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Field Performance of a Single Chassis Integrated Machine System in Planting Oil Palm Seedlings

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Abstract : Current technique and technology employed for new planting and replanting of oil palms by the plantation industry in Malaysia are very laborious and time consuming. The whole planting operation involves many individual activities that were carried out in a staggered manner within a certain time involving different groups of workers. A single chassis integrated, self propelled, wheeled type machine system has been designed, developed, and tested to overcome such problem in the oil palm plantation. This two-man operation machine system integrates 6 individual activities in the planting operation within a single machine pass. The complete machine system consists of a universal prime mover that carries at the back a transplanter unit having a seedling bin, support sleeves, planting assembly, operator compartment and hydraulic system. Field evaluation and testing with the machine system shows that this mechanized planting system resulted with a planting capacity of 120 seedlings man^{-1} day^{-1} or 0.75 ha man^{-1} day^{-1}, human energy inputs of 7.90 Kcal min^{-1} man^{-1}. Assessment on the planting quality of the planted seedling shows planting success of 99.25±0.28%, leaning angles of 86.04±0.29 degree, spacing deviations of 5±4.14 cm, row alignments of 4.55±0.24 cm, and pulling forces of the planted seedlings of 380.8±23.72 N. As a conclusion, an increased in the planting capacity per man-day of 2.67 times and a reduction of human energy per min-man-day of 2.16 times were obtained with this mechanized system compared to the commonly employed manual method in the oil palm plantation.
Key words : Mechanised planting, seedling planting, planting machine, oil palm cultivation

INTRODUCTION

Oil palm is considered to be an important crop that provides high economic income to Malaysia. Malaysia with Indonesia now stands as the two biggest producers and exporters of palm oil in the world where they account more than 85 percent of world's production. Admittedly, replanting is known to be one of the useful strategies to improve oil palm productivity within an area. Moreover, the replanting program to replace the uneconomical over age oil palms in the plantations could be made effectively by increasing the total production of oil palm seedlings from 82,115,439 seedlings in year 2005 to 86,429,974 seedlings in year 2009 (MPOB, 2010).

Shortages of human labour have been the major treat to the sustainability of the oil palm plantations in Malaysia and the problem has not been solved until today. The total number of foreigners working in the plantation sector in Malaysia is 520,449 which is about 52% of its total workforce in the plantation for the year 2009.

Current technique and technology employed by the oil palm plantation industries in the planting of the oil palm seedling for new planting and replanting are very laborious. The whole planting operations rely us non mechanized and involve different groups of workers and different days for different stage of operations. Pebrian et. al (2010) conducted a study on the human energy in the oil palm cultivation for the purpose of identifying the most critical field and most critical activity within any field operation that need to be prioritized in the mechanized program. They reported that the current employed method of seedling planting in the oil palm plantation required a total 17.10 Kcal min^{-1} man^{-1} human energy which was the highest human energy consumption among other nursery and field operations in oil palm cultivation in Malaysia.

Therefore the present study is aimed to develop a machine system for planting oil seedling under varying terrain topography and evaluate this new mechanized system with respect to its operational time, operator performances and planting quality in an actual field planting operation.

MATERIALS and METHOD

Machine System Design Specifications

The following specifications were considered in founding the overall design of the proposed oil palm seedling planter:

(a) Self-contained unit that could be easily mounted on and dismounted off a universal prime mover
(b) Single chassis machine system that could be easily maneuvered in the current plantation field layout.
(c) Two-man operation system; one for driving the prime mover and one sitting at the back to operate the hydraulic controls of the functional machine parts.
(d) Totally integrated system that is able to adjust the vertical drilling position with respect to terrain slope, prepare the planting hole, deliver the seedling into the prepared hole, cover the seedling in the prepared hole, and compact the soil around the planted seedling.
(e) Reliable machine system that is able to provide high machine field capacity in the seedling planting operation at any terrain conditions.
(f) Precise machine system that is able to give good planting quality on the planted seedlings at any terrain slopes.
(g) Simple in overall design, construction and operation in order to reduce its investment and operating costs.
(h) Robust in overall construction in order to overcome the rough plantation terrain.

