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Short Communication

Pineapple Crop Fertiliser Application Method: A Preliminary Study on the Performance and Effectiveness of a Boom Sprayer and a Sprayer Drone

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Abstract: Fertilisation of pineapple crops can be done by using either the combination of dry and liquid fertiliser or just the liquid fertiliser. A boom spraying machine is often used to apply liquid fertiliser but recently drone spraying has gained popularity among farmers because of its speed and convenience of use in applying chemicals, particularly for pest and disease control. However, the performance and efficacy of drone applications used for fertilisation have yet to be proven. The aim of this study is to evaluate both spraying techniques to observe and compare the performance, which included the effects of fertilisation on crop growth by comparing the plant height and leaf length. A tractor-mounted boom spraying machine with a tank capacity of 400 L equipped with 10 m boom and a 10 L capacity spraying drone with 4 m effective spraying width were used in this preliminary evaluation. The evaluation was conducted in split plots with an area of 0.2 ha with 9000 plants per area each. The performance of both machines was measured in terms of the work rate, effective field capacity and field efficiency. According to the results, the application work rates of the boom spraying machine and the drone were 0.95 ha/h and 3.88 ha/h, respectively. Due to the small chemical tank capacity, the drone application is less efficient, with an effective field capacity of 0.08 ha/h compared to the boom sprayer's 0.29 ha/h, which requires frequent fertiliser preparation to satisfy fertilisation needs. There was no significant difference in crop growth performance between the two applications with a *p*-value >0.05. Drones have the potential to improve fertiliser spraying activity for pineapple crops, but they must be scheduled more often than boom spraying machines. The mixing method should be improved because of its time-consuming preparative work.

Keywords: Pineapple; Fertiliser application; Boom spraying machine; Spraying Drone;

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1. Introduction

Fertilisation is important in crop cultivation for ensuring crop growth and the quality of the produce. Fertilisation of the pineapple crops can be done either with a combination of granular or dry and liquid fertiliser or just the liquid fertiliser (MPIB, 2020; Reddy *et al.*, 1983). According to Malézieux and Bartholomew (2003), the amount of nitrogen (N) and potassium (K) needed for pineapple cultivation ranges from 250 to 700 kg.ha^{-1} (4–10 g N per plant) and from 200 to 1,000 kg.ha^{-1} (~8–20 g K per plant), respectively. All elements needed are dependent on planting density, soil condition, and expected fruit weight.

A boom sprayer is often used to apply liquid fertiliser because of the practicability for spraying high volumes of water and solution mixed fertiliser. The machine can either be tractor mounted or self-propelled. However, the frequent use of a machine in a planting area may cause soil compaction (Gursoy, 2021). Besides that, direct exposure of crops to a machine may spread diseases and pests (FAO, 2022).

A drone application can be deployed to address the aforementioned problems. Drone spraying has recently gained popularity among farmers because of its speed and convenience of use in applying chemicals, particularly for pest and disease control (Garre & Harish, 2018; Souvanhnakhoomman, 2021). Additionally, there is no direct contact between the drone to the soil and the crop, which leads to fewer disturbances in the field. However, the efficacy of the drone application on fertilising has yet to be proven.

Thus, the objectives of this study were to gather some preliminary data and information for a better understanding on the application of liquid fertiliser to pineapple crops using a drone compared to boom spraying in terms of the field performance and effectiveness. This information is to be a baseline for setting up further experimental studies regarding the mechanisation of liquid fertiliser application.

2. Materials and Methods

2.1. Field Plot

The tests were conducted at MARDI Pontian Johor, one of the MARDI stations that have a large peat soil area and specialised in pineapple research. Two split plots with an area of about 0.23 ha each were used for the test. Each plot has about 9000 pineapple plants of MD2 variety with a planting density of 90 cm between beds, 60 cm between rows in a bed and 30 cm between plants in a row, which is suited for mechanisation use. Figure 1 shows the layout of the planting distance.

