

Original Research Paper

3-in-1 Disc Ridger: Development of an Integrated Implement for Plant-bed Making, Fertilizing and Weeding for Sweet Potato

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Abstract: Mechanization has been the solution to counter issue such as labour shortage and low production rate on field in the agricultural sector. Adaptation of mechanization system could lower the cost of production, improve quality of the product and also reduce the tedious work of labour. Current manual practice contributes to high labour cost since the job are labour intensive. Therefore, Malaysian Agricultural Research and Development Institute (MARDI) has developed a complete machinery package for sweet potato production from land preparation until harvesting. One of the important activities that require an implementation of machinery aspect is ridge forming. This activity is essential due to the height of the ridge influencing the yield. As proven in the previous study, the higher the ridge the more aeration contributed to the higher yield of crops. In this manuscript, the authors report on the development and evaluation of the disc ridger. This implement is capable to be used as a bed forming during land preparation. In addition, this implement is also equipped with granular-based fertilizer applicator, in which two tasks can be performed together, which are weeding and fertilizing. The recorded field capacity of this machine was 0.29ha/hr for bed forming and 0.28ha/hr for inter-row weeding and fertilizing. In terms of fertilizer application performance, the average amount of fertilizer withdrawn for each plant was 7.65g, which are complied to the agronomist recommendation.

Keywords: Sweet potato; disc ridger; bed forming; inter-row cultivator; fertilizer applicator

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1. Introduction

Nowadays, sweet potato has become one of the major crops planted in BRIS soil, especially in Kelantan and Terengganu because it has been recommended as an alternative industrial crop to replace the tobacco plantation (Zaharah *et al.*, 2010). Thus, Malaysian Agricultural Research and Development Institute (MARDI) have announced varieties of sweet potato such as Gendut, Telong and Jalomas and VitAto (Zaharah *et al.*, 2010). As a result, there is an increment in total planting acreage in Malaysia since 2016 until 2019 as reported in Vegetables and Cash Crops Statistics by Department of Agriculture Malaysia (DoA). Therefore, the mechanization aspect is essential in order to facilitate the field operation for sweet potato cultivation in Malaysia.

Based on normal monsoon conditions, there are two planting seasons in a year for sweet potato cultivation, especially in Kelantan and Terengganu. The first and second season starts during January until May and July until November, respectively. However, the second season is quite troublesome for the farmers due to heavy rainfalls (Tan *et al.*, 2006). From the experiment, it is verified that the total yield from the second season is reduced with high percentage of low-quality yield (<150 g/sweet potato) (Tan *et al.*, 2006). This is due to the heavily rainfall season, the water table is increasing. This situation has led to the growth of roots and tuber development becomes limited.

In order to solve the problems, the raised bed planting system is recommended by the agronomist from MARDI. Furthermore, the use of raised bed planting system is thought to increase the yield and it also helps to prevent the crops from being flooded during monsoon season. According to Maniyam *et al.* (2012), the highest root yield was obtained on raised planting bed, > 0.4 m higher compared to the normal planting bed. The higher yield recorded is probably due to better soil aeration permitted and less tendency for soil compaction.

Thus, MARDI has developed a new planting bed maker, called 3-in-1 integrated disc ridger. This implement is an upgraded version from the existing implement that is available in the market for bed making such as rotary ridger and normal disc ridger. The purpose of using the 3-in-1 disc ridger is to perform a raised planting bed up to 0.55 m. In addition, other mechanism has been added to carry out other operations such as fertilizing and mechanical weeding through soil earthing up, which is performed simultaneously during fertilizing.

Weeding may become necessary, particularly in the early stages of the crop growth within three weeks after planting. Earthing up the soil brings about weed control, besides

improving the physical condition of the soil as reported (Adam 1992; Harrison & Peterson 1991; Roy Chowdhury *et al.*, 2003).

The objective of this study was to evaluate the machine's performance in the aspect of Theoretical Field Capacity (TFC), Effective Field Capacity (EFC) and Field Efficiency (FE) during plant-bed forming as well as fertilizing and mechanical weeding. Besides that, this study was also carried out to determine the effect of raised plant-bed and normal plant-bed with respect to the total yield of sweet potato.

2. Materials and Methods

2.1. 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 24°C–32°C, respectively.

