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Design and Test of Fruit Power Ladder

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ABSTRACT

A 196 cm. wide by 530 cm. long three-wheel power ladder for fruit havesting was designed and constructed. The platform and the wheel were direct driven by hydrostatic transmission system and the platform could be lifted up to 420 cm. high. The three-wheel ladder moved forward at the speed of 5 kilometers per hour and could be turned by fixing one of the two front wheels. The turning radius was 3.87 m. and the weight was 770 kg. The platform speed of upward and downward was 0.148 and 0.404 m. per sec respectively. Fuel consumption was 0.925 l per hr and the noises intensity was 83 decibels. The vehicle can be handled by one operator.

Performance of this power ladder was comparatively tested between 2 methods of mango harvesting, i.e. 3-wheel power ladder with 2 m. long rattan picker and 4-wheel power ladder with 2 m. long rattan picker. Mango havesting by the 3-wheel power ladder with 2 m. long rattan picker showed higher capacity (147 kg/hr) than havesting by the 4-wheel power ladder with 2 m. long rattan picker (114 kg/hr). Fruits dropped down and remained in the mango tree were small and insignificantly different (at 95% confidence level). On the average, the fallen and the remained fruits were 1.15% and 5.15% respectively.

Keywords : power ladder, harvesting method

INTRODUCTION

RNAM reported that the labour for harvesting and threshing was about 46% of all labour in agricultural production. Presently, Thailand is developing rapidly in both agriculture and industrial sectors but the growing of industrial sector is larger than agricultural sector. As the case, the labour in agricultural sector has shifted to industrial sector, so that the agricultural sector lacks of labour and labour cost in agricultural sector is increased. In the situation that the manual labour is scarce and expensive and agricultural activity needs intensive labour force. Mechanization in the agricultural production is urgently developed and mechanization is another choice for the farmers to choose since it is difficult for farmer to increase production from manual labour only.

Status of fruit harvesting and machinery for harvesting aids in Thailand was intensive studied by Jarimopas et. al. (1994). This research would like to develop fruit harvesting vehicle which had high efficiency and appropriatness to Thai fruit gardens.

DESIGN

Design criterias

1. The width and length should be suitable for transportation by a 6-wheel truck.
2. The height of 4m.
3. The centre of gravity should be the lowest possible.
4. Practical in approaching the target.
5. The platform should be quickly lifted up and down without impact.
6. Movement can be controlled by operator on the platform.
7. Safety first.
8. Only one operator.

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Figure 1. showed fruit harvesting chassis of 2 metre wide, 3 metre long and the plat form of 4 metre high such that the vehicle together with other harvesting aids of 2 metre long could reach the tree of 6-8 metre high. The vehicle was 3 wheels for practical and suitable operation in the field without winding the branch or stem of plant. The vehicle was hydrostatic transmission by 2 front wheels which each one was free from each other for easy turning control. The 2 front wheels were driven by hydraulic motor. Pathaveerat (1993) has shown all detail of design calculation.

The fruit harvesting vehicle consisted of:

1) Chassis composed of the parts for weight distribution, wheel, the engine, oil tank, hydraulic pump and boom holder.

