DEVELOPMENT AND PERFORMANCE EVALUATION OF SWEET POTATO SIEVE TYPE HARVESTER ON BRIS SOIL

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ABSTRACT

Sweet potato harvesting on BRIS soil involves a partial reliance on mechanized methods, specifically utilizing conveyor-type harvesters. The process typically takes around 7-8 hours per hectare. These harvesters operate effectively when the soil moisture is below 35%. However, challenges arise during the wet season in the east coast area of Malaysia, where planting occurs at the end of the year, coinciding with the monsoon and resulting in high soil moisture content. Due to the demand and favorable prices, farmers often engage in a second season planting, commencing in August or September and concluding with harvesting in December or January each year. This situation necessitates the development and evaluation of a sweet potato harvesting machine designed specifically for the wet season when soil moisture exceeds 35%. The study aims to design and fabricate a prototype machine, focusing on criteria such as reliability in terms of working mechanism, field capacity, and field efficiency. Post-harvest losses are also assessed by comparing the prototype to existing methods. The prototype machine is a sieve-type harvester connected to a four-wheel-drive (4WD) tractor. A movable digging blade is attached to a 3-point link structure, and a 900mm sieve is integrated into the main body structure to dig and separate the harvested sweet potatoes from the soil. A Power Take Off (PTO) gearbox connects the tractor's PTO to drive all the mechanisms on the machine. Evaluation results indicate satisfactory performance, with a field capacity of 0.11 hectares per hour and a field efficiency of 78.6%. Meanwhile, mechanical losses are recorded at 1.7% per hectare.

Keywords: Sweet potato, sieve-type harvester, field capacity, mechanical damage

INTRODUCTION

Globally, sweet potato production exceeds 110 million tons annually. China stands out as the leading producer, contributing a substantial 100 million tons per year, constituting 90% of the world's total production (FAO Stat2014). Sweet potatoes are a prevalent staple in many developing and low-income countries, accounting for 95% of the total production. Among the top five sweet potato producers worldwide are Tanzania, Nigeria, Ethiopia, and Indonesia. The versatility of sweet potatoes in adapting to diverse climates, from arid to tropical conditions, places them as the 7th most significant food crop (Sweet Potato - Crop Trust 2015).

In Malaysia, the cultivation of sweet potatoes is experiencing substantial growth each year. Notably, the VitAto plantation has emerged as a flagship project of the Ministry of Agriculture and Food Security, fostering collaboration among government entities like the Malaysian Agricultural Research and Development Institute (MARDI), Department of Agriculture (DOA), Lembaga Pertubuhan Peladang (LPP), and the Federal Agricultural Marketing Authority (FAMA). Sweet potatoes have gained prominence as a major crop in BRIS soil, particularly in Kelantan and Terengganu, serving as an alternative industrial crop to replace tobacco plantations as reported by Zaharah, 2010. MARDI has introduced several sweet potato varieties, including Gendut, Telong, Jalomas, and VitAto. In 2017, MARDI unveiled the Anggun variety, characterized by its purple flesh while Lembayung variety in 2019. Typically, sweet potato cultivation in Kelantan and Terengganu follows two planting seasons each year. The first season spans from January to May, while the second season extends from July to November. However, the second season poses challenges for farmers, especially in dealing with heavy rainfall, as noted by Tan S.L in 2006.

In 2019, the cultivated area in peninsular Malaysia was estimated at 3,062 hectares, resulting in a total production of 52,224 metric tons. The yield per hectare typically falls within the range of 15 to 20 tons, influenced by various factors including planting methods, fertilization, weed control, and irrigation. The efficiency of harvesting therefore becomes crucial to support and expedite harvesting activities. Manual harvesting methods are time-consuming, and existing machines face challenges in operating effectively during the wet season when moisture content exceeds 40%. As a result, the role of harvesting machines becomes paramount in enhancing productivity and addressing the limitations posed by manual and existing mechanized methods.

Hence, MARDI has innovated an enhanced sweet potato harvester to enable its operation in both wet and dry seasons. The primary goal of this study is to assess the improved harvester's performance, focusing on effective field capacity and field efficiency. Additionally, post-harvest losses are examined in this experiment by comparing them to the outcomes of the existing method.

MATERIALS AND METHODS

Experimental site

The research was conducted at the MARDI Bachok Research Station on a designated research plot. The location is characterized by BRIS soil, and it experiences an annual precipitation ranging between 2500-2800 mm and temperatures ranging from 24°C to 32°C.

Sweet potato variety

This experiment involved the evaluation of two sweet potato varieties, namely Lembayung and VitAto. The selection of these varieties was based on their extensive production, particularly in Kelantan and Terengganu. Additionally, the tuber shapes differ slightly, with VitAto exhibiting a long elliptical form, while Lembayung has an elliptical shape.