2.2. Preparation of Plant-Bed

The plot was ploughed to a depth of 30cm using rotavator after decomposed manure was broadcasted at a rate of 8–10 tonne per hectare. Six ridges of 1.2 m x 50 m x 0.5 m (width x length x height) for raised bed and six ridges of 1.2 m x 50 m x 0.3 m (width x length x height) for normal bed were made by using disc ridger and rotor-ridger, respectively. The six ridges for each type of bed represent one plot and were replicated for three replications each.



(a)



(b)

Figure 1. Plant-bed making (a) normal height by rotor-ridger and (b) raised bed by disc-ridger.

2.3. Preparation of Planting Material

Three varieties of purple flesh sweet potato were selected in this experiment namely, Anggun 1, Anggun 2 and Anggun 3. The vines were cut into 0.3 m in length as planting materials and mechanically planted by using sweet potato mechanical transplanter for both

plant-bed types: raised plant-bed and normal plant-bed with 1-row planting system. These three varieties have been planted randomly at the experimental plot with three replications.

2.4. Planting and Crop Management

Cuttings were spaced at 0.25 m of intervals between plants. Plants were maintained until harvesting stage at 3.5 months for data collection.

2.5. Machine Description

The 3-in-1 disc ridger was used for three major operations in sweet potato production which were; making a raised plant-bed, fertilizing and mechanical weeding. A raised planting bed was made using this machine during land preparation. Meanwhile after three weeks of planting, the machine was used again for the 1st fertilization and for mechanical weeding. Then, the next fertilization process was performed on the 6th and 9th week of planting.

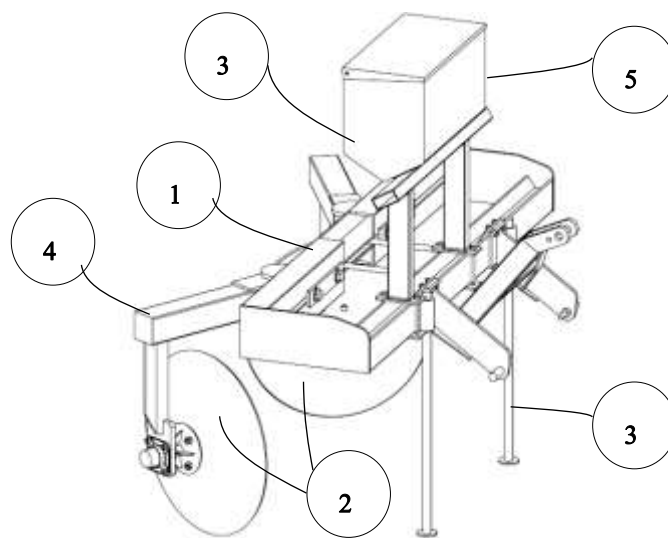


Figure 2. List of parts used in 3-in-1 disc ridger.

Table 1 and Figure 2 shows the main parts of 3-in-1 disc ridger. This tractor-mounted implement was designed with two units of high quality steel discs, which was attached to the frame with disc diameter and thickness of 720 mm and 6 mm, respectively. This disc ridger is able to form either a single row or double row planting ridges to suit with the desired planting system for sweet potato. This is due to the adjustable disc's arm.

Table 1: Parts of 3-in-1 disc ridger.

No.	Parts	Dimension (mm)
1.	Main frame	1900
2	Steel disc	720
3	Fertilizer tank	800 (l) x 400 (w) x 200 (h)
4	Disc's arm	650
5	Fertilizer rate adjuster	300
6	Stand	1000

This machine was required to attach to a 4-wheel tractor with 70hp and above. After being pulled by the tractor, the steel disc chopped and ploughed the soil in two opposite directions, simultaneously. The disc moved due to the contact with the soils. The faster the tractor speed, the better plant-bed can be formed. In this experiment, the tractor speed tested was at 2.5 km/hr.

The angle of the discs was adjustable to ensure the desired planting bed can be formed according to the agronomic practices. Meanwhile, the width of the discs can also be adjusted according to the planting system either the 1-row planting system or 2-rows planting system. Minimum tuning only needs to be done by the operator with 4 bolts and nuts to get the desired plant-bed width.

2.6. Fertilizing mechanism

Several mechanisms for fertilizing have also been added to this machine to enable the fertilization operation to take place. These include the addition of a 150 kg stainless steel tank. This machine is also equipped with fertilizer rate adjuster to ensure the discharge rate can be adjusted to the required amount from 3 g/plant until 15 g/plant. However, the recommended rate for sweet potato planting is approximately at 7–8 g/plant. Besides that, a special metering device has also been added to ensure the uniformity of the amount of the discharge rate as per illustrated in Figure 3.