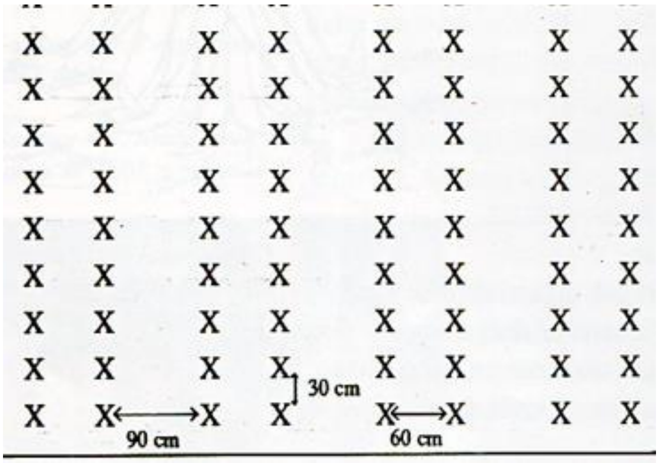

Figure 1. Planting distance

2.2. Spraying Equipment

A tractor-mounted boom spraying machine was used in this study. The spraying machine was mounted to a 38 hp tractor modified with a rubber track system to replace the wheel for overcoming peat soil's low bearing capacity problem as in Figure 2(a). The tractor was also modified to have high ground clearance for enabling operation in the crops area. The boom sprayer has a 400 L capacity water tank. There are 20 nozzles installed vertically on the sprayer’s boom with the same interval of 50 cm apart on a 10 m boom. The working height of the boom was between 0.5 and 1.0 m from the top of the plant canopy which gives effective spraying width of 12 m.

The boom sprayer was compared with an eight-rotor spraying drone model DJI Agras MG1-P with a tank capacity of 10 L as in Figure 2 (b). The drone operation payload was up to 24.8 kg. The drone was powered by a 12,000 mAh Li-Po battery that provides up to 20 mins of flying time with a full tank capacity. The drone has a total of 4 nozzles arranged on both sides which gives an effective spraying width of 4 m at a flying height of 1.5 m above the plant canopy. The spraying flow rate is 1.3 L per min as per the specification given. The drone was operated by trained personnel during the study.

(**a**) (**b**)

Figure 2. The applicators used in the study. (**a**) A boom spraying machine mounted on 38hp rubber track tractor; (**b**) Spraying drone

2.3. Liquid Fertiliser and Application

Liquid or foliar fertiliser used in the study was a solution of soluble type NPK fertiliser of 18:18:18 + TE. The soluble fertiliser rate was calculated using a direct conversion from MPIB's standard dry fertiliser recommendation of 42 g/plant/season (total N & K of 6.3 and 6.72 g/plant each season, respectively) by using Pineapple Mixed Fertiliser, PMF (15:0.5:16). The amount of soluble fertiliser calculated from this direct conversion was 37 g/plant/season based on the highest fertiliser element, the K as calculation 1 below:

Calculation 1:

Require fertiliser PMF (15:0.5:16) = 42 g/plant/season

The highest fertiliser element is potassium (K), 16%

Total K element from the required fertiliser

= 42 × 16% = 6.72 g/plant/season

Required soluble fertiliser (18:18:18) based on K element

= 6.72 / 18% = 37.3 g/plant/season

The fertiliser was diluted by following the manufacturer's guidelines of 40 kg fertiliser to 600 L of water. The total fertiliser needed was divided into 10 applications at one-month intervals, where the spraying applications were conducted every month from the 1st month until the 10th month. Based on the calculation above, the 9000 pineapple plants require about 333 kg of soluble fertiliser per season or 33.3 kg per application. The required amount of water was calculated as follows:

$$\text{Water required} = \frac{600}{40} \times 33.3 = 499.5 \text{ liter} \tag{1}$$

However, the dilution rate was adjusted for the drone application to match the tank's maximum capacity and the drone's maximum concentration that can be sprayed at a rate of 5 kg fertiliser to 10 L water. With the adjustment, the preparation of the diluted fertiliser solution was conducted repeatedly for about seven times to fulfil the required amount of fertiliser for the plot size.

2.4. Calibration of Equipment for the Study

Calibration is important to ensure that the application rate of the fertiliser given meets the recommendation. The spraying drone has an automatic system that can self-calibrate to meet the volume of water sprayed per unit area as set, but the boom sprayer does not come with that system, so it must be calibrated to meet the requirement.

The boom sprayer was calibrated for having a correct tractor driving speed that suit to the spraying flow rate. Then, the determined speed was used for obtaining the right tractor gear setting. Below is the step of the calibration.

2.4.1. Nozzle flow rate determination

The flow rate of the spraying machine was determined by collecting the amount of water sprayed from each nozzle at a particular time, then calculated with the Equation (2).

$$\dot{Q}_N = \frac{Q_N}{t_{test}} \times 60 \tag{2}$$

where, $\dot{Q}_N$ = Average of the nozzle flow rate (*L/min*), Q_N = Average of the water volume sprayed per nozzle (*l*), t_{test} = time taken for the test that here were 20 sec

2.4.2. Tractor speed determination

The tractor driving speed was obtained by using the Equation (3):

$$V_T = \frac{0.06 \times A_s \times \dot{Q}_N \times n_N}{Q_A \times L_s} \tag{3}$$

where V_T = tractor driving speed *(km/h)* A_s = Area of test plot (m^2), $\dot{Q}_N$ = Average nozzle flow rate *(l/min)*, n_N = Number of nozzles, Q_{ha} = Water volume per area *(L/m^2)*, and Ls = Effective spraying width (*m*).

