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FIELD EVALUATION OF HARVESTING MACHINES FOR TALL OIL PALMS

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ABSTRACT

Harvesting is a very important activity in any agriculture business. Cheap and efficient harvesting processes are factors that ensure good returns. Efficient mechanical harvesting of oil palm fresh fruit bunch (FFB) remains an issue that needs to be addressed. The current methods of harvesting involve the use of a chisel or sickle, which require manual labour and is therefore tedious. As the country is facing a labour shortage in the plantation sector, the introduction of farm machinery would be one way of increasing labour productivity. This article describes the performance of two oil palm mechanical harvesting machines in the field as compared to a manual operation. The machines carried out cutting operations of the FFB, which were transported to the road side and unloaded either onto the mainline transport or to the ground. A time motion study during the cutting operation was carried out, and the quantity of detached loose fruits produced were recorded. Machine performance in terms of productivity and cost-effectiveness were also monitored. It was found that the productivity of the machines ranged from 3 to 6 t per day depending on various factors. This study also indicated that the loose fruits collection could be minimised by using the harvesting machine. A comparative study of the harvesting machines with and without grapple shows that the latter is slower, even though it is only used for cutting operation, without deposition of the bunches into the bucket. The productivity (man per day) of the complete harvesting machine was almost double, compared to manual harvesting that uses buffalo-carts for the evacuation of the FFB. However, the economic analysis shows that the cost per tonne for mechanical harvesting machine was slightly higher as compared to manual operation. It is envisaged that with the successful introduction of the mechanical harvester, opportunities for new technologies would open up for the development of more efficient and cheaper machines in the future.

Keywords: oil palm, harvesting machine, tall palm.

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INTRODUCTION

The mechanical harvesting of oil palm fresh fruit bunch (FFB) remains an issue that needs to be solved. The current methods involve the use of a chisel or sickle, which requires manual labour and proves to be inefficient. For it to be an effective cutting operation, skill as well as energy are required. Skilled harvesters are difficult to get, hence, harvesting productivity has to be improved. Plantations are now looking for more efficient harvesting tools to double the harvesting productivity, as well as

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reduce the number of workers. About 92.2% of the harvesters in the plantations are foreigners (Azman, 2012). As the country is facing a labour shortage, the introduction of field machinery would be one way of increasing labour productivity (Tan, 1990).

In the early days, bamboo was the most popular pole used for harvesting FFB for tall palms (Foo, 1981). However, due to its low productivity and scarcity, other options had to be identified. Realising the problem, the Palm Oil Research Institute of Malaysia (PORIM) (now the Malaysian Palm Oil Board) had developed an improved harvesting pole made of light aluminium alloy that had better strength and durability, thus making it easy to handle (Abdul Halim *et al.*, 1988). This type of pole is now widely used by plantations.

Besides the aluminium pole, MPOB introduced a motorised cutter known as *Cantas* in 2006 for palms of intermediate height (less than 5 m) and the industry is now beginning to accept this tool. The *Cantas* is used for harvesting and pruning and employs a specially patented C-sickle that performs the cutting operation by a vibrating mechanism.

MPOB is also working on the development of harvesting machine mainly for tall palms. In the early stage of development, a number of machines was identified to have the potential for harvesting. There are two concepts of harvesting (Abd Rahim *et al.*, 1989): sending the manual cutter close to the bunch; and bringing only the cutting tool to the bunch, where the cutting is controlled from the driver's seat (*Figure 1*). Both concepts have been taken up by a number of machine manufacturers to develop prototype machines. At this stage of development, it is important to determine whether the machine can function as a harvester and to further improve the efficiency of the machine.

MATERIALS AND METHODS

The Machine

The main components of the machine are the prime mover, main boom, secondary boom, cutter, grapple and bucket. All these components are attached to the prime mover. The prime mover is of the tracked type, which gives better stability during operations, good traction during ascending and descending slopes and minimises ground compaction.

The boom can reach palms up to 11 m high (*Figure 2*). In the cutting operation, the grapple will first be deployed to hold the FFB, followed by extending the cutter for cutting the FFB (*Figure 3*). Using the telescopic boom, the FFB is then loaded into the bucket (0.5 t capacity) located at the back of the machine. Since the bunch does not fall to the ground, the amount of scattered loose fruits on the ground is minimised.