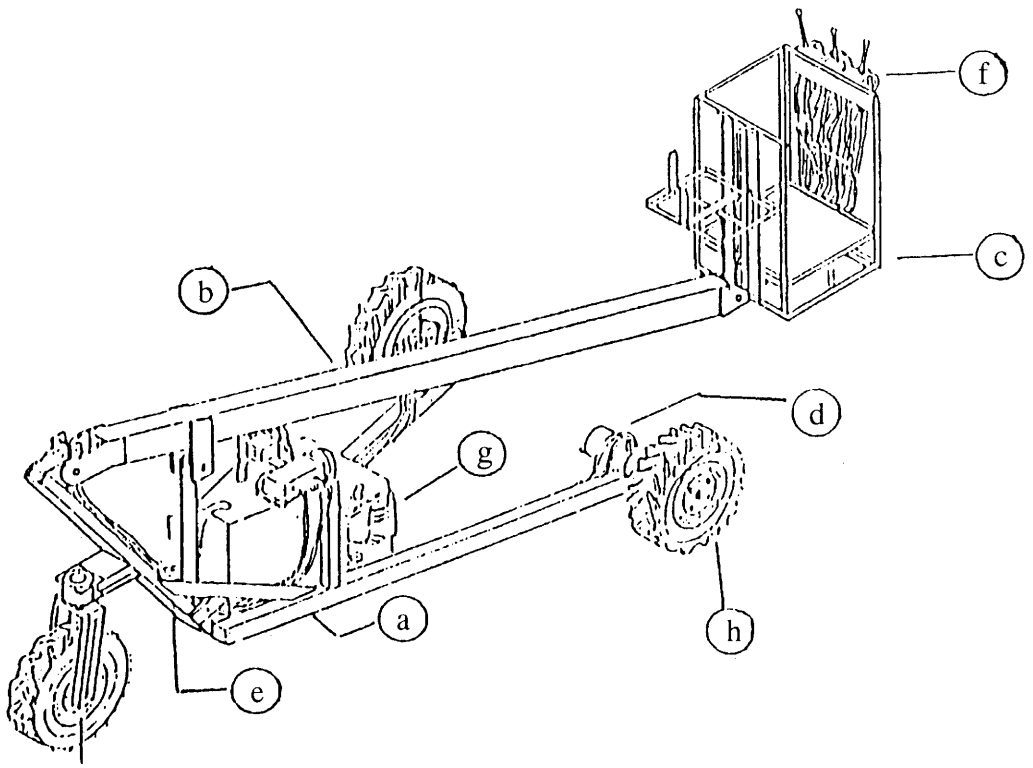
1.1 Weight distribution and wheels parts which had a triangle figure (top view), were made from perpendicular iron of size 3 inch and $^1/_4$ inch thick. This part was formed in the shape of square block for weight distribution and equiped with hydraulic motor and drived wheels.

1.2 Engine, oil tank and hydraulic pump parts were the base next to the wheels which were made of iron plate 10 centimetre thick for the lowest point of center of gravity.

13. Boom holder part was iron beam next to the engine and inclined at 60°C with horizontal plane. Boom holder was made from U channel steel size of 6" × 3", 3/8" thick.

2) Boom was the part to lift the crane or platform made of square block iron sized 5" × 5"and 0.1875" thick and total length of 4.6.

3) Crane of platform was the part for picker to stand and place the container of fruit. Crane was made of perpendicular iron of $1^1/_2$" of $^1/_4$" thick and



a) Chassis
b) Boom
c) Platform
d) Hydraulic motor
e) Hydraulic cylinder
f) Controlled valve
g) Engine
h) Wheel

Figure 1 Components of three-wheel harvesting vehicle.

circular iron pipe of 1" diameter. The body of crane was 60 x 60x 80 cm^3 while the base was block form for keeping hydraulic hoses and controlled valves of direction control of left and right wheels, control valve for crane lifting and engine acceleration cylinder of all fixed in the front of the base.

4) Hydrostatic transmission system consisted of 2 gear pumps of size displacement 15 cm3/ rev. The pump was 2 stage for driving hydraulic motor of 2000 psi or 140 kg/cm^2.

4.1 Flow rate of 15 l/min

4.2 Hydraulic hose of $^1/_2$ " diameter 2 ply type of SAE 100 R2, Type A and AT.

4.3 Two hydraulic motors of orbit and displacement type of 380 cm^3/rev each. The motor could bear the torque of 80 kg-m at the pressure of 140 kg/cm^2

4.4 Two sets of controlled valves of tandem, 4 way-direction and 3 position type.

4.5 Oil strainer used filter of suction type with aperture size of 125 mesh.

4.6 No. 10 hydraulic oil

5) Hydraulic systems for crane lifting.

5.1 Hydraulic pump of gear type, displacement size of 6 cm^3/rev. at the pressure of 140 kg/ $cm.^2$ and flow rate of 6 l/min. at the revolution speed of 1000 rev./min.

5.2 Hydraulic cylinder which had the piston diameter of 6.3 cm. positive displacement of 51 cm. flowing control by double acting and piston rod diameter of 3 cm.