Currently, the planting of oil palm seedlings are conducted manually in Malaysia. The preparing of planting hole is either done manually with a hoe or with the use of a mechanized driller. The driller could be a tractor mounted powered digger or a portable powered post hole digger. The actual planting tasks involves, manual placing of the seedling in the prepared hole, covering the seedling in the planting oil with nearby soil manually with a hoe, and compacting the soil around the planted seedling by manually feet stamping or hoe hitting on the soil surface around the planted seedling. This method of planting is known to be very laborious and low in field capacity, especially when the operation has to be done in an extensive scale. For manual method, the planting capacity of planting seedlings is 45 seedlings /man.day (Rankine and Fairhurst, 1999).

Machine System Configuration

The design configuration of the transplanting unit for the proposed mechanized method shown in Figure 1 consists of the Seedling Bin, Support Sleeves, Planting Assembly, Operator Compartment and Hydraulic System. The overall dimensions of the unit are 2800 mm length, 1880 mm width, and 2987 mm height. The unit has been designed for palm seedlings of 12 to 14 months in polythene bag of 28 cm X 36 cm size with a maximum carrying capacity of 28 seedlings per planting trip. The developed transplanter unit as in Figure 2 is mounted on a 4 wheel drive and 4 wheel steer universal prime mover. Detail technical specifications of the complete prime mover are presented in Table 1. The prime mover as described by Pebrian (2011) had been designed to be used individually with other related machine attachments.

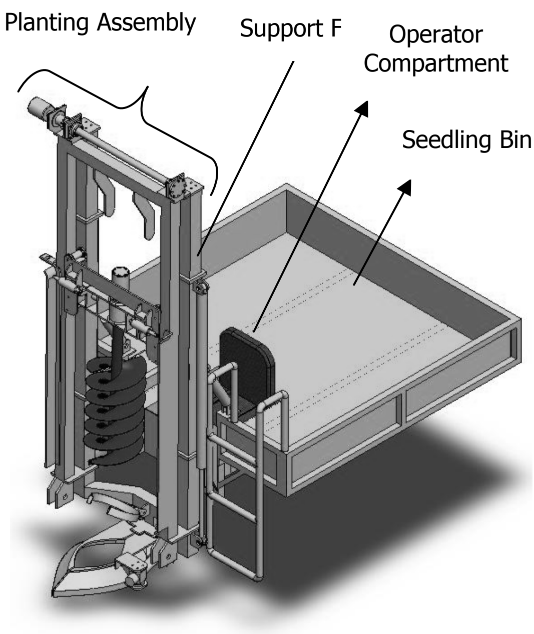

Figure 1. Seedling planting unit

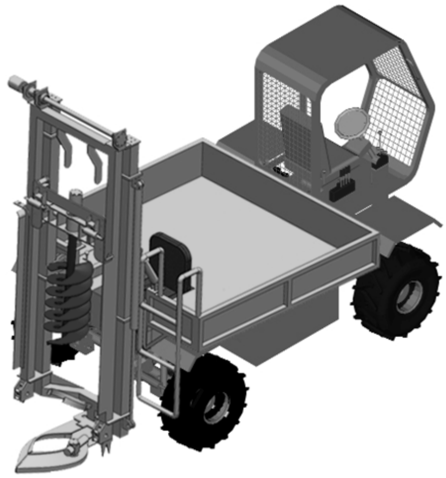

Figure 2. Complete machine system

Table 1. Prime mover technical specifications

Description	Details
Engine	Kubota V3300-E , liquid-cooled, 4-cylinder diesel 50.7 kW @ 2600rpm
Main Pump	Sauer Danfoss 40 Axial Piston 46cm^3/rev @ 210 bar
Auxiliary Pumps	Ronzio-6 Gear 6.28 cm^3/rev @ 300 bar, Ronzio-11 Gear 11.3 cm^3/rev @ 300 bar , and Ronzio-20 Gear 20.1 cm^3/rev @ 200 bar
Motors	Eaton Char Lynn Motor 2000 Axial Piston 46 cm^3/rev @ 205 bar
Axles	Oscillating type with differential ratio 4.875:1
Wheels	Four wheel drive and four wheel steer with Bobcat heavy duty tire 12 ply,12-16.5

