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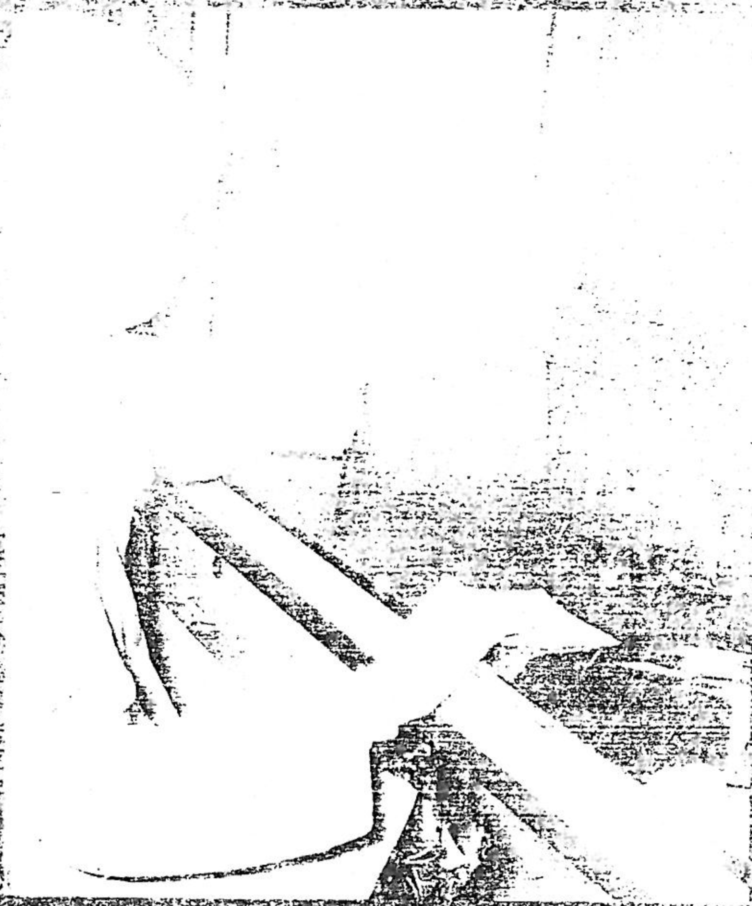

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The Effects of Physical Characteristics of Aluminium Pole on the Harvesting Productivity of Tall Palms

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ABSTRAK

Empat model galah aluminium, setiap satunya sepanjang 15 meter, telah diuji bagi menilai kesan ciri-ciri fizikal galah ke atas produktiviti bagi penuaian pokok tinggi (> 12m). Ciri-ciri fizikal ini terdiri dari dimensi galah (diameter dan ketebalan), bentuk dan panjang galah. Kesan ciri-ciri fizikal ini ke atas berat galah, lenturan, daya mengangkat dan momen telah diperhatikan. Ujian fizikal dijalankan di PORIM, manakala ujian ladang telah dijalankan di sebuah estet dekat Teluk Intan. Kajian yang dijalankan menunjukkan ciri-ciri fizikal galah memberi kesan yang nyata ke atas produktiviti penuaian, di mana galah yang mempunyai lenturan dan momen yang rendah didapati berupaya menuai lebih banyak buah tandan segar (BTS) berbanding galah yang mempunyai lenturan dan momen yang tinggi.

INTRODUCTION

Efficient harvesting of fresh fruit bunches (FFB) plays a vital role towards improving the quality of harvested FFB. There are two important components in harvesting, labour and tool (Stanners, 1992). However, the tool is the only component that can be designed and developed without limits, whereas labour performance is normally unpredictable. Serious losses of productivity may result if the tool is not improved.

Harvesting of short palm is a relatively simple operation. A chisel attached to a short steel pole is normally used. Cutting is performed by throwing the tool at a very high speed to the target. Weight of tool combined with its very high speed will give enough energy to cut through the material. However, harvesting of tall palm requires different method and technique. Two activities have to be carried out, that is to lift the pole upright and to cut fronds as well as the bunches. Normally, a sickle attached to a long pole is used. Bamboo poles were widely used in the early days, but since 1986, aluminum pole has been introduced by PORIM as bamboo became scarce and expensive (Abdul Halim Hassan *et al.*, 1987). There were various model of poles introduced in the market since then.