5.3 Hydraulic hose of $^1/_2$ " diameter, 2 ply type of SAE 100 R2, type A and AT.

5.4 Oil filter of suction type with aperture of 125 mesh.

5.5 Controlled valve of tandem 4 way direction, 3 positions, and built in relief valve.

6) Hydraulic oil tank of trapezoidal form for matching with chassis, 60 cm. high and 60 l capacity. The tank was not only for oil storage but also for heat dissipation.

7) Engine of Yanmar TF10.5 of 10.5 horse power

8) Three traction types of power tiller wheel size 6-12.

TESTING

Materials

1. Three wheel harvesting vehicle with engine.
2. Four wheel harvesting vehicle with engine.
3. Weight of 1 and 60 kilograms.
4. Watch
5. Ratten takraw for picking mango fruits
6. mango trees of consistent fruit size

Methods

Methods were preliminary, laboratory and field tests together with engineering analysis and evaluation.

Laboratory test

The laboratory test was done to collect the data of three wheel harvesting vehicle designed by the project and locally made four wheel harvesting vehicle No. 329. The recorded data were:

- Dimensions of width, length and height
- Center of gravity in X, Y and Z planes of the lowest and highest positions of the crane
- The widest inclined angle which no turn over of the car
- Proper speed for working
- Turning radius of wheels
- Vehicle weight
- Height in maximum operating
- The intensity of loudness
- Fuel consumption

Field test

Comparative tests of fruit harvesting vehicle between locally made four wheels and three wheels belonged to the project were performed with Kheo Sawoey mango trees of 7 metre high and 6x6m. between trees. The methods of harvesting were:

1. Locally-made 4 wheel harvesting vehicle together with 2 m long ratten takraw.
2. Project-designed 3 wheel harvesting vehicle together with 2 m long ratten takraw.

The test was done in a randomized complete block design of 2 means of harvesting processes and the fruit set of mango as the block of 6 fruits/m^2, 8 fruits/ m^2 and 10 fruits/m^2. The mango trees of 6 m bush radius were employed in this test. When the operator was already to start picking, the time of harvesting was recorded from picking, collecting the mangoes in

Figure 2 Harvesting mangoes with three wheels power ladder with 2 meter long rattan picker.

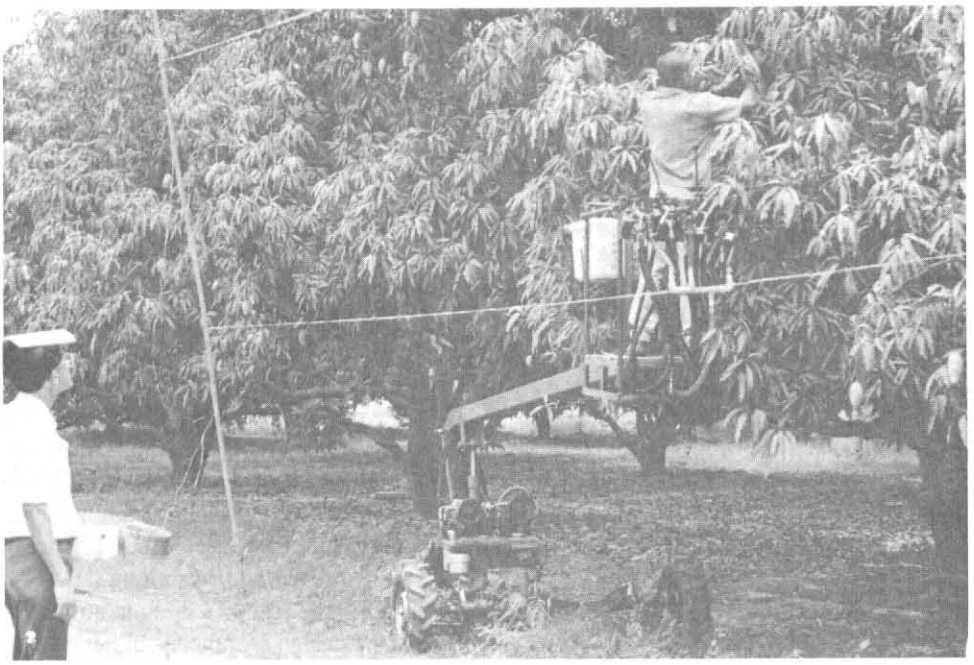


Figure 3 Harvesting mangoes with four wheels power ladder with 2 meter long rattan picker.