Machine System Operations

The operator compartment as in Figure 3 comprises of the seat and the 3 spools control levers for the available hydraulic actuators. The right or left shift on Control Lever No.1 is for the operational control of the auger to rotate in a counter clockwise or clockwise rotation, respectively. The right or left shift on Control Lever No.2 was used for the operational control of the drilling unit to move upwards or downwards while the forward or backward shift is for the operational control of the planting assembly to tilt forward or backward, respectively. Finally, the right or left shift on Control Lever No.3 was used for the operational control of the position of placement-covering unit to move upward and downward while the forward or backward shift was used for the operational control of the clamping jaws to close or wide-open, respectively.

The detailed planting activities with the machine system as indicated in Figure 4, involves adjusting the vertical drilling position with respect to terrain slope, preparing the planting hole, delivering the seedling into the prepared hole, covering the seedling in the prepared hole, and compacting the soil around the planted seedling in the field. In order to initiate the transplanter for the planting operation, the operator first has to push and hold Control Level No.2 using his right hand either forward or backward to tilt forward or backward in order to vertically position the planting assembly with respect to the terrain surface. Once the planting assembly in at vertical position with the terrain surface, the operator has to push and hold Control Lever No.3 using his right hand to reverse position in order to wide-open the clamping jaws of the placement-covering unit. Then the operator pushes and holds Control Lever No.3 with his right hand to leftward position in order to move the placement-covering unit to the reach the terrain surface. Once the placement-covering unit touches the terrain surface, the operator used his right hand to push and hold Control Lever No 2 leftward position in order to move the drilling unit from its initial position downwards while using his left hand to push Control Lever No.1 rightward position in order the auger to rotate in a counter clockwise rotation. The moving and rotating auger stars cutting the soil as the auger bit penetrate into the terrain surface. When the rotating auger reaches to the required planting depth, the operator uses his right hand to push and hold Control Lever No. 2 to rightward position in order to move up the drilling unit back to its initial position and at the same time uses his left hand to push Control Lever No.1 to middle position in order to stop the auger bit from rotating. When the drilling was at its initial position, the operator used his right to push and hold Control Lever No.3 to the forward position to close the clamping jaws of the placement-covering unit. Following that, the operator used his right hand to push and hold Control Lever No.3 to rightward position in order to move up the placement-covering unit until it was at the operator sitting level position. For delivering the seedling into the prepared hole, the sitting operator firstly grabbed one seedling inside the seedling bin using his two hands and placed the seedling on top of the clamping jaw.