Preparation of plant-bed

The research plot was ploughed to a depth of 30cm using a rotavator after the application of decomposed manure at a rate of 8-10 tonnes per hectare. Subsequently, 64 plant-beds were created, each measuring 1.3m in width, 0.5m in height, and 50m in length.

Planting and Crop Management

The VitAto variety was planted in 32 beds, and the Lembayung variety was planted in the remaining 32 beds. Cuttings were spaced at intervals of 0.25 meters between plants. On-farm crop management adhered to the standard sweet potato practices recommended by MARDI. The plants were tended to until the harvesting stage, which occurred at 3.5 months, for the purpose of data collection.

Machine Description

The prototype machine is a sieve-type harvester specifically designed for the wet season harvesting of sweet potatoes. This design was selected due to its effectiveness in segregating soil from the harvested sweet potatoes, distinguishing it from the commonly employed conveyor-type harvester.

Figure 1. List of parts used in sieve type harvester

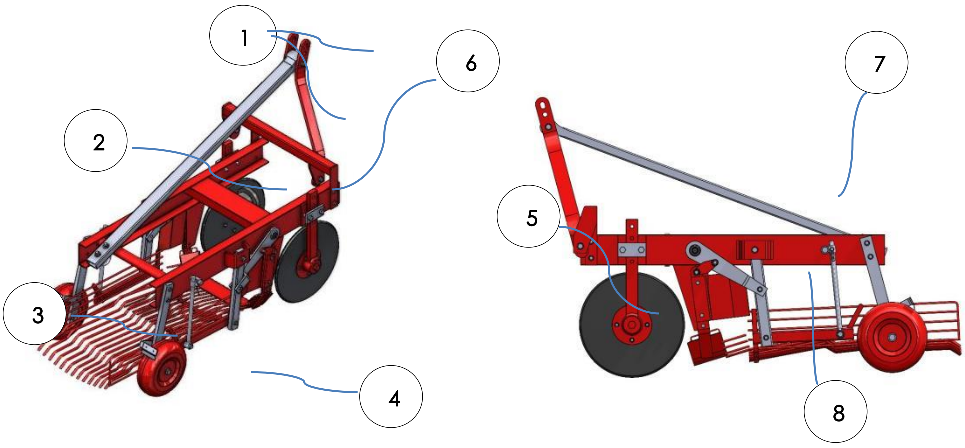


Table 1 and Figure 1 illustrate the essential components of the sieve-type harvester. This implement is mounted on a tractor and is connected to a four-wheel drive (4WD) tractor. A movable digging blade is affixed to a 3-point link structure, and a 900mm sieve is integrated into the main body structure to excavate and segregate the harvested sweet potatoes from the soil. Simultaneously, a PTO gearbox is incorporated into this prototype machine to link the power from the tractor's Power Take Off (PTO), facilitating the movement of all mechanisms on the harvester.

Table 1: Parts of sieve type harvester

No.	Parts
1.	3-point link structure
2.	Main frame
3.	Sieve
4.	Support tyre
5.	Cutting disc
6.	PTO gearbox
7.	Support frame
8.	Sieveing mechanism

This machine necessitates connection to a 4-wheel tractor with a horsepower of 70 and above. Once pulled by the tractor, the harvester engages in digging the crop boundary at a variable depth. Typically, a depth ranging from 25cm to 30cm is deemed adequate for excavation without causing damage to the tubers. Subsequently, as the tubers move on the sifter, they undergo separation based on the power take ff (PTO) speed. This process effectively segregates the tubers from the soil. Upon completing the sifting phase, the tubers are released onto the ground, requiring additional operators to gather the harvested produce.

Data Collection

In the study of machine performance, parameters such as Theoretical Field Capacity (TFC), Effective Field Capacity (EFC), and Field Efficiency (FE) were evaluated. EFC signifies the machine's capability to function in real field conditions, as noted by Zhou et al. (2012). FE is defined as the percentage of time during which the machine operates at its full rated speed and width in the field, as explained by Nasri et al. (2015). FE reflects the efficiency of time utilization for completing the work, as highlighted by Grisso et al. (2014). Due to factors like headland turns, machine issues, ground surface variations, and overlapping, the FE for actual field operations consistently falls below 100%, as observed by Zandonadi (2012).

The formula that has been adopted to calculate TFC, EFC and FE are as reported by Hanna (2016). The formulas are:

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

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)

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

Other data taken is the percentage of tuber damage due to mechanical injury during harvesting. This data will be compared to the existing harvesters as a benchmark for losses during mechanical harvesting.

RESULTS AND DISCUSSIONS

Machine's Performance

Based on the conducted evaluation, the table below illustrates the Effective Field Capacity (EFC) and Field Efficiency (FE) for this sieve-type harvester.