(a)



(b)

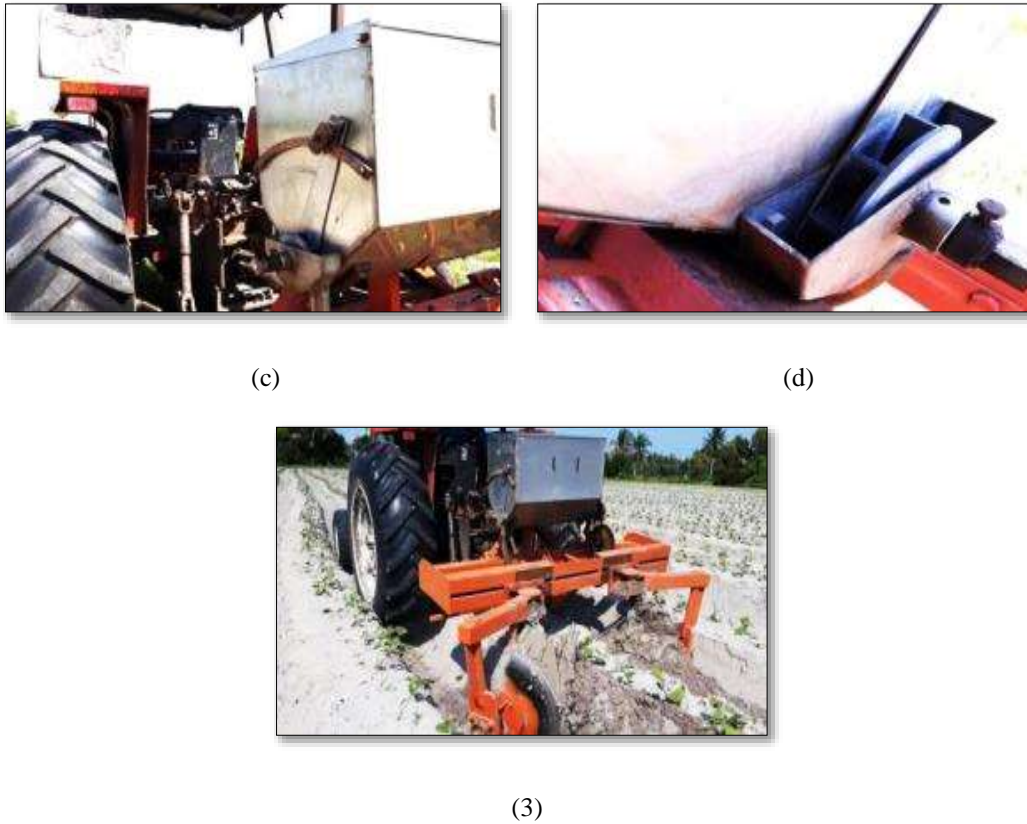


Figure 3. Main features of the 3-in-1 disc-ridger; (a) 3-in-1 disc ridger during soil earthing-up and fertilizing, (b) 720 mm disc diameter to make a raised planting bed, (c) 150 kg fertilizer tank and fertilizer rate adjuster, (d) Special metering device to apply the fertilizer uniformly, and (e) adjustable width to suits with single and double row planting system.

2.7. 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:

$$FC = \frac{S \times w}{10} \quad (1)$$

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)

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

Other data that have been collected are the effect of the raised plant-bed (3-in-1 disc ridger) and normal plant-bed (rotor-ridger) to the total yield. Total yield of three varieties of purple flesh sweet potato were evaluated with three replications as per explained in the preparation of plant-bed section. The average yield for each variety was used to calculate and compare the total yield per hectare to analyse the effect of the yield at different types of plant-bed.

3. Results and Discussions

3.1. Machine's Performance

From the data analysis as shown in Table 2, the effective field capacity (EFC) shows slight differences between both implement for plant-bed forming.

Table 2: Machine parameter and performance evaluation during bed forming.