This is a one-man-operated-machine, performing, *i.e.* cutting, loading and transporting the FFB to the roadside. All the movements of the components are executed by hydraulic means. Below are the objectives of the field trials:

- to minimise detached loose fruits from harvesting;
- to compare differences in productivity between two types of harvesting machines; and

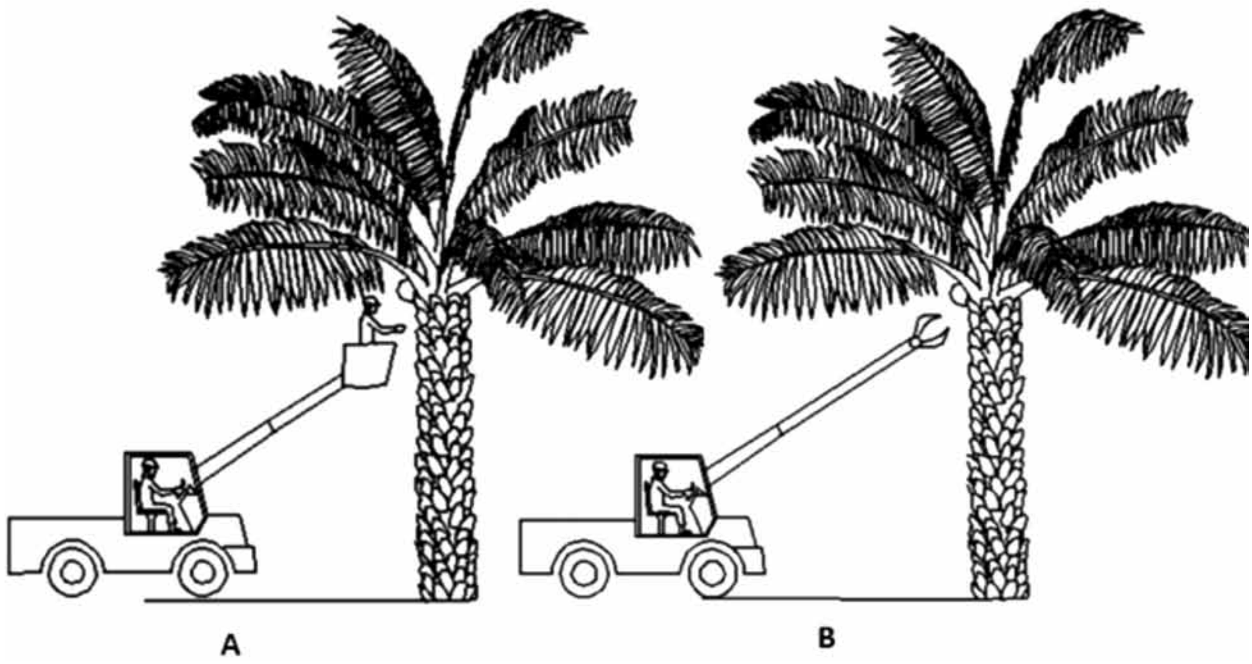


Figure 1. Concept of mechanical harvesting.