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For harvesting of tall palms (> 12m), focus is made on two major components, the pole and the cutting knife. The existing cutting knife (sickle) which is popular amongst the harvesters is made of spring steel and it weighs about one kilogram. Personal survey conducted showed that the existing design of sickles are popular among the harvesters (Razak, 1994). Realizing this, the focus is now only on the pole. A good harvesting pole should be easy to handle beside producing a better productivity.

This paper highlights the physical tests carried out and a field trial on four models of aluminum poles which are currently being used by the harvesters in the country.

OBJECTIVES

The objectives of this study were:

i. To investigate the effect of pole physical characteristics on the poles' distance of centre of gravity (*cofg*), deflection, lifting force and torque requirement. These physical characteristics were pole dimensions (diameter and thickness), shape, combination of length, and weight.

ii. To investigate the effect of pole physical characteristic on the harvesting productivity of tall palms.

MATERIALS AND METHODS

Determination of Centre of Gravity (*cofg*), Deflection and Weight of poles

Centre of gravity (*cofg*) is the centre of weight of the pole, while deflection is defined as the maximum deflection of pole when it is hung at the point of centre of gravity (where both end of pole is free from touching the ground). While torque is the multiplication of the distance of *cofg* and the required lifting force at the point of *cofg*. It indicates how much effort is required to lift the pole up.

Four models of aluminum poles were tested, marked as pole 1, 2, 3 and 4. The total combination length of poles were either of combination of two poles or three poles to make up its total length of 15m. The poles were named as basic pole (x), first extension pole (y) and second extension pole (z) for the biggest diameter, medium diameter and smallest diameter, respectively. The poles were joint by U-clip. Their dimensions are shown in *Table 1*.

TABLE 1. DIMENSION OF TESTED POLES

Model	Length (m)			Diameter (mm)		
	x	y	z	x	y	z
1	6	9		44.4	38	
2	7.5	7.5		44	38	
3	3	6	6	43	38	33
4	6	9		45	35	

Note: x: basic pole
y: first extension pole
z: second extension pole

Test Procedures

An experimental rig was developed to carry out the tests. The pole was lifted up by pulling it using a cable (somewhere in the middle) until both of its end is just lifted off from the ground as shown in *Figure 1*. The place where the cable was positioned at a balance position was the centre of gravity of the pole. The distance of this point from the ground level was measured to indicate its maximum deflection. The weight of the pole recorded by a spring balance (located in the middle of the cable) was also taken.

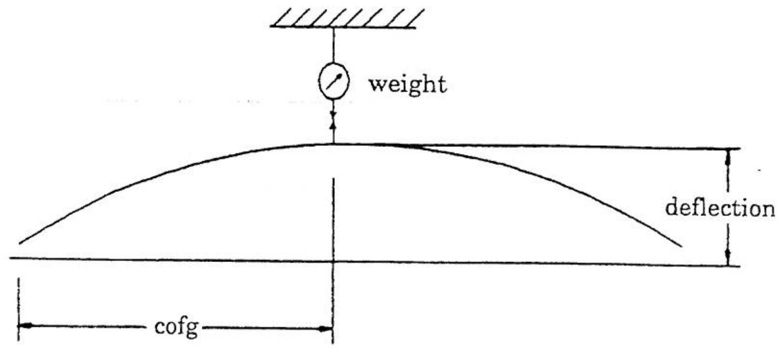

Figure 1. Determination of weight, cofg and deflection of pole (free end)

Determination of the Lifting Force of the Pole

Test Procedures

The same test rig was used to carry out the second experiment. The bottom end of the test pole was fixed to a fulcrum to enable the whole length of the pole to be raised vertically (*Figure 2*).

By assuming that the fulcrum was free of friction, then the pole was lifted at point s (see *Figure 2*) by hoisting the cable until the far end of the pole is just above the ground. The required lifting force was recorded by the spring balance. The variation of the lifting force along the length of the pole was made by varying, the points of lifting.

