.09	181.58	177.72	18.51	18.51

UAV aerial spraying was performed 5 times of fertilization period; 15, 35, 55, 65 & 75 Days After Transplanting (DAT) throughout the experiment. The flight height was remained constant at about 2.0 m as shown in Figure 2. UAV flying speed was maintained at 2 m/s during all the session of aerial spraying since better droplet deposition, pattern, amount and sufficiency were recorded from previous UAV aerial spraying test [7].

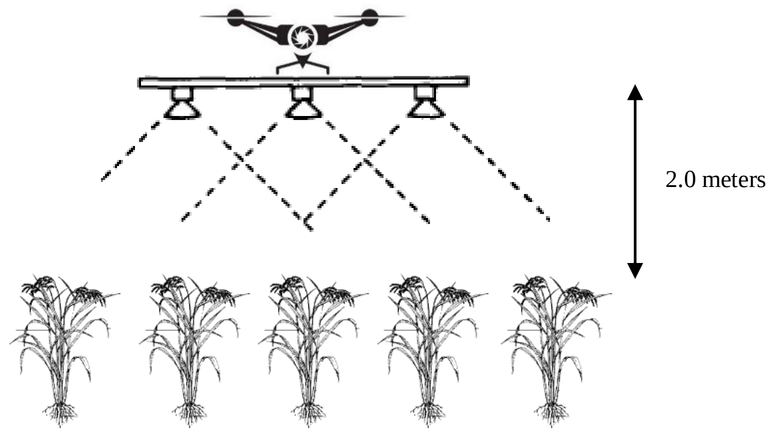

Figure 2. UAV aerial spraying was performed at height of 2.0 meters above rice canopy

UAV Field Capacity & Time Recorded

In the experiment, the UAV was deployed to spray the test field in the same manner that would be used to treat the field in commercial operations. During the aerial spraying, time was monitored and recorded manually. However, UAV landing, take-off, repositioning, and ferrying the UAV from the loading site or landing bay to the test field were not recorded due to the different distance of each treatment plot from the UAV landing bay that could vary the post-analytic procedure. Determination of the UAV field capacity (ha/hr) of aerial spraying procedure for every treatment was calculated. The field capacity was determined by using equation (1).

$$\text{Field capacity (ha/hr), FC} = \frac{A}{T} \qquad (1)$$

Where;
A = actual spraying area, ha
T = total spraying time, hr

Data Analysis

The data measurements were analyzed statistically by using an analysis of variances (ANOVA) through Statistical Analysis System Software (SAS 9.1, SAS, USA) package. Mean separation and comparison were performed using the Tukey's Honest Significant Difference (HSD) test at probability level p<0.05.

RESULTS AND DISCUSSION

Total Time Recorded for UAV Aerial Spraying Operation

The distribution of UAV flying time for aerial spraying operation of all the treatments is shown in Table 3. The results demonstrate that both treatments of uniform rate inorganic and organic showed the highest-flying time during the fertilization period of 15 DAT, 65 DAT & 75 DAT and maintaining similar trends of flying time throughout other fertilization periods. Then followed by treatment of VRA organic fertilizer that had highest flying time during the period of 35 DAT and 55 DAT while the rest of period shows third highest in flying time. Treatment of VRA inorganic shows the lowest flying time for the aerial spraying process and shows a significant difference to other treatments during all the fertilization periods.

Table 3. Comparison between all the treatments for UAV aerial spraying flying time (minute) on various DAT

Treatments	Area (ha)	15 DAT	35 DAT	55 DAT	65 DAT	75 DAT
Uniform rate Inorganic	0.6	39.75a	39.82b	39.85b	39.80a	39.83a
Uniform rate Organic	0.6	40.33a	40.27b	40.23b	40.25a	40.27a
VRA Inorganic	0.6	5.53c	15.44c	13.51c	5.36b	5.60b
VRA Organic	0.6	18.01b	60.47a	59.18a	6.16b	6.27b

* Means separation in each column followed by the same letter are not significantly different at p = 0.05.

The main reason why there was a significant difference among the treatments for the UAV flying time was due to different volumes of liquid fertilizer was performed for each of the treatments. Where the volume of uniform rate fertilizer was performed according to the supplier recommendation based on the size of the areas of planting field which the volume was already fixed accordingly. While the volume of fertilizer for the VRA method was performed based on the site-specific nutrient management that calculates precisely the actual requirement of nutrients that needed by the rice plant according to their specific growth stages which volume varied throughout the fertilization periods.