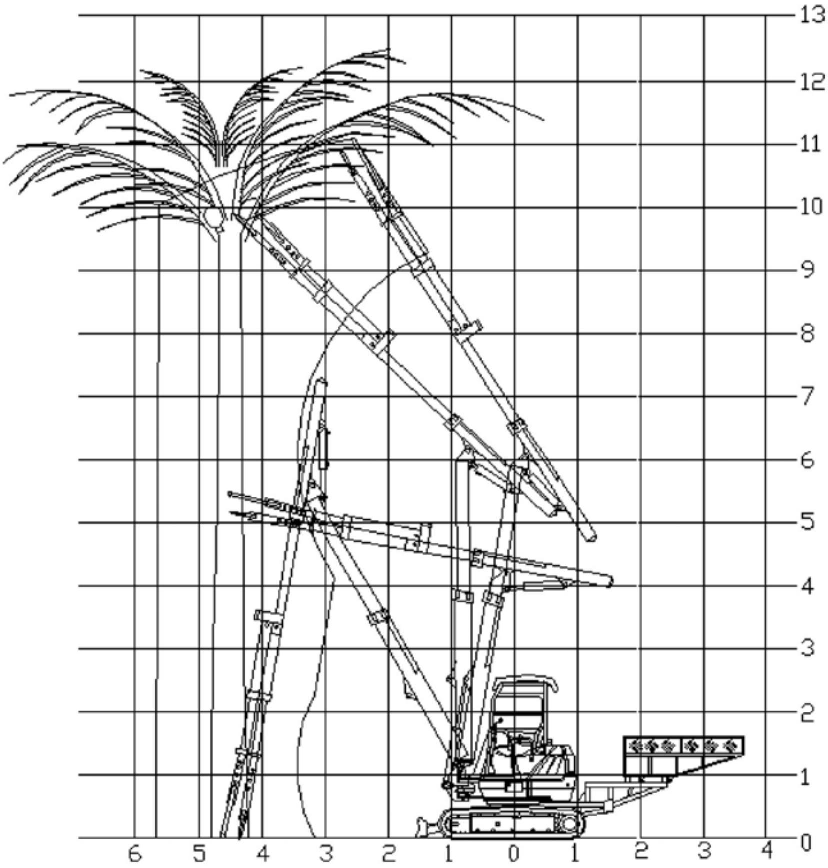


Figure 2. Working envelope of the telescopic boom.

Figure 3. The machine in a cutting position.

- to compare differences between manual harvesting and mechanical harvesting.

Two types of harvesting machines were monitored during this stage, *i.e.* H1: complete harvesting machine with a bucket and H2: cutting only harvesting machine without a bucket. It was hypothesised that the harvesting machine could perform better if it only focused on the cutting operation, without having the grapple and bucket incorporated (*Figure 4*).

A plantation at Segamat, Johor was chosen for a one-year field trial. The estate has suitable topography and uniform palm height, suitable for the trial. A 100 ha field with the average palm height of 8 m were allocated for testing the machines. Planted in 1991, the average bunch weight at the allocated site is 23 kg.

Time and motion study. A time and motion study (TMS) is ideal in determining the standard and efficiency of any activity performed by the operator and the machine itself. The TMS recorded the time required in carrying out activities involved to complete one cycle of harvesting one fruit bunch; which includes positioning the machine under the palms, lifting up the booms, executing grapple and cutter, putting the cut FFB into the bucket and

Figure 4. The grapple removed from the system.

moving the machine to the next palm. Both types of machines (H1 and H2) were studied in the TMS.

Detached loose fruits. The number of detached loose fruits due to the cutting operation was compared between mechanical and manual harvesting. It was claimed that by using the harvesting machine, loose fruits collection could be minimised.

The number of detached loose fruits was counted and weighed before and after the cutting operation. Each bunch was also weighed and the duration of time involved in the collection of loose fruits was recorded. A total of 30 samples were collected in three different cycles (15 days of harvesting round) for each method.

Comparison of productivity between mechanical and manual harvesting. Another study was conducted to compare the one-man productivity between the mechanical and manual harvesting methods. The types of evaluation were as follows:

- complete harvesting machine with a bucket versus manual harvesting with transportation (buffalo-cart); and
- cutting only harvesting machine (without a bucket) versus manual harvesting without transportation.

For the manual method, a buffalo-cart was used to transport FFB since it was the current practice of the estate (*Figure 5)*. It could carry more FFB compared to the wheelbarrow or the manual carrier. Any other modes of transportation such as mini-tractor, *etc*. were not found to be suitable for use in this trial site as the harvesting path was not prepared for the purpose. In addition, any changes in the in-field transportation system would affect the overall estate management system, which needed to be avoided.

Figure 5. Manual in-field transportation using the buffalo-cart.

The daily productivity for each method was measured over three days, over three cycles. There was no limitation in terms of working hours during the trials. The harvesters were encouraged to harvest as much as they could, depending on their own capability for that day. During rainy days or when machines broke down, the data for that day was rejected and repeated the following day. Manual harvesters were required to have at least two years experience in harvesting activities, while for machine operators were required to have at least 10-11 months of experience in handling the machine.

For statistical analysis, a comparison of means was performed using t-tests, where appropriate.

Overall performance. A logbook provided for each machine enabled the operators to record their daily performance. The logbook had to be signed by their supervisors for verification. Data on harvesting productivity, repair and maintenance cost, and fuel consumption were recorded accordingly.

RESULTS AND DISCUSSION

Time and Motion Study

Table 1 shows the time taken for stated activities.

