The Study of Cassava Digger Attached to a Tractor's Side

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ABSTRACT

This research objectives were to design and construct a cassava digger prototype attached to a tractor's side. The prototype had a working width of 60 cm. The digger was attached to the left side of an L-shaped frame on the tractor's three-point hitch. Testing of the prototype was carried out to study factors affecting its performance and to compare the results with a farmers' cassava Digger. The research's factors were a digger speed at three levels: 2.30, 2.60 and 3.20 km/hr and a 9-month age of cassava plants. The results indicated that the machine's suitable speed was 3.20 km/hr Other results were as follows: the percentage of total cassava tubers dug out was 88.80%, and of complete cassava tubers dug out was 73.05% of damaged cassava tubers was 15.75% of undug tubers remaining in the soil was 11.20% of total losses was 26.95% field capacity was 0.68 rai/hr, time efficiency was 72.66% and fuel consumption was 4.67 l/ rai.

Keywords: Cassava, Digger, Side of a tractor

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Introduction

Cassava is one of Thailand's important cash crops, and the total domestic plantation area is approximately 6.52 million rai, yielding roughly 30 tons of fresh cassava annually. Thailand is the largest world exporter of cassava products. In 2010, the whole export value was over 50,000 million [1]. The current method of cassava harvesting begins with cutting the plant leaving about 30 cm of the trunk above the ground. The cassava tubers are then unearthed and gathered by labor or digging machine. These tubers are, later, separated from their rhizomes by labor or cutting machine. The assemblage of tubers after harvesting can be operated only by one process which is by labor. The gathered tubers are placed in baskets and transported onto the trucks. The process requires about 7-10 people in each operation [2]. The cassava production process involves quite a number of stages, the most important of which can bear an impact on cassava's quality and quantity is harvesting. The harvest stage consists of cutting the tree, digging, piling for cutting tubers from the root, and conveying tubers onto trucks [3-9]. Harvesting requires a lot of labour and high wages.

Regarding total production cost, soil preparation, planting, maintaining, and harvesting accounted for 52 percent of the process. In Thailand, regular cassava harvest practices are broadly classified into two methods: sole-labour digging and a cassava digger with labours manually collecting tubers. For the traditional method, labours use primary farm tools, and 10 - 15 labours are required for each field operation [10]. The latter uses a cassava digger with a farm tractor as the power source. The digger is installed at the trailer joint PTO. This method helps mitigate the labour shortage problem and can reduce the cost of hiring a lot of labour. Currently, the use of cassava diggers is becoming popular and tends to increase.

Today's cassava diggers have many limitations, particularly when the machine is installed on a medium to a big-sized tractor. Digging is usually not continuous. Also, after digging, human labour is required to pick tubers from the furrow so that a tractor can move further down the next row. So that the dug tubers will not get damaged by the wheels of the tractor when moving [11]. Positional vision during digging operations is also a problem. Since the digger is installed at the rear end of the tractor with the 3-point hitch, the tractor driver has to control the tractor in line with the planting row. The tractor wheels will be in the furrows with the plants underneath the tractor. While digging, the tractor driver has to look at the direction and the plant row ahead of him. Then alternately, a driver has to look back at the digger at the rear so that the digging position is right on the tubers under the soil, resulting in large quantities of cassava tubers dug with minimum damage and loss. The problem here lies in the planting, where the distance between rows of plants is not constant, depending on the areal fertility. The digger cannot work continuously because it needs to be adjusted for the correct positioning. After all, the digger is at the central position between the two rear wheels. When the plant rows are too close, the digger position is not in the same correct line, leading to failure to dig out all tubers, or the tubers can be damaged. A digger attached to a tractor side was designed to solve the excessive

length problem of the overall unit, which causes inconvenience in turning at the end of each plant row during the harvest.

The cassava digging machine attached to a tractor's side is another solution in developing cassava diggers to work in plantations with different constraints. It will also lead to developing a cassava digger and conveyor for higher capability and work efficiency. This research aimed to design, construct, and test the cassava digger attached to a tractor's side.