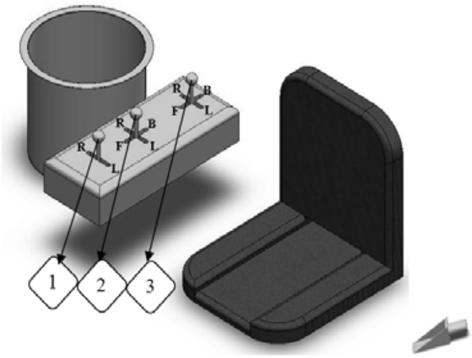

Figure 3. Operator's compartment

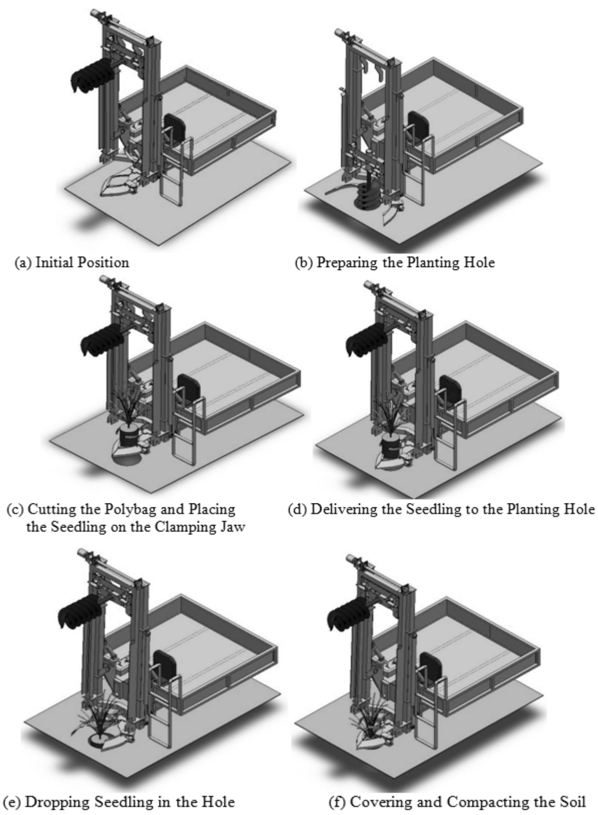

Figure 4. Detailing planting activities

Upon completion, the operator used his right hand to push and hold Control Lever No.3 to leftward position in order to move down the placement-covering unit with the seedling closed to the terrain surface and in-lined with the prepared planting hole. The operator used his right hand to push and hold Control Lever No.3 backward position to wide-open the clamping jaws and this sudden action dropped the seedling into the prepared planting hole.

For covering the seedling in the planting hole and compacting the soil around the planted seedlings, the operator repeatedly to push and hold the Control Lever No.3 forward and reserve positions to repeatedly open and close the clamping jaws in order to cover the seedling in the planted hole and alternately pushed and hold Control Lever No.3 leftward and rightward positions repeatedly to push and lift the clamping jaws of the placement-covering unit in order to compact the soil surrounding the planted seedling. Finally, the operator to push and hold Control Lever No.3 to rightward position in order to move up the placement-covering unit until it back at the operator sitting level position.

Machine Operational Time

Operational time to complete the seedling planting operation with the machine system and the time spend to conduct the various activities within the seedling planting operation by the various components of the machine system was studied.

Time for loading the seedlings into the machine system is the total time for the driver and operator to place 20 seedlings on the seedling bin.

Time for moving to the first planting point is the total time taken by the prime mover to move from seedling supplying point to the first point of planting in the plantation field.

Time for preparing the planting hole is the total time for the auger to rotate while moving the auger penetrates in the soil surface to the required the planting depth, lifting up the auger bit, and finally tilting the drilling unit to its initial position.

Time for applying CIRP fertilizer is the total time for the operator to grab the shovel in the fertilizer plastic container, throw the available fertilizer in the cup into the planting hole, and drop back the shovel into the fertilizer plastic container.

Time for pacing the seedling onto the clamping jaws mechanism is the total time to close the clamping jaws of the placement-covering unit, move up the placement-covering unit until it is at the operator sitting level position, grab the seedling from the seedling bin and place the seedling on the clamping jaws. The clamping jaws are used as the transporting platform before the seedling is dropped into the planting hole.

Time for delivering the seedling into the planting hole is the total time to move down the placement-covering unit with the seedling on top of the prepared planting hole and to wide-open the clamping jaws for dropping the seedling into the prepared planting hole.

Time for covering and compacting the soil around the seedling is the total time to wide open the clamping jaws mechanism and close back the clamping jaws to push the deposited soil around the planting hole to cover and compact the planted seedling.

Time for moving between planting points is the total time for the machine system to move from one planted seedling to the adjacent planting point within the planting row.