TABLE 1. TIME TAKEN TO CARRY OUT HARVESTING ACTIVITIES

Movement/activity	Average time taken, (s)	
	H1 (n=9)	**H2** (n=9)
Telescopic booms extending until they reach the bunch	18	17
Cutting process	34	64
Telescopic booms retracting	28	19
Machine moving to the next palm and resuming its cutting activities	38	43
Total	118	143

Note: H1: complete harvesting machine with bucket.
H2: cutting only harvesting machine without bucket.

Table 1 shows that, to complete one cycle of cutting activity, the average time difference between the two types of machine is 25 s. However, the differences were not significant ($p>0.05$). During the cutting process, the H2 took a slightly longer time because without a grapple, the harvesting process was difficult.

The H1 took a longer time to retract the boom because it had to turn 180° to bring down the bunch to the bucket for temporary storage. *Table 1* also shows that the travelling time for both machines searching for ripe bunches contributed to almost 30% of the total operation time. The travelling time depended on the FFB yield seasons, *i.e.* for the peak season the travelling time could be shorter, as the possibilities of having ripe bunches on every palm were high.

From the study, it was found that in a harvesting cycle, 30% of the time was for travelling and searching for ripe bunches, while another 20% of the time was for the boom movement; either to extend or to retract it down. Increasing machine productivity was quite challenging, as the machine needed to travel from one palm to another, and was always challenged by the uneven ground which affected the travelling speed of the machine. Hence, an improvement of the travelling speed and the boom movement will have a positive impact on productivity.

Detached Loose Fruits

Figure 6a shows the scattered loose fruits on the ground due to the impact of fallen bunches. The loose fruits were collected and packed in marked plastic bags (*Figure 6b*) before weighing and counting them.

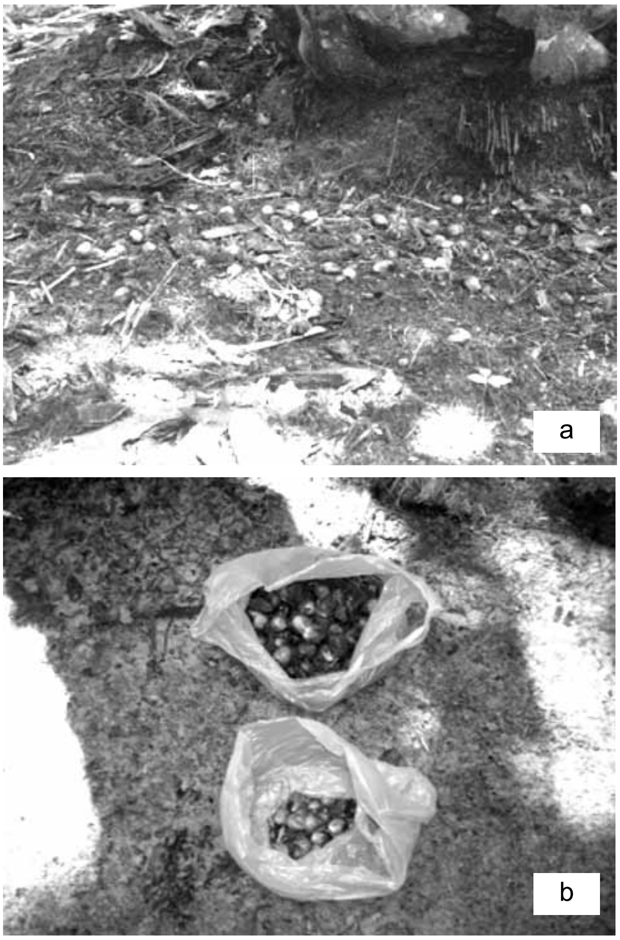


Figure 6. Two bags were used for temporary storage of detached loose fruits, before and after cutting.

There was a significant difference ($p<0.05$) between the mean of the number of detached loose fruits produced by using the machine (92±16 loose fruits, n=3) and the manual method (168±32 loose fruits, n=3). *Table 2* shows that by using the harvesting machine, the amount of detached loose fruits produced during harvesting was reduced 45% compared to manual harvesting as the bunch does not hit the ground. However, there was no significant difference ($p>0.05$) in terms of collection time between both methods.