Objectives of the study

This research objectives were to design and construct a prototype of a cassava digger attached to of a tractor's side.

Methodology

The study was divided into three different steps. First, studying the physical characteristics of the crop and properties of the soil in the cassava plantation. Second, designing and constructing the digger attached to a tractor's side. Third, testing and evaluating the cassava digger attached to a tractor's side the test method of [2-3].

The first step was the preliminary study of the crop's physical characteristics and soil properties in the cassava plantation, which were considered in setting the design conditions. The data studied included the distribution patterns of cassava tubers both horizontally and vertically, the width and height of plantation furrows, distance between plants, distance between rows, soil moisture at the 10 cm depth and 20 cm depth, hardness of soil at the 10 cm depth and 20 cm depth, and soil density at the 10 cm depth and 20 cm depth.

The second step involved designing and constructing the prototype. The digger had a triangular shape, with a width span of 60 cm and a longitudinal length of 50 cm. The two side wings made an obtuse angle with the base. The wings curved out in the middle. The tilling part had spiked to loosen the soil while digging. The inclination of this cassava digger could be adjusted, as well as the depth it could reach into the soil. The digger was designed to be attached to the left side of the tractor, between the front and the rear wheels. This position offered good visibility. The frame was installed with the 3-point hitch, having an overall L-shape. The side for the hitch connection was 170 cm long, whereas the length parallel to the digging direction was 190 cm. The digger was controlled via the tractor's hydraulic system that controlled the 3-point hitch. The tractor driver could adjust the digging depth and lift the digger when turning and manoeuvering the plantation.

The third step aimed to determine the performance of the cassava digger attached to the side of a tractor. The parameters investigated comprised the three different digging speeds: 2.30, 2.60 and 3.60 km/hr. The cassava age was set at nine months, the average popular age considered by farmers. The obtained parameters were compared with those of the conventional rear-attached cassava digger. The performance indicators included the percentages of dug tubers, undamaged tubers, damaged

tubers, tubers remaining in the soil, total loss, field capacity, time efficiency, and fuel consumption. Five steps were taken in the test. First, harvest preparation by cutting the cassava stalks, leaving a height of 20-30 cm. The germinating parts were removed from the field for ease of data collection. Second, the physical data of cassava and the soil properties before cassava digging were collected. Third, the fields were divided into equal areas of 250 m^2 to conduct a parallel test for the three speeds. Fourth, conducting the tests for both the designed cassava digger attached to the tractor's side and the conventional digger used by the farmers. Lastly, conducting the test at three different speeds: 2.30, 2.60 and 3.20 km/hr, then compared with a conventional machine working at the speed of 3.70 km/hr. The indication parameters of the performance were randomly sampled, as shown in (Fig. 1).

a b

Figure 1 The designed cassava digger attached to the tractor's side (a) -The conventional cassava digger used by farmers (b).

Results

Results of the first step

The cassava plantations were considered before designing the machine. It was found that cassava tubers spread horizontally and vertically after nine months, i.e., 56.58 cm and 32.70 cm, respectively. The width of the furrows was 64.05 cm, while the furrow height was 24.97 cm. The distance between plants was 61.73 cm, and the distance between rows was 107.33 cm. When cassava reached its 9-month age, the soil moisture was 0.37% (db.) weight at a depth of 10 cm in the ground. It was 0.42% (db.) at the 20 cm depth. Soil hardness at 10 cm depth was 3.31 kg/cm^2, and 11.15 kg/cm^2 at 20 cm depth. Soil density was 166.92 g/m^3 at 10 cm depth and 169.80 g/m^3 at 20 cm depth.

Results of the second step

The numerical data from step 1 were the basis for the cassava digger attached to the tractor's side, as shown in (Fig. 2). After studying the necessary information, a test set was designed and constructed according to principles of engineering design [12-13]. According to the figure, the digging position conformed to the angle the tractor driver would clearly see the digger while it was working.