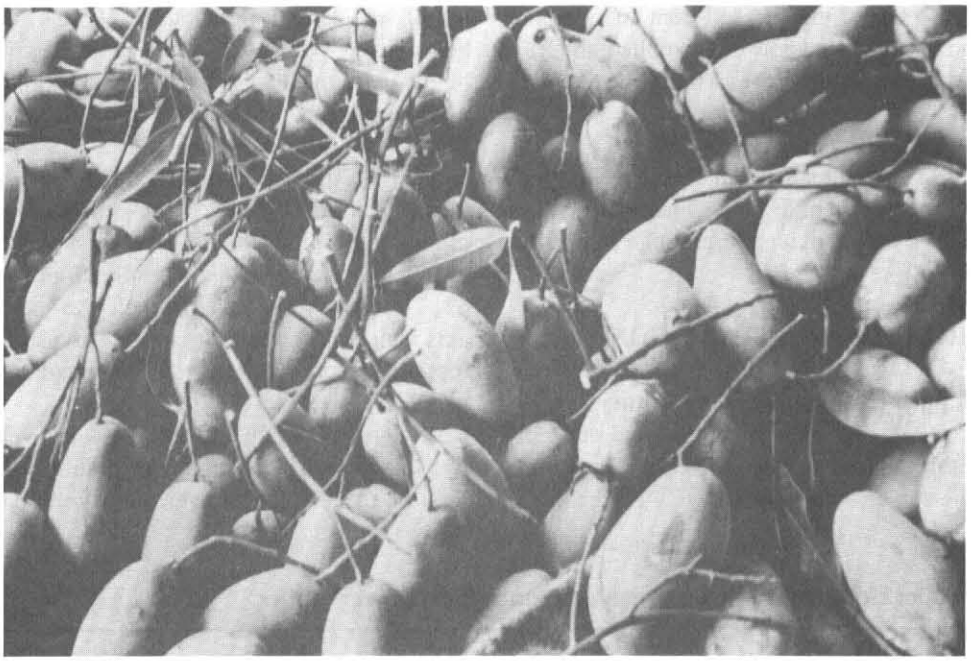


Figure 4 Mango fruits were harvested by the power ladder.

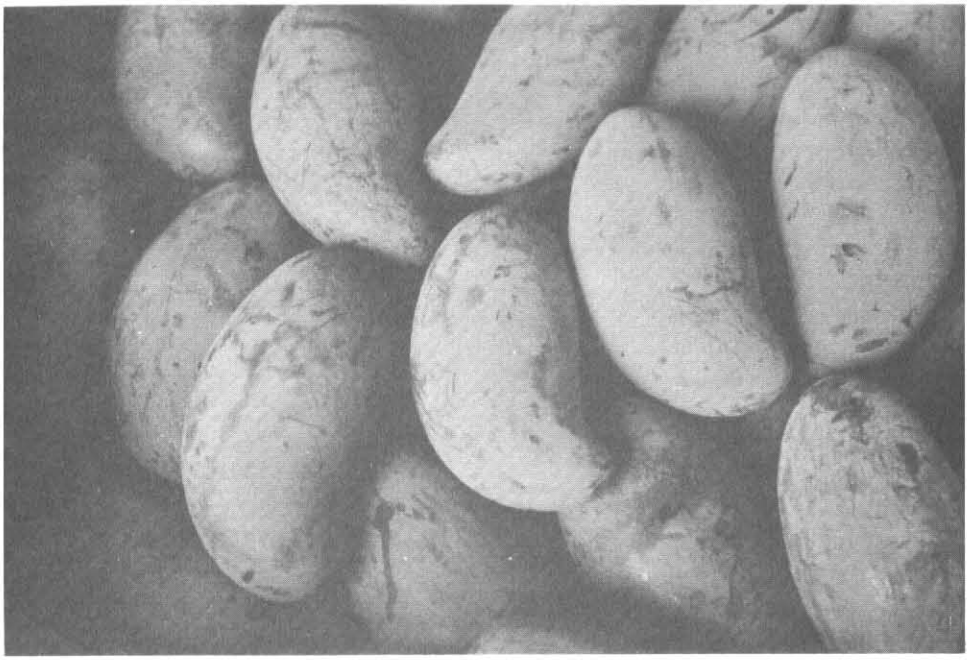


Figure 5 Mango fruits were haevested by hand and 4 m. long rattan picker.

