DEVELOPMENT OF A MECHANICAL WEEDING AND FERTILIZING MACHINE FOR WATERMELON PRODUCTION

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ABSTRACT

Watermelon weeding and fertilizing are currently done manually. These two operations are usually carried out separately, which consumes much time and energy. Most watermelon farmers in Malaysia use a knapsack sprayer to apply herbicides during the weeding operation. It requires approximately seven hours to complete the weeding operation for one hectare. After weeding, the farmers will spread N.P.K. fertilizer on the watermelon plants according to the predetermined rate. This process takes between 23 to 24 hr/ha. Therefore, this paper describes the development and evaluation of a mechanical weeding and fertilizing machine for *watermelon planting. The study's objective was to design and fabricate a prototype machine that can be used for these two operations, specifically for open-field cultivation. The main criteria considered during the design and evaluation of the prototype machine are its reliability in terms of working mechanism, field capacity, and field efficiency. In addition, the mechanical weeding technique and uniformity of fertilizer rate are also evaluated in this experiment by comparing it to the existing method. This prototype was developed from a rotavator structure as the basis of the chassis. Afterward, the fertilizer tank and its fertilizing mechanisms were added to the main structure, allowing two operations (fertilizing and mechanical weeding) to be carried out simultaneously. This prototype machine needs to be connected to a 4-wheel tractor and uses the power from the tractor's power take-off (P.T.O.) to move the mechanism that has been installed on the prototype machine. According to the evaluation, the prototype machine's field capacity is 0.32ha/hour, with a field efficiency of 91.4 % for both operations. In addition, the use of fertilizer can also be saved up to 18% compared to existing methods due to uniform distribution.*

Keywords: *watermelon, mechanical weeding, mechanical fertilizing, field capacity, field capacity*

INTRODUCTION

Watermelon is a popular short-term fruit and has been classified under significant fruit planted by the Ministry of Agricultural and Food Security (MAFS). These major fruits are being promoted for commercial planting due to their potential to generate income for the farmers and the economy.

In Malaysia, the total acreage of watermelon cultivation in 2020 was 9,247 hectares, with a production of 134,225 tons valued at RM 184,559,000 (Department of Agriculture Malaysia, 2020). In terms of export and production, Malaysia was ranked 19th worldwide with a share in export of 0.68%, while 49th with a share in the production of 0.13% (tridge.com/watermelon/2022). Most of the watermelon cultivation in Malaysia is in Kelantan (2230 ha), Pahang (1991 ha), Johor (1168 ha), and Terengganu (889 ha). Watermelon takes 65 to 75 days to harvest and produce 20 to 25 tons per hectare.

Throughout the planting period, three times fertilization will be carried out. However, the most important is the third fertilization, which will be performed with weed control. Weeding involves the removal of unwanted plants (weeds) that compete with watermelon plants for nutrients, space, and water. Weeds can also serve as hosts for pests and diseases that can damage watermelon plants. The current method is that farmers spray herbicides on weeds found outside the plastic mulch. Then, the farmer will continue making a furrow on the edge of the plastic mulch and put N.P.K. fertilizer in the furrow according to a specific rate. After that, the farmer will re-cover the fertilizer with soil using a hoe. Covering the fertilizer with soil is very important to maintain the quality of the watermelon when harvested, as watermelon skin is susceptible if exposed to fertilizer, which will cause fruit damage or become unmarketable.

Therefore, the objective of this study was to evaluate the machine's performance in the aspect of Theoretical Field Capacity (T.F.C.), Effective Field Capacity (EFC), and Field Efficiency (F.E.) during mechanical weeding as well as fertilizing. Besides that, this study was also carried out to determine the effect of these two mechanical operations concerning the total yield of watermelons per hectare.

MATERIALS AND METHODS

Experimental site

The experiment was carried out at a research plot in MARDI Bachok Research Station. The site is characterized by BRIS (Beach Ridges Interspersed with Swales) soil with annual precipitation and temperature between 2500–2800 mm and 24ºC–32ºC, respectively.

Preparation of plant-bed

The plot was plowed to a depth of 30cm using a rotavator after decomposed manure was broadcasted at a rate of 8–10 tons per hectare. 25 plant-bed were made by using a disc-ridger with a plant-bed size of 4.5m x 50m (width x length).

Preparation of planting material

A seedless watermelon, namely the Princess variety by Known-you Seed Co. Ltd. was chosen for this experiment. According to the variety information, the potential weight per fruit ranges between 4 and 8 kg. This variety was chosen based on the most common variety planted by local farmers. After 10-14 days, the seeds germinated in a seedling tray and were ready to be planted.

Planting and crop management

Seedlings were spaced at 0.5m intervals and well maintained until the harvesting stage at 65 days for machine evaluation and data collection. The prototype machine was evaluated when the watermelon plants reached 15-20 days after planting or just before the vines started to spread out. The fertilizer that has been tested is NPK Blue (Yara & Nitrophoska) 12:12:17. The standard fertilization rate that has been practiced is 70-80g per plant. It was randomly sowed manually and by using prototype machine. This experiment was conducted in two planting seasons.

Machine design

The table below shows the main parts of the watermelon weeding and fertilizing machine. In general, this machine has five significant parts, as listed below.