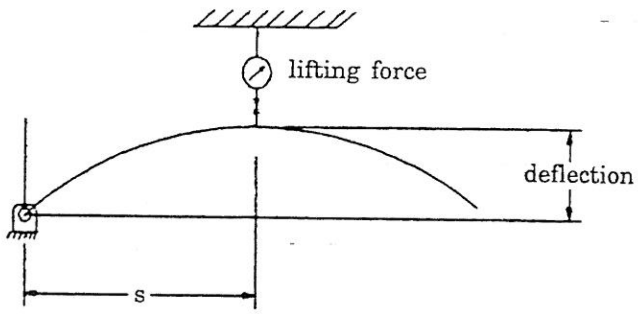

Figure 2. Determination of lifting force at various distance from the base (x)

Field Trial of Harvesting Pole

The performance of poles were assessed in an estate at Teluk Intan, Perak. The poles used were of similar characteristics as used in the two experiments earlier. This trial consisted of (i) time and motion study (TMS) and (ii) harvesting productivity (number of bunches and fronds cut per day).

Trial Site

The topography of the estate where the trial was carried out was flat. For harvesting, the estate was divided into blocks. A team of one cutter and one carrier would begin harvesting in one block first. On completion of their task in the first block, they next move to the adjacent block.

The height of palms were between 12 metres to 15 metres height and the cropping level during the trial period was considered fairly good. The study site produced about 25 tFFB/ha - 30 tFFB/ha annually. No mechanized infield transportation was used.

Trial Procedures

In the field trial, the present harvesting system above was maintained. One worker did the harvestings while another one did the stacking of frond, collecting of loose fruits and transporting the FFB to the roadside. Each harvester used the same brand of harvesting sickle to avoid variations in the data collected. The sickles were sharpened every morning before harvesting. The loose fruits and FFBs were transported by means of wheelbarrow.

As there were four models of poles to be tested, four skilled harvesters were selected. On the first day, each harvester was given one model to be used for two successive days. However, he was allowed to use it for one hour to enable him to be familiar with it, before a proper recording was made. Each harvester was followed by a recorder to record the time and motion study (TMS) and number of bunches obtained for the day. TMS included time taken to lift the pole up, to carry it upright, to cut fronds and to cut FFB. TMS was taken at only 20 minutes in every hour, so that the rest of the time, the recorder would record the number of fronds and FFBs harvested.

After that period, each harvester would switch to another pole model and the trial procedures were repeated. These poles were rotated among them until each of harvesters have completed using all models. The recorder and harvester remained unchanged throughout the study.

RESULTS AND DISCUSSIONS

Determination of Centre of Gravity (cofg), Deflection and Weight

From the experiment carried out, the *cofg*, deflection and weight of the poles tested are shown in *Table 2*.

Pole 2 had the longest distance of *cofg* (7.19m ± 0.31m), while pole 4 had the shortest value (6.97m ± 0.21m) from the base of pole (*Table 2*). For the deflection at *cofg*, pole 4 produced the highest deflection (1.09m ± 0.04m) compared to pole 1 which produced the lowest (0.68m ± 0.04m). Therefore, the distance of *cofg* and deflection of pole were very much influenced by its physical characteristics which includes diameter, thickness, shape and combination of

TABLE 2. CENTRE OF GRAVITY, DEFLECTION AND WEIGHT OF POLES (Average of 5 Data)

Pole	Point of *cofg* (m from bottom)	Deflection at *cofg* (m)	Weight (kg)
1	7.15±0.25	0.83±0.05	8.5±0.20
2	7.19±0.31	0.68±0.04	9±0.25
3	7.02±0.26	0.88±0.04	7±0.31
4	6.97±0.21	1.09±0.04	7±0.27

(Note: average of six replicates)

length. Statistical analysis showed that the weight of pole did not affect the distance of *cofg* and the deflection significantly.

As pole 3 was a combination of three lengths, therefore its centre of gravity was a bit further than other pole. Since the diameter of second extension pole was a bit smaller, the pole became less stiff hence contributing a higher deflection. While for pole 4, as it has an ellipsoidal cross-section, therefore the deflection was higher when it was hung at the horizontal position. Thus, the deflection of this pole was the highest compared to others.