Item	Data	
	Machine Parameters	
Prime Mover	FIAT, 70 hp	FIAT, 70 hp
Area (ha)	0.5	0.5
Implements	3-in-1 Disc Ridger	Rotor-ridger
Power take off	-	540rpm
Height of plant-bed	0.5–0.55 m	0.3–0.35 m
	Performance Evaluation	
TFC (ha/hr)	0.31	0.35
EFC (ha/hr)	0.29	0.32
FE (%)	93.5	91.4

Generally, it takes about 3–4 hours of operation per hectare for both implements. However, the EFC of bed forming by using disc ridger is slightly higher because of the factor of traction. It is because; more power of tractor is needed to pull the soils in order to make the raised bed, which results in higher operation time. In terms of field efficiency, 93.5% was recorded by using 3-in1 disc ridger compared to 91.4% by rotor-ridger indicating that the disc ridger was more efficient in conducting plant-bed forming compared to the existing machine. In terms of plant-bed quality, the 3-in-1 disc ridger managed to form a significant height of plant-bed, which is approximately 0.5m to 0.55m height compared to 0.3m height made by rotor-ridger. Hypothetically, at this height, it offers a better soil aeration and fewer tendencies for soil compaction, which is good to the development of the tubers.

Besides that, from the observation through the experiment, it shows that the quality of plant-bed can be improved by using the 3-in-1 disc ridger, if the moisture content of the BRIS soil is at 20–30%. At this moisture content, the plant-beds are neater and firmer so that the risk of the soils to collapse is low. Therefore, the irrigation system to irrigate the required area before the bed forming takes place is recommended to increase the soil moisture content especially during the dry season.

Table 3: Machine parameter and performance evaluation during fertilizing and weeding.

Machine Parameters	
Prime Mover	FIAT, 70 hp
Area (ha)	0.5
Implements	3-in1 Disc Ridger (Fertilizing & weeding)
Power take off	1200 rpm
Performance Evaluation	
TFC (ha/hr)	0.31
EFC (ha/hr)	0.28
FE (%)	90.3
Average of NPK fertilizer amount per bed (50 m)	1.53 kg
Average discharge per plant	7.65 g

Table 3 shows the machine's performance during the 1st fertilization on the 3rd week after planting. As suggested by the agronomist, the fertilizer withdrawn for each plant was 7.65 g plant, which are compliant to the recommended rate. This result was obtained at the tractor speed of 1.6 km/hr with the power take off speed at 1200 rpm. Meanwhile, the EFC

was recorded at 0.28 ha/hr with the field efficiency at 90.3% for fertilizing and weeding operations.

Through the observation from the experiment, the fertilizer that has been sown is located in the middle of the plant-bed, which is good to prevent it from falling into the furrow. In addition, the soil earthing up also helps to make sure the fertilizers are intact and covered with the soils on the plant-bed. Meanwhile, the weed control during the soil earthing up is a surplus for this machine. Other than chemical spraying, this mechanical weeding is a great option to the farmers to control the weed especially at the both side of the plant-bed. Weed control is important in the early stages of planting especially during the 1st week until 4th week after planting to prevent the competition from the plant and the weed. Hence, the employment of mechanical weeder is required to reduce the herbicide cost.

3.2. Yield Performance

Table 4 shows the comparison on the total yield of sweet potato between raised plant-bed and normal plant-bed.

Table 4. Effect of bed system on the total yield of sweet potato.

Item	Data					
	Anggun 1		Sweet Potato Variety Anggun 2		Anggun 3	
	Raised Bed	Normal Bed	Raised Bed	Normal Bed	Raised Bed	Normal Bed
Type of bed	Raised Bed	Normal Bed	Raised Bed	Normal Bed	Raised Bed	Normal Bed
Average yield per bed	161.25 kg	102.27 kg	126.20 kg	105 kg	159.2 kg	148 kg
Total yield per hectare	26.87 MT	17.04 MT	21.03 MT	17.50 MT	26.53 MT	24.67 MT

From the data tabulated in Table 4, it is clearly shown that the raised plant-bed gives a higher yield among three varieties of sweet potatoes (Anggun 1, Anggun 2 and Anggun 3). As stated in the introduction, it is proven that the height of the plant-bed is one of the important factors that influence the yield. From the result, the yield is increased by 7.5% (Anggun 3) up to 57.7% (Anggun 1). Therefore, it is proven that a higher plant bed provides better aeration for tubers optimum development.

4. Conclusion

The 3-in-1 disc ridger has been developed and evaluated. It shows a promising performance in three mode of operations; raised plant-bed forming, fertilizing and weeding. 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 plant-bed forming, fertilizing and weeding was at 0.29 ha/hr and 0.28 ha/hr respectively, while the field efficiency (FE) was recorded at 93.5% and 90.3%.

The result shows that the 3-in-1 disc ridger was more efficient in conducting the plant-bed forming operation for sweet potato in BRIS Soil. Besides that, the disc ridger managed to form a raised plant-bed than the rotor-ridger which results in increasing the total yield up to 57.7%.

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