2.4.3. Tractor gear setting

Based on the driving speed calculated above, the gear setting for the tractor was obtained through a trial and error approach. The actual speed of the tractor on a particular gear setting was calculated by using the Equation (4);

$$\text{Tractor driving speed} = \left(\frac{\text{Travel distance}}{\text{time taken(s)}} \times 3.6\right)\text{km/h} \quad (4)$$

The travel distance was 20 m and the tractor's engine speed was set to 1500 rpm, as was the same for the nozzle flow rate test.

The test was repeated until the tractor driving speed was obtained at the particular gear setting near the calculated speed as in Equation (2). Then, the water volume was adjusted to suit the actual driving speed that has been obtained to minimise the application rate error.

2.5. Field Evaluation

Both spraying types of equipment were evaluated for the performance to spray fertiliser to the test plot. The speed of the tractor and drone while performing the job were taken to determine the theoretical field capacity. The overall time taken for the operation started from fertiliser preparation until the job done for spraying the plot was recorded and analysed as effective field capacity. The theoretical and effective field capacities were compared to obtain the field efficiency of the running operation in the farm layout. The equations used for obtaining the above information are as follows:

Theoretical field capacity

$$\text{TFC} = \frac{\text{W} \times \text{S}}{\text{C}} \quad (5)$$

where, TFC = theoretical field capacity, W = the width of effective spraying spacing (m), *S* = the average forward speed (km/h) and *C* = constant, *10*

Effective capacity

$$\text{EFC} = \text{W} \times \text{S} \times \text{FE} = \text{TFC} \times \text{FE} \quad (6)$$

where EFC = effective field capacity which is the work rate achieved over the whole plot with considering the total time taken for the work done at the plot,

Also, EFC can be obtained as,

$$\mathrm{EFC} = \frac{\text{Total area (ha)}}{\text{total time taken (h)}} \tag{7}$$

Field efficiency, in %

$$\mathrm{FE} = \frac{\mathrm{EFC}}{\mathrm{TFC}} \times 100 \tag{8}$$

2.6. Crop Growth Performance

Crop growth performances were measured as an indicator of the fertiliser efficacy on the crop based on the applicator employed. Each split plot was divided into four blocks of 2250 plants each. Eight plants were chosen at random and tagged from each block to measure their growth rates, in terms of plant height, and leaf length. The data were collected at 1-month intervals after a month of the initially sprayed fertiliser.

3. Results and Discussions

The study results were divided into three parts, calibration, applicator field performance and crop growth performance. The calibration result gave the initial information needed before the study was conducted. Meanwhile, the application's field performance result shows the operation comparison to determine which one is better in terms of fieldwork operation and crop growth to observe the efficacy of fertiliser based on the applicator used.

3.1. Calibration Result

As mentioned above, the calibration was only conducted on the boom sprayer to synchronise the spraying flow rate with the tractor driving speed to have a correct rate of fertiliser application per unit area. The boom sprayer's nozzle flow rate was measured at an average of 0.034 L per sec or 2.04 L per min at an engine speed of 1500 rpm. The spraying system's pressure was maintained between 2.5 to 3.0 bars by adjusting the pressure regulator. With 20 nozzles, the spraying flow rate was 40.8 *L/min* as stated in Table 1.

Based on the calculated amount of fertiliser per plant as in Calculation 1, for the 9000 plants per 0.23 ha area, the total amount of soluble fertiliser required was roughly 333 kg per season or 33.3 kg per application. Based on the water requirement, spraying flow rate, and plot area size, the calibrated spraying speed was 0.94 km/h.

The tractor obtained the needed speed by employing a low-2 gear setting at a 1500-rpm engine speed that gave the nearest actual driving speed of 0.79 km/h. The water requirement was corrected with the actual driving speed by manipulating Equation (3), which gave a new water volume of 596.5 L and was rounded to 600 L.

Due to the boom sprayer's water tank limit of 400 L per operation, the amount of fertiliser for the boom sprayer was divided in half to reduce operator error and for easier management. Each application took about 17 kg fertiliser with 300-L of water. One application will cover up to about 0.115 ha.