Table 2: Machine parameter and performance evaluation during harvesting

Machine Parameters	
Prime Mover	Kubota 4WD, 95 hp
Area (ha)	0.5
Implements	Sieve-type harvester
Power take off	1500 rpm
Performance Evaluation	
TFC (ha/hr)	0.14
EFC (ha/hr)	0.11
FE (%)	78.6

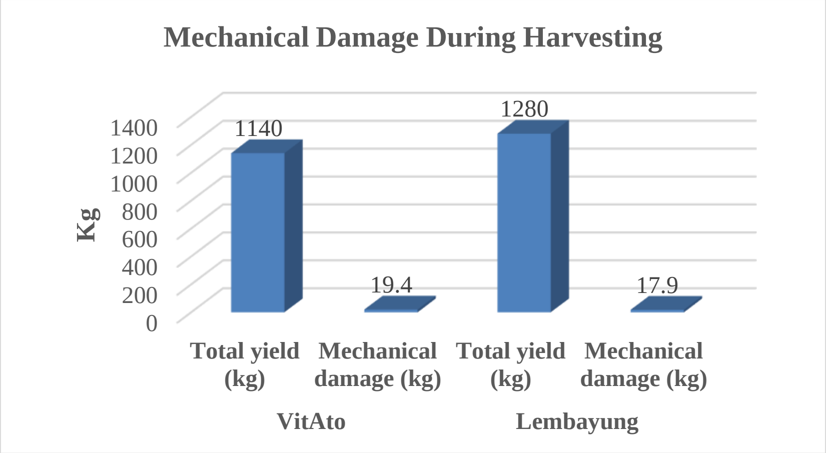
Utilizing this harvester for harvesting requires approximately 7-8 hours per hectare, as indicated by the parameter settings in the aforementioned table. This operation encompasses the tasks of digging and separating the tubers from the soil. However, an additional workforce of at least 4 operators is needed to collect the harvested tubers, ensuring the completion of the entire harvesting process within the specified time-frame. Consequently, the total man-hours required using this machine amount to 40 man-hours per hectare. In comparison, manual harvesting during the wet season demands a significantly higher number of man-hours, totalling 180 man-hours per hectare.

The hypothesis of this study suggests that the sieving mechanism implemented in this prototype machine effectively separates tubers from the soil during the wet season. During this study, the soil moisture was recorded at 42%. Moving forward, further assessments will be conducted to explore the operational limits of this machine, particularly in conditions with higher soil moisture content.

Furthermore, various other parameters were examined as part of the evaluation, including the optimal tractor speed, Power Take-Off (PTO) rotation speed, and digging angle. The recommended speed for the tractor when utilizing this harvester is gear 1 LOW, maintaining a speed of 1.3 km/h. Simultaneously, the PTO rotation speed is set at 1500 r.p.m. These specific settings are carefully configured to ensure the effective execution of digging and the proper separation of tubers from the soil.

In the evaluation of losses attributed to mechanical injury, the selection of the digging angle is crucial to ensure tubers are excavated beyond the 25 cm mark, surpassing the designated tuber zone. Consequently, various angles, including 15, 30, and 45 degrees, underwent evaluation. At a 15-degree angle, a considerable portion of tubers experienced damage as the digging points did not reach sufficient depth, ranging only between 10-15 cm from the soil surface. Conversely, a 30-degree angle allowed the digger to reach beyond the tuber zone, with a depth spanning between 25-30 cm from the soil surface. However, at a 45-degree angle, while tubers could be harvested, the separation from the soil posed challenges due to an excessive soil volume, hindering perfect sifting.

Therefore, a 30-degree angle was selected for assessing the total damage to tubers resulting from mechanical factors. A total of 10 planting beds with a length of 50m for each variety underwent evaluation based on the predefined parameters. The findings from this assessment revealed minimal damage, accounting for 19.4 kg (1.7%) of the harvested 1,140 kg for the VitAto variety and 17.9 kg (1.4%) of 1,280 kg for the Lembayung variety as shown in the figure 2 below.



In comparison to conveyor-type harvesters, which demonstrated a damage percentage of 2.3%, the prototype harvester exhibited a reduction in damage percentage. The decrease in the damage may be attributed to the machine's relatively compact size, facilitating easier operation for the operator compared to the previously assessed conveyor-type harvester.

CONCLUSION

The development and evaluation of the sieve-type harvester have demonstrated promising performance in uprooting and separating sweet potatoes from the soil.The conducted experiments included the evaluation of Theoretical Field Capacity (TFC), Effective Field Capacity (EFC), and Field Efficiency (FE). The machine exhibited TFC and EFC values of 0.14 ha/hr and 0.11 ha/hr, respectively, with a recorded field efficiency of 78.6%. These results indicate that the sieve-type harvester proves to be more efficient in harvesting sweet potatoes during the wet season on BRIS Soil. Furthermore, the harvester exhibited superior performance in minimizing mechanical damages compared to the existing conveyor-type harvester.

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