The supplementary component was the 2,400 cc, 50 horsepower tractor, or a medium-sized tractor. The digger was designed to attach to the tractor's left side at a 40 cm distance from the centre of the front wheel and 70 cm from the centre of the rear wheel. The distance measured from the edge of the internal tiller wing to the tractor chassis was 60 cm. The design made the harvesting operation of this side-attached digger work in an anticlockwise direction.

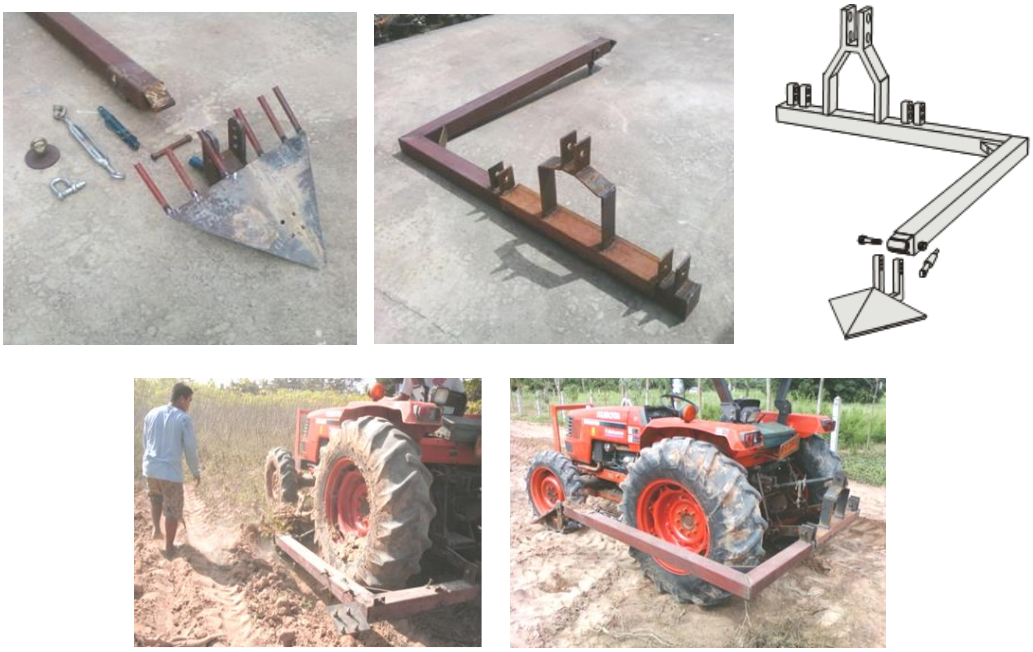

Figure 2 Components of the experimented cassava digger attached to the tractor's side

Results of the third step

The results of the tests conducted on the speed of digging and the age of cassava were as follows

1. Percentage of cassava tubers obtained from digging

Testing of the digger attached to the side of the tractor showed that when the digging speed increased from 2.3- 2.6 km/hr, the percentage of dug tubers tended to decrease. When the speed increased from 2.6-3.2 km/hr, the percentage of dug tubers tended to increase, as illustrated in (Fig. 3). The tubers here were obtained from digging and had not been sorted for good tubers and damaged ones, which would be presented below.

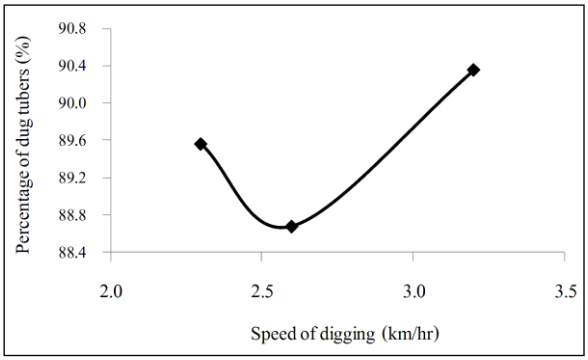

Figure 3 Correlation between percentage of dug tubers and speed of digging.