the baskets, transporting the full containers to the ground and changing the new one to collect the fruit again until harvest all the fruit on a tree. The recorded data were:

- Harvesting time (min)
- Harvested mango fruits weight (kg)
- The weight of dropping mango fruits (kg)
- The weight of retaining mango fruits from harvesting (kg)

RESULTS AND DISCUSSION

Results of performance test in laboratory

1) Results of tests and engineered data collected for three-wheel harvesting vehicle developed by the project, were shown in Table 1. As the three-wheel vehicle had the width of 196 cm, the lengt between the wheel of 310 cm and the machine height of 166 cm at the lowest crane position. So that three-wheel vehicle was easily transported by six-wheel truck which had the floor width of 204 cm and the length of 400 cm. The crane floor height was 420 m at the maximum lifting. The center of gravity at minimum position along X-axis (from left wheel), Y-axis (from front wheel) and Z-axis (from ground) are 87, 72 and 42 respectively, where the shortest of Z-axis increased the stability of the harvesting vehicle for not easy turnover. The total weight of the vechicle was 770 kg.

The driving speed for three-wheet vehicle was two front wheel driving by hydraulic motor with forward speed of 5.11 km./hr. and revolution speed of

Table 1 Laboratory test of three wheel and four wheel power ladder.

Data	3-wheel	4-wheel
Dimension		
width (cm.)	196	155
length (cm.)	530	490
min. platform height.	166	180
max. platform height.	420	400
Center of gravity at min. position		
X-axis (frim left wheel) (cm.)	87	64
Y-axis (from front wheel) (cm.)	72	106
Z-axis (from ground) (cm.)	42	79
Weight (kg.)		
speed at 1st. gear (km./hr.)		
forward	5.11	3.0
backward	4.8	3.0
Speed at 2nd. gear (km./hr)		
forward	-	4.0
backward	-	4.0
Turning radius (m.)		
front wheel	3.87	4.23
platform	2.71	5.5
Max. angle of inclination (degree)	12	12.2
Engine	diesel	diesel
	10.5 hp.	7.5 hp.
Fuel consumtion (l/hr.)	0.925	0.885
Noise intensity (dB)	83	85
Platform speed (m./s)		
up ward	0.148	0.107
downward	0.404	0.480

the wheel was 47 rev./min. The backward speed was 4.8 km./hr. and the revolution speed of the wheel was 43 rev./min. The turning radius was very narrow of 3.87 m which equared the distance between fornt and back wheels. The speed of liffing the crane up and down was 0.148 and 0.404 m/sec. respectively. This level of speed was adjusted from the controlled valve of flow and the driver felt that this speed was suitable for this kind of work. The power engine was diesel engine of 10.5 hp. with the noise intensity of 83 dB. measured at the driver position.

Pertormance testing in the shop found that the three-wheel vehicle performed the turning system by braking the wheel of required side. This turning system was practical in moving around the fruit tree.

2) The four wheel harvesting vehicle is 155 cm wide and 490 cm long. The minimum plaftorn height of 180 cm and the maximum platform height of 400 cm. The centers of gravity at minimum position along X-axis (from left wheel), Y-axis (from front wheel) and Z-axis (from ground) were 64, 106 and 79 cm. respectively and the weight of the vehicle was 925 kg which 155 kg heavier than the three wheel harvesting vehicle. From the dimensions and weight of the four wheel harvesting vehicle, it could be transported by truck. The speed was able to adjust in 2 gears (1 and 2 at 3.0 and 4.0 km per hour at the engine speed of 900 rev. per min while the forward and backward speeds were the same rate. The speeds of lifting the platform up and down were 0.107 and 0.408 m./s. respectively. The speed of liffing the crane up for four-wheel harvesting vehicle was 0.047 m./s. slower than the three-wheel harvesting vehicle, which had no effect to harvesting rate as the platform was lift up and down time to time during fruit harvesting. The speed of lifting the platform down for four-wheel harvesting veshicle was 0.08 m.s. quicker than three-wheel harvesting vehicle. The widest angle of turning at the platform for four-wheel harvesting vehicle was 5.5 m which was wider than the three-wheel harvesting vehicle. The wide angle of turning caused unpractical movement around the shape of tree, as the vehicle had to move backward before turning operation. Moving on a rather straight road had no problem. The engine was diesel of 7.5 hp. The intensity of noises at the speed level of 900 rev./min. was 85 dB. measured at the driver position.