UAV Tank Refilling and Battery Changes Frequency

The frequency of refilling the UAV tank during the aerial spraying process for all the treatments can be viewed in Figure 3. According to Figure 3, both treatments of uniform rate inorganic and organic required a higher frequency of refilling the UAV tank during a period of 15 DAT, 65 DAT, and 75 DAT. However, during the period of 35 DAT and 55 DAT, treatment of VRA organic showed the highest frequency. Whilst treatment of VRA inorganic had the lowest frequency for refilling process of UAV tank to complete the aerial spraying process. The frequency of refilling the UAV tank was closely associated with the volume of liquid required for the aerial spraying process where most of the fertilization periods, treatment of uniform rate fertilizer required a much higher volume of liquid for aerial spraying compared to VRA fertilizer treatment. Apart from that, the limitation of the UAV tank was a crucial factor that needs to be a highlight in reducing the frequency number of refilling processes which later can help to fasten further the time in performing the overall spraying operation thus can cover more areas of the field during the aerial spraying process.

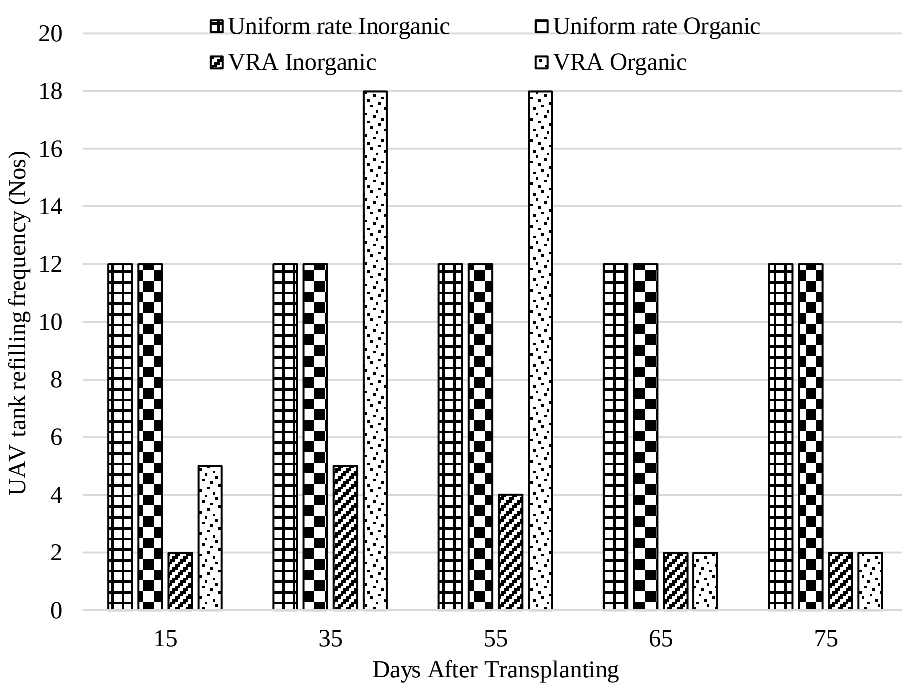

Figure 3. UAV tank refilling frequency (Nos) during the aerial spraying process on various DAT

In the experiment, multiple sets of batteries were prepared to ease the aerial spraying operation. One set of batteries could last for 15 to 20 minutes for a UAV to fly optimally. Based on the theoretical flight planning process, battery requirement was calculated accordingly to the size of the planting areas, UAV tank capability, UAV flying speeds, UAV spraying speeds, and UAV flying routes. This to ensure that the UAV aerial spraying operation can be performed effectively and able to reduce the risks of crash accidents due to lack of power during the flying process [8]. As presented in Figure 4, treatment VRA organic had a higher frequency in changing the battery set during the period of 35 DAT and 55 DAT. The battery set was changes four times to complete an aerial spraying operation, however only require one set of batteries during other fertilization periods. While treatment of Uniform rate inorganic and organic had the higher frequency in changing battery set during the period of 15 DAT, 65 DAT, and 75 DAT due to high volume of liquid were required and consumed about 39 to 40 minutes to complete the spraying process. Treatment of VRA inorganic had the lowest frequency in changing the battery set. The treatment only requires only one set of the battery to complete an aerial spraying operation throughout the fertilization period.