2. Percentage of undamaged cassava tubers obtained from digging

The percentage of undamaged tubers was obtained from sorting the good tubers from all dug tubers. Since this study aimed to develop a cassava digger that could be used with a conveyor system in the future, the percentage of good tubers would mean the produce that would be conveyed for the next stage. The percentage of damaged tubers indicated the portion to be improved so that this percentage would decrease. Alternatively, an additional component may have to be designed and added in the future to lessen the damage. As shown in (Fig. 4). the testing results showed that with the increased speed, the percentage of undamaged tubers tended to increase according to the fact that the soil moisture in the plantation was low while soil hardness was high. The low speed of digging was good for soil breaking, where the soil was not too hard or contained some moisture. Thus, with low moisture content and higher hardness, if the speed increased from 2.30, 2.60 and 3.20 km/hr, the soil would break better, resulting in a greater yield of good cassava tubers.

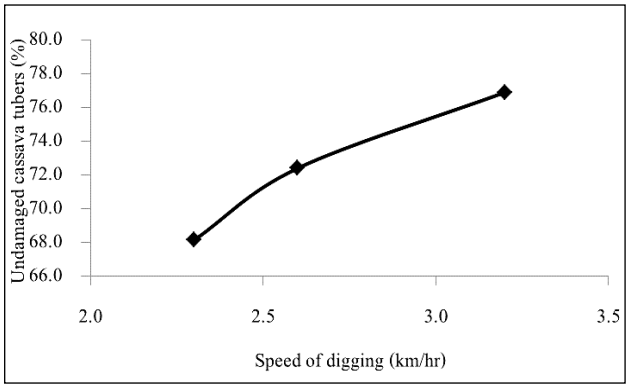

Figure 4 Correlation between percentage of undamaged cassava tubers and speed of digging.

3. Percentage of damaged cassava tubers

The percentage of damaged or bad tubers accounted for the tubers torn from the stumps or broken during digging. It was found that with increased speed of digging, the percentage of damaged tubers decreased (See Figure 5). The results of damaged tubers are similar to undamaged tubers, i.e.,

the digging speed caused the soil to break well, hence a higher percentage of good tubers and a lower percentage of damaged tubers.

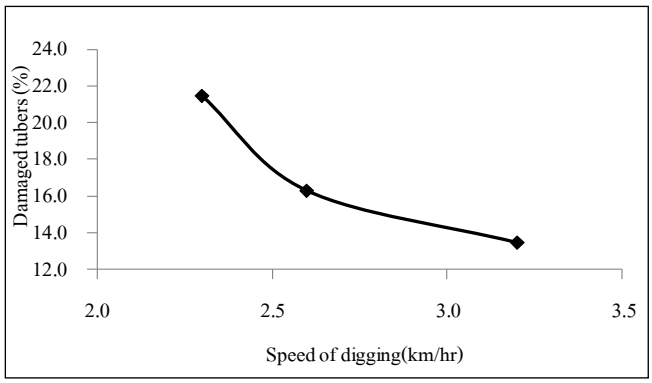

Figure 5 Correlation between percentage of damaged tubers and digging speed.

4. Percentage of tubers remaining in the soil

The percentage of tubers remaining in the soil accounted for undug cassava stems and damaged tubers left in the soil. The test showed that when the speed increased from 2.3-2.6 km/hr, there was a tendency for more tubers to remain in the soil. However, when the propelling speed increased from 2.6-3.2 km/hr, the percentage of tubers remaining in the soil tended to decrease, as illustrated in (Fig. 6)

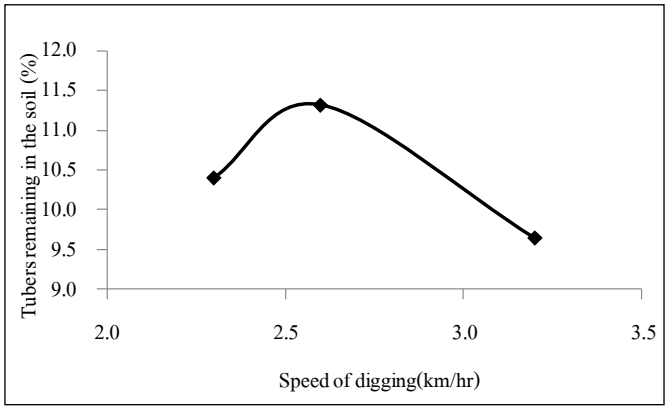

Figure 6 Correlation between percentage of tubers remaining in the soil and speed of digging.