Results of performance testing of fruit harvesting vehicle in the field.

Comparison of testing between three and four wheel harvesting vehicles with mangoes of Khao Sawoey trees which had the bush radius about 3.5 m and the height of 7 m. The results from testing showed that the rate of mango harvesting was statistically difference at 95 percent confident level. From the method of analysing by LSD found that the harvesting rate by four wheel harvesting vehicle was 114.42 kg/hr. The harvesting rate by three-wheel harvesting vehicle was higher than the four-wheel harvesting vehicle. As the three-wheel harvesting vehicle was more practical in moving and better moving to tht target. The turning system by braking one of the two front wheels at the required side of turning was convenient and quick even though the platform levels were high or low. The control sets attached at the front

Table 2 Comparison of harvesting methods for harvesting mango Kheo Sawoey variety at 0-7 meter height.

Method	Harvesting rate[1] (kg./hr.)	Fruit drop (%)	Retaining fruit (%)
3-wheel power ladder with 2 m. long rattan picker	147.34a	1.20	3.00
4-wheel power ladder with 2 m. long rattan picker	114.42b	1.03	7.27
C.V. = 1.38%			

1 means followed by different letters are significantly different (P = 0.05) according to LSD.

was easily operated to find the targets and harvesting planning than the ones attached at the back. The percentage of fruit drop was no diference between the three and four wheel harvesting vehicles. The percentage of fruit drop by three and four wheel harvesting vehicles were 1.20 and 1.03, respectively. Furthermore, the percentage of retaining fruits was not different between two vehicles. As the percentage of retaining fruits by three and four-wheel harvesting vehicle was 3 and 7.27 respectively (Table 2).

CONCLUSION

The design of three-wheel harvesting vehicle which front wheels driven by two hydraulic motors and two sets of pump for driving motor, was able to lift the platform of 4.2 high and pick the fruits at 6 m high. The maximum speed of driving was 5 km/hr and the narrow angle of turning which made possible by suddenly braking the wheel of the required side. The vehicle moved conveniently around the tree in zig zag shape. The speed of lifting the platform up and down was 0.148 and 0.404 m/sec. respectively. The power engine capacity was 10.5 horsepowers and handled by one operator.

The testing of locally-made-four-wheel harvesting vehicle showed that it was able to lift the platform of 4 km/hr and the speed of lifting the platform up and down was 0.107 and 0.480 m/sec. respectively. The power engine capacity was 7.5 horsepowers and handled by one operator.

Mango harvesting from trees of 7 m tall was compared between three-wheel harvesting vehicle together with 2 m long rattan takraw and four-wheel harvesting vehicle together with 2 m. long rattan takraw. The three wheel harvesting vehicle together with two m. long rattan takraw, gave higher rate of picking than the four wheel harvesting vehicle together with two m. long rattan takraw, with the harvesting rate of 147.3 and 114.4 kg/hr respectively. There was no statistical difference between the two methods of harvesting in percentage of fruit drop which was 1.2 for three wheel harvesting vehicle and 1.03 for four wheel harvesting vehicle. The percentages of retaining fruit for three- wheel and four wheel harvesting vehicle were 3.0 and 7.3 respectively. There was a tendency to increase the rate of harvesting the mangoes by utilizing the three-wheel harvesting vehicle together with more efficient and lighter weight of picking tools such as those equipped with hydraulic mechanic. The picking aids of light weight will help cutting of peduncle more quicker. Furthermore, the three wheel harvesting vehicle should be tested in harvesting other fruit crops such as rambutan, lyche, durian, sweet tammarind and young coconut and also postharvest trimming of the tree branches.

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