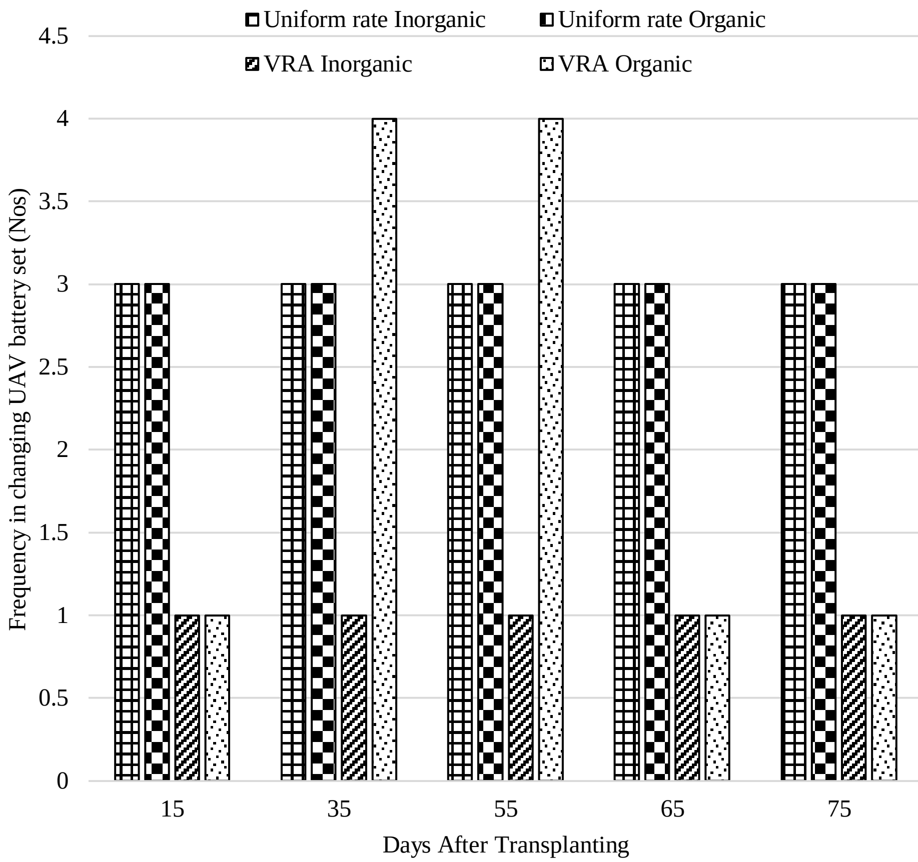

Figure 4. UAV battery changes frequency (Nos) during the aerial spraying process on various DAT

Field Capacity

The efficient use of farm machinery starts with determining working capacity in conjunction with the amount of work to be accomplished on time. The term capacity means the amount of work that can be performed. The field capacity for all the treatment areas in the experimental fields were shown in Table 4. It is found that treatment VRA inorganic fertilizer had the highest field capacity (6.51 ha/hr) and shows significance different to other treatments throughout all the split fertilization period. While treatment of uniform rate inorganic and uniform rate organic show no significantly different to each other and had lower field capacity throughout all the split fertilization period except during the period of 35 DAT and 55 DAT. During the period of 35 and 55 DAT, treatment of VRA organic had the lowest field capacity (0.60 ha/hr and 0.61 ha/hr) and showed significant differences to other treatments. The main reason why a treatment that performed VRA fertilizer had higher field capacity was due to the lower volume of liquid fertilizer sprayed to the rice field. During the period of 35 DAT and 55 DAT, both treatments of VRA inorganic and organic showed decreasing in the field capacity due to the high amount of liquid fertilizer sprayed on top of the rice canopy. Moreover, during the period of 35 and 55 DAT, rice plant requires a high amount of nutrients especially nitrogen for active growth to increase the number of tillers and later on contributed more for grain yield productivity [9] [10]. So, a higher volume of liquid fertilizer was needed during those periods which later increase the operating time to sprayed completely the rice field. Hence, this suggests that the VRA fertilizer procedure can regulate the precise amount of nutrients required by the crop to grow well and produce a better yield.

Table 4. Comparison between all the treatments for UAV field capacity (ha/hr) on various DAT

Treatments	Area (ha)	15 DAT	35 DAT	55 DAT	65 DAT	75 DAT
Uniform rate Inorganic	0.6	0.91c	0.90b	0.90b	0.90b	0.90b
Uniform rate Organic	0.6	0.89c	0.89b	0.89b	0.89b	0.89b
VRA Inorganic	0.6	6.51a	2.33a	2.66a	6.72a	6.43a
VRA Organic	0.6	2.00b	0.60c	0.61c	5.84a	5.74a

* Means separation in each column followed by the same letter are not significantly different at p = 0.05.

CONCLUSION

The results of this study show that the field capacity of UAV aerial spraying operation was varied according to different types of fertilizer rate applied to the rice field. Treatment that used the VRA fertilizer method shows higher field capacity, faster in flying time, less refilling process and use less battery set compared to treatment that supplies fertilizer in uniform rate to the rice field. Overall, the UAV field capacity, total time of flying operation, frequency of refilling the tank, and frequency to change the number of battery sets were influenced by the volume of liquid during the aerial spraying process.

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