5. Percentage of total loss

The percentage of total loss included all parts of cassava, both undug cassava stems and damaged or broken tubers remaining on top of and within the soil. The test showed that total loss tended to decrease when speed increased, as shown in Figure 7. It could be concluded that higher digging speeds enabled continuous digging, more consistent digging depth, and as a result, the tubers affected by the digger head decreased. Therefore, the number of tubers being broken or torn from stumps decreased. We also found no stems undug when using our digging component.

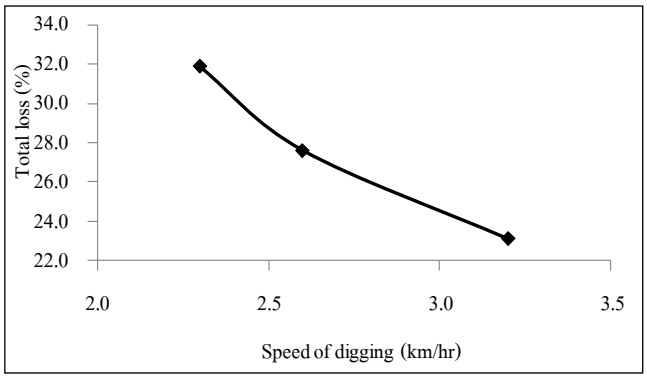

Figure 7 Correlation between percentage of total loss and speed of digging.

6. Field capacity

The test results for field capacity in relation to working speeds are shown in Figure. 8. When the speed increased, the working rate tended to increase. The capacity for the speeds of 2.6 and 3.2 km/hr was about the same.

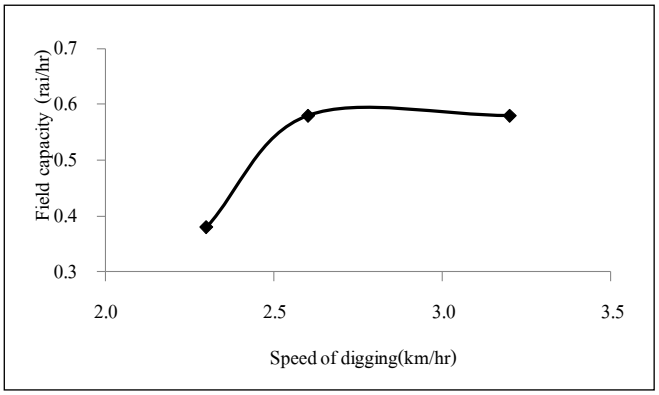

Figure 8 Correlation between field capacity and the moving speed of digging.

7. Time efficiency

The test results for time efficiency are illustrated in Figure 9. It was found that with increased speed, time efficiency tended to be higher. Increased cassava planting correlated to field capacity, i.e., the speed applied in digging.

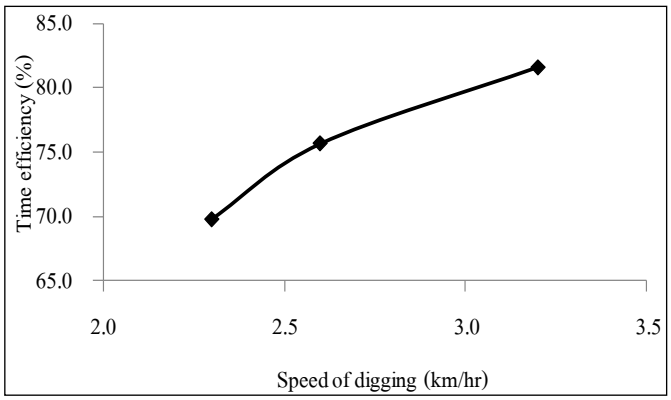

Figure 9 Correlation between time efficiency and speed of digging.