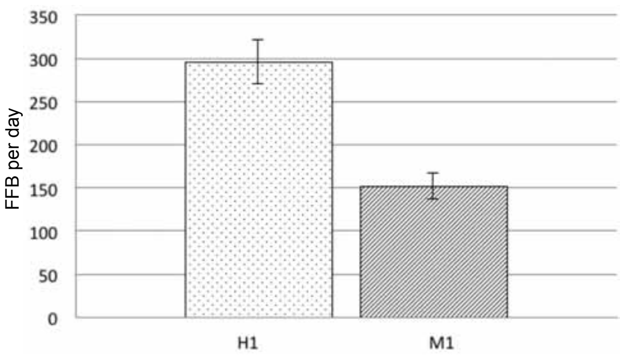
A Comparison of Productivity between the Mechanical and Manual Methods of Harvesting

Figure 7 shows that the mean productivity of H1 machine is almost double that of manual harvesting ($p<0.05$, H1: 296±25 bunches, and M1: 151±15 bunches, n=9). Therefore, it proves that the mechanical harvesting machine is better than the manual method of harvesting. During the trial, it was also noticed that the machine operators were capable of harvesting for 10 working hours, which

TABLE 2. A COMPARISON OF DETACHED FRUITLETS BETWEEN THE MECHANICAL AND MANUAL HARVESTING METHODS

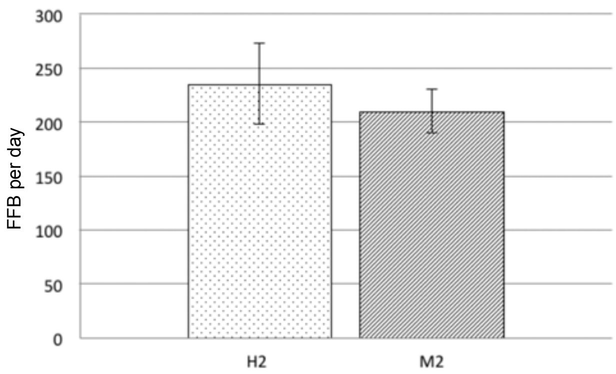
Cycle	Ave. bunch weight (kg)		Ave. No. of detached fruitlets				Ave. collection time of detached fruitlets (s)	
	M1	M2	M1		M2		M1	M2
			Before	After	Before	After		
1	27.2	23.3	23	97	35	196	55.0	76.0
2	26.6	23.6	42	106	46	174	48.0	60.3
3	26.1	26.0	32	74	23	134	40.3	51.7
Mean	26.6	24.3	32	92	34	168	47.8	62.7

Note: M1: machine. M2: manual.



Note: FFB – fresh fruit bunch.

Figure 7. Average productivity per day for a complete harvesting machine with bucket (H1) and manual harvesting with a transportation-buffalo cart (M1).



Note: FFB – fresh fruit bunch.

Figure 8. Average productivity per day for the cutting only harvesting machine without a bucket (H2) and manual harvesting without transportation (M2).

meant that more FFB could be harvested, whereas the manual harvesters worked for a maximum period of 8 hr.

It is clear therefore that an operator is more productive when using a machine, especially as he would be less tired. By extending the working hours from 8 to 10 hr, the operational costs can eventually be reduced. This approach is more acceptable by the estates because working with a two shift system is not favoured by most of the workers.

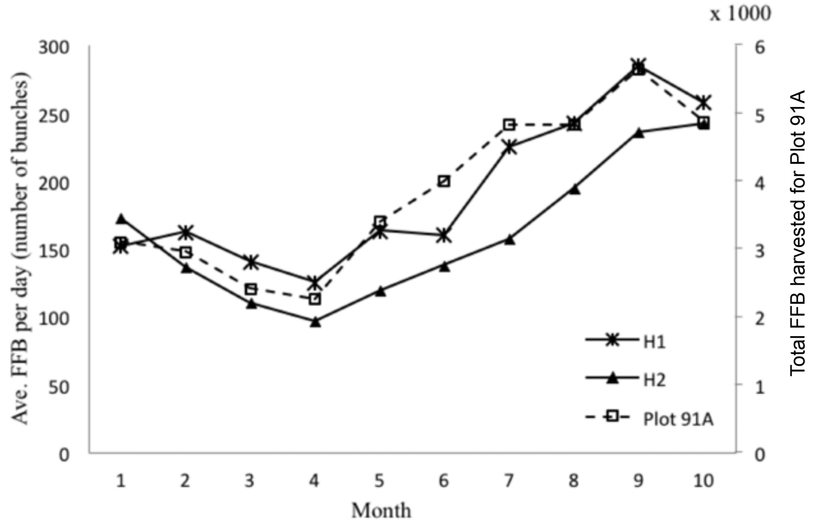
Figure 8 indicates that there is no significant difference ($p>0.05$) between the mean of H2 (235±37 bunches, n=9) and M2 (210±20 bunches, n=9). As discussed earlier, difficulties during cutting operations for H2 had contributed for the poor performance.