Table 1: Main parts of watermelon harvesting and collecting machine

No.	Name of part(s)	Requirement:
1.	Tractor	4WD, 70HP above
2.	Three point linkage	-
3.	Rotorvator unit	1400 mm
4.	Fertilizer tank	400 kg capacity
5.	Fertilizer discharge mechanism	-

Figure 1: Prototype machine during weeding and fertilizing operation

Machine description

The prototype machine is made up of a rotavator as the main structure. Then, a fertilizer tank and discharge mechanism were installed on the structure as a complete prototype. Finally, the three-point hitch was fitted to the prototype machine to connect to a three-point linkage system which commonly uses in a four-wheel drive (4WD) tractor. This system allows the operator to control such as lifting and lowering the implement and to ensure the machine is in a fixed position to the tractor. This experiment was tested with a tractor speed of 2.5 km/hr.

Fertilizer discharge mechanism

This machine was required to attach to a 4-wheel tractor with 70hp and above. It uses the tractor's power takeoff (PTO) as a power source to move all the mechanisms. Rotavator works as a mechanical weeding and loosens the soil. Meanwhile, this machine has added fertilizing mechanisms to enable fertilizing operations. These include the addition of a 400 kg stainless steel tank and fertilizer rate adjuster to ensure the discharge rate can be adjusted to the required amount from 70g/plant to 100g/plant. However, the recommended fertilizer rate is approximately 80-90 g/plant.

Data collection

During the machine performance study, Theoretical Field Capacity (TFC), Effective Field Capacity (EFC) and Field Efficiency (FE) were measured. EFC can be described as an ability of the machine to operate under an actual field condition (Zhou et al., 2012). FE was defined as the percentage of time, when the machine is operated at its full rated speed and width in the field (Nasri et al., 2015). FE described how effective the time was spent to do the work (Grisso et al., 2014). Because of the headland turns, machine trouble, ground surface and overlapping, the FE for an actual field operation was always less than 100% (Zandonadi, 2012). The formula that has been adopted to calculate TFC, EFC and FE are as reported by Hanna (2016).

The formulas are:

$$FC = \frac{S\,x\,w}{10} \qquad (1)$$

where, s = average speed of machine, (km/h)
w = rated width of machine, (m)

$$EFC = \frac{A}{t} \quad (2)$$

where, A = total area (ha)
t = total time (hr)

$$FE = \frac{EFC}{TFC} x\ 100 \quad (3)$$

Other data that have been collected are yield comparisons between the existing method and the prototype machine. This ensures the yield performance is at par with the existing method or even better.

RESULTS AND DISCUSSIONS

Machine's Performance

From the data analysis as shown in Table 2, the effective field capacity for this prototype machine are as follows:

Table 2: Machine parameter and performance evaluation

Item	Machine Parameters
Tractor	80 HP
Area (hectare)	0.5 ha x2 plot (1 ha)
Implement	Watermelon weeding & fertilizing machine
Power take-off	1200 r.p.m
	Performance Evaluation
TFC	0.35 ha/hr
EFC	0.32 ha/hr
FE	91.4%

Generally, it takes about 2.8 man-hours per hectare for both operations (weeding and fertilizing). However, compared to the existing method, as explained in the introduction, it takes about 31 man-hours per hectare for both operations. Seven hours are needed to spray herbicides, while 24 hours are required for fertilizing, including making furrows, spreading fertilizer, and covering the furrows with soil. The evaluation that has been carried out shows that the prototype machine can speed up the operation and can even save as much as 28 man-hours for one hectare of planting area. Based on the TFC and EFC, the field efficiency was 91.4 percent.

Through the observation from the experiment, the fertilizer that has been sown is located near plastic mulching as practiced by farmers, which is at the root zone after watermelon plants start to spread out (15-20 days after planting). As designed, a rotating disc has been installed on the prototype machine to cover the fertilizer with soil. At the same time, mechanical weed control has also been done to ensure the vines spread without competing with weeds. Besides chemical spraying, this mechanical weeding is an excellent option for farmers to control weeds without using herbicides. Hence, the employment of a mechanical weeder is needed to reduce the herbicide cost.

Yield Performance

Table 3 compares the total yield of watermelon between standard practice and mechanical weeding and fertilizing.

Table 3. Effect of weeding and fertilizing method on the total yield of watermelon

	Data			
Method	**Manual**		**Machine**	
Planting Season	**1st Season**	**2nd Season**	**1st Season**	**2nd Season**
Average yield per bed	982 kg	1061 kg	963 kg	1145 kg
Total yield per hectare	24,550 kg	26,525 kg	24,075 kg	28,625 kg

The data tabulated in Table 3 clearly shows that there is no significant difference between the practices. However, since both operations have been carried out simultaneously through machines, it will speed up the operation and save costs since no herbicides are being used. Besides that, this machine offers a uniform fertilizer distribution compared to manual methods.

CONCLUSION

The prototype machine was successfully developed and evaluated. It shows promising performance in two modes of operations; mechanical weeding and fertilizing. Through the experiments that have been conducted, the Theoretical Field Capacity (TFC), Effective Field Capacity (EFC), and Field Efficiency (FE) were evaluated. The EFC for both operations was 0.32 ha/hr, while the field efficiency (FE) was 91.4%.

The result shows that the prototype machine can be used in both operations for watermelon production on a farm. Besides can speed up the operation and providing uniform fertilizer distribution, this machine also can reduce operational time by up to 28 man-hours for one hectare.

Funding: This research was funded by the MARDI Development Project with project number P-RM 521

Acknowledgments: The author would like to thank to MARDI especially MARDI Bachok Research Station and staffs for proving infrastructures and continuous support.

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