Table 1. Calibration information for the boom sprayer

Plant Number	Fertiliser required per season (kg)	Fertiliser required per application (kg)	Average nozzle flow rate (*L/min*)	Boom spraying flow rate (*L/min*)	Water rate (*L/0.23ha*)	Estimation speed (*km/h*)	Gear setting	Actual speed (*km/h*)	Adjusted water volume rate (*L*)
9000	333	33.3	2.04	40.8	499.5	0.94	Low - 2	0.79	600

3.2. Applicator Performance

Table 2 shows the specification and performance results for both applicators used to apply foliar fertiliser to the test crops. The tank capacity of the boom sprayer is 40 times bigger than the drone, meaning that it can hold more water and thus requires less frequent preparation of the liquid fertiliser as compared to the drone. If the same rate of fertiliser dilution (ratio of water) is needed as the boom sprayer has for the drone, preparation of the fertiliser needs to be done forty times. However, in this study, the drone application used a dilution rate of 5 kg fertiliser to 10 L of water that needs a minimum of 7 times additional preparation.

In terms of spraying flow rate, the boom sprayer has about 30 times higher flow rate compared to the drone, which was 40.8 *L/min* versus 1.3 *L/min*. This shows that the coverage per unit area has more water by using the boom sprayer than the drone, which means that less fertiliser concentration was applied to the plants. A high concentration of fertiliser may potentially damage the pineapple leaf tissues (Contributor, 2021). Boom sprayer application is therefore better for the prevention of this issue. A drone may potentially be used with frequently scheduled spray with a new specially formulated fertiliser that can minimise the effect of fertiliser burn.

The effective spraying width of the boom sprayer is 12 m, which is three times wider than the drone of 4 m width. This will make the drone passes for spraying to an area more than the use of a boom sprayer even though there is no direct contact with soil or crops when employing a drone. The use of a longer boom sprayer in the planting area could reduce the number of tractors passes, resulting in less soil disturbance and disease and pest spread.

In terms of speed of spraying operation and theoretical field capacity, the drone can complete the spraying work 12 times faster than the boom sprayer, but only if the drone uses a different fertiliser dilution rate. The development of a specially formulated fertiliser for drone application is necessary to enhance the drone's potential in fertiliser applications.

Spraying results with the boom sprayer and the drone demonstrated poor effective field capacity, with 0.29 ha/h and 0.08 ha/h, respectively. This was due to the time required to prepare the fertiliser for spraying. The fertiliser used for the drone had to be mixed several times to meet the requirements of the area. On the other hand, filling the tank of the boom sprayer with water was also time-consuming because of the poor flow rate of the domestic piping line. Wages of both applications in using boom and drone spraying were calculated to be at RM 25.5 and RM 93.75 respectively by taking in the work force requirement of 3.4 man-hours/ha for boom spraying and 12.5 man-hours/ha for drone spraying. All of these issues should be addressed in order to improve the application in the next study.

Table 2. Applicator specification and performance comparison

Specifications & performance	Boom sprayer	Spraying drone
Tank capacity (*l*)	400	10
Spraying flow rate (*l/min*)	40.8	1.3
Effective Spraying width (*m*)	12	4
Spraying height (*m*) (above canopy)	0.5-1	1.5
Operation speed (*km/h*)	0.79	9.72
Total fertiliser preparing time (*min*)	29.3	85
Theoretical field capacity (*ha/h*)	0.95	3.88
Effective field capacity (*ha/h*)	0.29	0.08
Efficiency (%)	31.1	2.1
Man hours/ha	3.4	12.5
Wages (RM 7.5/h)	25.5	93.75

3.3. Plant Growth Rate

Table 3 shows the parameter of plant growth rate to observe the efficacy of application methods on different types of applicators between the boom sprayer and spraying drone. Based on the t-test conducted at the significance level of 0.05, there was insufficient evidence to conclude that there was a difference in the mean growth rate of both parameters taken by different applicators used. This implies that the use of drone spraying also has the potential for applying liquid fertiliser to pineapple crops. Hence, this study should be conducted again with randomise design experimental plot and with an improved application method to see the actual potential.

Table 3. Plant growth rate by different applicator used for fertilisation of pineapple crop

Plant growth rate	Boom sprayer	Drone	P value
Crop height (*cm/month*)	3.53 ± 2.95	2.56 ± 2.08	0.18
leaf length (*cm/month*)	3.31 ± 2.5	2.28 ± 1.99	0.11

4. Conclusions

A boom sprayer is more practical for spraying liquid fertiliser than a drone with the current fertiliser type. However, drones can potentially be used if the spraying activity is scheduled more frequently and with a specially formulated fertiliser. The use of drones is more convenient and can protect the crop from having direct contact with machines. The liquid fertiliser preparation technique should be improved for more efficient operation. Future studies are needed to be carried out with proper experimental design layout and improved application method from the preliminary information gathered in this study in order to verify the true potential of the drone application in fertilising pineapple crops.

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Conflicts of Interest: The authors declare no conflict of interest.

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