8. Rate of fuel consumption

The test results for fuel consumption rate are shown in Figure 10, which reveals that the increased speed tended to decrease fuel consumption at the speeds of 2.3 - 2.6 km/hr. Moreover, it tended to increase when the speed increased to 3.2 km/hr.

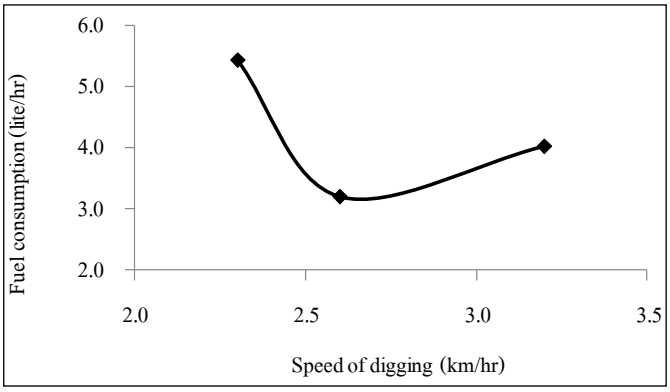

Figure 10 Correlation between fuel consumption and speed of digging.

The tests found that the speed of 3.2 km/hr was appropriate for digging 9-month old cassava. The comparison was made between the digger attached to the tractor's side, designed to handle the speed of 3.2 km/hr and the farmers' digger attached to the rear end of the tractor, which had been designed to work at the average speed of 3.7 km/hr. With a designed digger of this research attached to the tractor's side, the average tubers obtained was 90.35%. In contrast, the farmers' digging machine attached to the tractor's rear yielded an average of 86.44%. The percentage of undamaged tubers obtained from our machine was 76.89%, compared to 67.21% of the conventional digger. The percentage of damaged tubers from this research machine was 13.46, which was lower than that of the farmers' machine at 19.23%. The remaining tubers in the soil for our machine were 9.64%, which was lower than that of the conventional machine at 13.56%. The designed digging machine yielded a total loss of 23.10%, which was lower than the conventional found to be 1.70 rai/hr and higher than the

designed cassava digger attached to the tractor's side, at 0.68 rai/hr. The time efficiency of the farmers' digger was 5635%. It was lower than our designed digger, at 81.61%. The conventional digger of the farmers consumed 4.80 l/rai was higher than the designed digger, at 4.03 l/rai. The percentage of undug stems for the farmers' digger was 0.50%, whereas no undug stems were found when using the digger attached to the side of the tractor (Table 1).

Table 1 Results of the comparison between different installation modes of the cassava digging components.

Results of the comparison		
Indicator	The position of digger	
	Rear of tractor	Side of tractor
Percentage of cassava tubers (%)	86.44	90.35
Percentage of undamaged cassava tubers (%)	67.21	76.89
Percentage of damaged cassava tubers (%)	19.23	13.46
Percentage of tubers remaining in the soil (%)	11.26	9.64
Percentage of total loss (%)	32.79	23.10
Field capacity (rai/hr)	1.7	0.68
Time efficiency (%)	56.35	81.61
Rate of fuel consumption (l/rai)	4.80	4.03
Percentage of undug stems (%)	0.50*	0*

Discussion and Conclusions

The study conducted on the cassava digger attached to one side of The digger was attached to the left side of an L-shaped frame on the tractor's three-point hitch. Testing of the prototype was carried out to study factors affecting its performance and to compare the results with a farmers' cassava Digger. The research's factors were a digger speed at three levels: 2.30, 2.60 and 3.20 km/hr and a 9-month age of cassava plants. The results indicated that the machine's suitable speed was 3.20 km/hr Other results were as follows: the percentage of total cassava tubers dug out was 88.80%, and of complete cassava tubers dug out was 73.05% of damaged cassava tubers was 15.75% of undug tubers remaining in the soil was 11.20% of total losses was 26.95% field capacity was 0.68 rai/hr, time efficiency was 72.66% and fuel consumption was 4.67 l/ rai.

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