Overall Performance

Figure 9 shows the average productivity per day for both types; H1: complete harvesting machine with a bucket and H2: cutting only harvesting machine without a bucket at the trial estate for 10 months.

For H1, the maximum bunches harvested per day were 284 bunches (7.68 t) and the minimum were 125 bunches (2.77 t). Whereas for H2, the maximum and minimum bunches harvested per day were 242 and 96 bunches (6.36 and 2.14 t), respectively. It also shows that a similar productivity trend can be found for each unit of the harvesting machines and the FFB yield trend in the estate field (Plot 91A). Besides the weather factor, the large variation between the maximum and minimum bunches harvested is believed to be due to the fruiting season.

There is no significant difference (t-test, $p>0.05$) between the mean for daily productivity for the H1 (191±56 bunches, n=10) and the H2 (160±51 bunches, n=10). However, the productivity of H2 is slightly lower because there is no grapple to hold the bunch, hence it is difficult to cut the bunch stalk. Due to gravity, the tendency of the cutter to get stuck on the bunch stalk while cutting, is higher, if the cutter is unable to cut the entire stalk with one movement. Therefore, the operator needs to cut the stalk again, thus increasing operation time. This was also proven in the TMS (*Table 1*).



Note: FFB – fresh fruit bunch.

Figure 9. Average daily productivity of H1 and H2.

A number of breakdowns were recorded during the trial that affected the overall productivity of those machines. Below are some causal factors that were identified:

- leaked or burst hydraulic hoses due to falling frond;
- cracked bucket and booms; and
- wear and tear of the under carriage systems.

Economic Analysis

From the following data:

Machine price = RM 220 000
Economic life = 6 years
Productivity = 250 FFB (6 t per day)
Labour cost = (RM 0.24 x 250 bunches)
= RM 60 per day
25 days working day a month

Based on the figures above, the cost of harvesting are:

Depreciation:	$\frac{\text{RM 220 000}}{6 \times 12 \times 25}$	= RM 122.23 per day
Labour cost		= RM 60 per day
Fuel consumption: 18 litre per day @ RM 1.80 per litre		= RM 32.40 per day*
Repair and maintenance cost		= RM 100.00 per day*
Total cost		= RM 314.63 per day
Therefore;		
Cost per tonne		= RM 317.87/6
		= RM 52.44 t^{-1}

Note: *Actual cost based on the study.

The average labour cost for harvesting bunches in the tall palm area is around RM 30 – RM 40 t^{-1}. From the calculation above, the difference between mechanical and manual harvesting is between RM 13 – RM 23 t^{-1}, which can be considered as high. On the other hand, in terms of productivity, the manual harvesting output is around 100 - 150 bunches man^{-1} day^{-1}, whereas for the machine it is around 200 - 250 bunches man^{-1} day^{-1}. There are three possible ways of reducing the machine harvesting cost: increasing productivity, extending working hours, and reducing the machine capital cost.

Reducing the machine's cost can be achieved in several ways, *i.e.* some modifications of the machine to get to the price required, using tyres instead of track system and getting a reliable manufacturer who can produce the machine with the same or even better quality, at a lower cost. MPOB is looking into these options.

CONCLUSION

The oil palm mechanical harvesting machine has a good potential of replacing the manual operation of harvesting tall palms, which is currently tedious. The study shows that the machine is able to perform all the necessary functions effectively and compete with the manual operation. The important role of the grapple to hold and bring down the bunch has been proven in this study and ensures that the machine can operate effectively. Furthermore, this three-in-one machine, which cuts, collects and transports produces clean bunches (with less mud and trash) with less loose fruits on the ground.

It is anticipated that the successful introduction of the mechanical harvester developed by MPOB will pave the way for new technologies to be developed, leading to the development of more efficient and cheaper machines in the future.

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