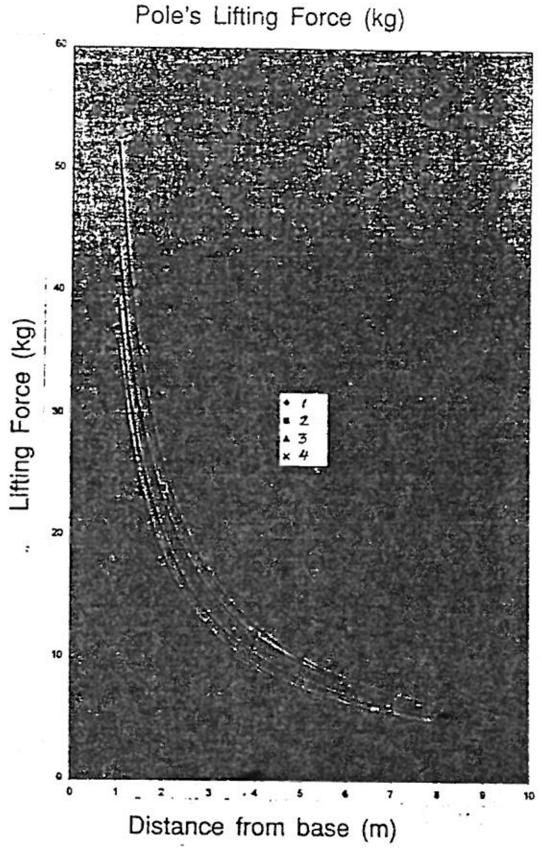

Figure 3. Poles' lifting force at various distance from base

Determination of Lifting Force

Figure 3 shows the lifting forces required by the four models of poles at various distance of lifting. The graph shows that all poles were having similar trend (exponential) with the regression equations as follows:

Pole 1: $F_l = 36.122x^{-0.8676}$; $R^2 = 0.9967$

Pole 2: $F_l = 43.91x^{-0.8363}$; $R^2 = 0.9995$

Pole 3: $F_l = 52.14x^{-1.0186}$; $R^2 = 0.9785$

Pole 4: $F_l = 39.411x^{-0.965}$; $R^2 = 0.9977$

where F_l = lifting force (kg)

x = distance from base (m)

R^2 = correlation coefficient

The maximum lifting forces were 36kg, 44kg, 52kg and 39kg for pole 1, 2, 3 and 4, respectively at one metre from base.

Poles' Performance

TABLE 3. TIME AND MOTION STUDY (second/activity) OF POLES TESTED

Activity	POLE 1	2	3	4
To lift the pole up (sec./lift)	17.7±0.81	13.17±0.89	14.27±3.59	17.77±4.13
To carry pole upright (sec./carry)	7.1±2.13	6.13±1.87	5.17±1.5	6.7±0.56
To cut frond (sec./frond)	22.2±9.24	30.03±3.38	25.8±4.2	37.67±1.25
To cut FFB (sec./FFB)	27.8±11.2	34.3±6.74	30.3±5.34	31.47±4.47
Total time taken (sec.)	**74.8**	**83.63**	**75.54**	**93.61**

Note: average of four harvesters

Table 3 shows the time and motion study (TMS) that was taken during the trial.

Least Significant Difference (LSD) was carried out to test the difference among the treatment means for all activities. The results showed that there were no significant difference in all activities for all models of poles tested. The results are shown below:

a. To lift the pole up
Means for pole 1, 2, 3 and 4 were 17.17s, 13.17s, 14.27s and 17.77s respectively (α = 0.05, df=9, MSE = 21.99, LSD = 7.5 and T critical = 2.26).

b. To carry the pole upright
Means for pole 1, 2, 3 and 4 were 7.1s, 6.13s, 5.17s and 6.7s respectively (α = 0.05, df = 9, MSE = 6.25, LSD = 3.99 and T critical = 2.26).

c. To cut frond
Means for pole 1, 2, 3 and 4 were 22.2s, 30.03s, 25.8s and 37.67s respectively (α = 0.05, df = 9, MSE = 125.87, LSD = 17.95 and T critical = 2.26).

d. To cut FFB
Means for pole 1, 2, 3 and 4 were 27.8s, 34.3s, 30.3s and 31.47s respectively (α = 0.05, df = 9, MSE = 77.37, LSD = 14.07 and T critical = 2.26)

In lifting the pole upright, pole 2 required the shortest time (13.17s) as compared to others. This may be resulted because of its lower deflection which allowed the harvester not to waste his time to overcome the deflection effect. While for pole 4, its elliptical shape may result in a higher deflection, thus difficult to be lifted up.

For cutting fronds, pole 1 required the lesser time (22.2 sec), while pole 4 required the longest time. It showed that the deflection had a significant effect in the cutting process in that pole with lower deflection would be easy to handle. Lower in deflection would also contribute to ease in the positioning of the sickle on the frond before cutting. While for pole 4, its high deflection may create some difficulties to the harvester to handle it, thus he needed a longer time to do the cutting.

In cutting of FFB, pole 1 required the least time compared to the others. This may be related to its lower deflection thus giving an advantage in the cutting process.

Effect of Poles' Characteristic on Total Time Taken and Productivity

The summary of findings are shown in *Table 4*. This table deliberates the effect of poles' physical characteristics on the total time taken to get one FFB, and the number of FFB harvested per day. Total timé taken was the total time in lifting the pole up, to carry the pole upright, to cut frond and to cut the FFB. As to investigate what factors are really affecting the total time taken and the number of FFB harvested, the pole's physical characteristics (weight, deflection and torque) were investigated by ranked them from 1 to 4. Rank no. 1 shows the best while rank no. 4 shows the worst. The ranking of poles is given in *Table 5*.

Overall, pole 1 gave the highest productivity and lesser time taken in handling it. This may be due to the combination of its lower weight, deflection and torque. Pole 4 produced the lowest productivity and longest time taken in handling it. This may be due to its higher deflection and torque. Even though the deflection of pole 2 was the lowest, its higher torque may contribute to its lower performance. Similar to pole 3 where the torque was the lowest, but its higher deflection would affect its performance.

It is, therefore clear that both lower deflection and moments are the main factors which affect the pole performance. These two factors are the main criteria to be considered when designing a harvesting pole for tall palms.

TABLE 4. THE SUMMARY OF THE EFFECT OF POLES' PHYSICAL CHARACTERISTICS ON TIME TAKEN AND PRODUCTIVITY

Pole	Weight (kg)	Moment (Nm)	Deflection at *cofg* (m)	To lift pole (sec.)	To carry pole upright (sec.)	To cut frond (sec.)	To cut FFB (sec.)	Total time taken (sec.)	Total no. of FFB harvested per day
1	8.5	46.8	0.83	17.7	7.1	22.2	27.8	74.8	66
2	9	60.6	0.69	13.17	6.13	30.03	34.3	83.5	57
3	7	42.19	0.88	14.27	5.17	25.8	30.3	75.8	62
4	7	50.2	1.09	17.77	6.7	37.67	31.47	93.4	54

Note: average of four harvesters

TABLE 5. POLE RANKING

Pole	Weight rank	Deflection rank	Moment rank	Total rank	Time taken rank	FFB harvested rank
1	2	2	2	6	1	1
2	3	1	4	8	3	3
3	1	3	1	5	2	2
4	1	4	3	8	4	4

CONCLUSION

The results of these study showed that:-

- The weight, distance of *cofg*, deflection and torque of poles were very much influenced by their physical characteristics, that is dimension (diameter and thickness), combination of length and shape.
- Poles with a higher torque and deflection were difficult to handle. This will obviously reduce productivity in tall palm harvesting.
- Deflection and torque of pole have a significant effect on harvesting productivity of tall palms. Thus, in getting a better harvesting pole, these characteristics must be taken into consideration.
- Weight of pole does not affect the distance of *cofg*, torque and deflection.
- Poles with lower torque and lower deflection were the main criteria to be considered when designing a better harvesting pole.

RECOMMENDATIONS

The study revealed that there are two main factors that need to be looked into in designing a harvesting pole for tall palms which would affect the harvesting productivity. These are the deflection and torque. It was proven that pole with lower deflection and torque would be easy to handle, and as a consequence, the harvester could harvest more FFB. To lower the deflection and torque, one should consider the design of pole which includes its diameter, shape and the combination of length. It is recommended to have only two combination of length instead of three because the lesser the combination, the lower the deflection will be. To lower the torque, the distance of *cofg* should be brought towards the bottom of the pole. This can be done by either to increase the diameter or to shorten the length of the basic pole.

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