Time for turning at headland is the total time for machine system to make turning and entering into the next row planting.

RESULT and DISCUSSION

Figure 5 shows the universal prime mover with the transplanter unit in operation in the plantation field.
Table 2 summarized the details of average times in field planting with the machine system for the first three days of operation. Base on the Duncan test in SAS method (SAS, 2008), Preparing planting hole was categorized under Group No.1 operation which was considered the most time-consuming operation. Following this, covering planted seedling and compacting soil around planted seedling which was under Group No.2 operation was the second most time-consuming operations. The operation times for placing seedlings on clamping jaws mechanism, delivering seedlings inside the prepared holes, and moving between planting points were not significantly different and were categorized under Group No.3 ($P>0.05$). Finally, the least time-consuming operations were loading seedlings into the machine, moving from seedling supplying point to the first planting point, applying CIRP fertilizer into planting hole, and turning at headland.
The operational times for these 4 activities which were categorized under Group No.4 were not significantly different ($P>0.05$). The average total operation time for planting of 20 seedlings with machine system was calculated to be 2636 seconds or 44 minutes.

Figure 5. Machine system in operation

Planting Quality

Table 3 shows the Percentage of Planted Seedlings, Leaning Angles of Planted Seedling, Spacing between Planted Seedlings, and Row Alignment Seedling. The planted oil palm seedlings were considered under upright category based on the three oil palm leaning categories by Mohd Tayeb et al. (1997).

Table 4 presents the result of the pulling forces of planted seedlings with machine system. The surrounding soils around the planted seedlings were able to be compacted consistently.

Table 5 presents the average human energy consumption for operator and driver for the duration period of 3 days. The average total human energy input for planting 20 seedlings was 7.90 Kcal/min. man.

CONCLUSIONS

Field evaluation and testing with the oil palm seedling planting machine shows that the mechanized planting system has a planting capacity of 120 seedlings $man^{-1}day^{-1}$or 0.75 ha $man^{-1}day^{-1}$, human energy inputs of 7.90 Kcal min^{-1} man^{-1}. Assessment on the planting quality of the planted seedling showed a planting success of 99.25±0.28%, leaning angles of 86.04±0.29 degree, spacing deviation of 5±4.14 cm, row alignment 4.55±0.24 cm, and pulling forces of the planted seedlings to be 380.8±23.72 N. As a conclusion, this proposed mechanized system has a planting capacity of 2.67 times greater and human energy inputs of 2.17 times lesser than the currently employed manual system in the oil palm plantation in Malaysia.

Table 2. Machine operational time for 20 seedlings in 3 days

Activity	No. of Days	Time[1], sec	Group	Total Time ,%
Loading seedlings onto machine system	3	98.33^{d}	4	3.73
Moving from supplying point to first planting point	3	8.75^{d}	4	0.33
Preparing planting hole	3	1057.5^{a}	1	40.12
Appling CIRP fertilizer into planting hole	3	116.5^{d}	4	4.42
Placing seedlings on clamping jaws mechanism	3	277.83^{c}	3	10.54
Delivering seedlings inside the prepared holes	3	239^{c}	3	9.07
Covering planted seedling and compacting soil	3	480.17^{b}	2	18.22
Moving between planting points	3	317.88^{c}	3	12.06
Turning at headland	3	40.13^{d}	4	1.52
Total operational planting time	3	2636.09	-	100

[1]Means with same letters not significantly different at 0.05 probability level.

Table 3. Planting quality

Day No.	Planting Row No.	Percentage of Planted Seedlings,%	Leaning Angles of Planted Seedling, Degree	Percentage of Leaning Categories 0-30°	31-60°	61-90°	Spacing between Planted Seedlings, cm	Row Alignment Seedling, cm
1	1	100	88.4±1.1	0	0	100	855±6.90	6.21±4.12
	2	100	88.1±1.5	0	0	100	855±8.55	6.58±5.89
	3	97	88.3±0.6	0	0	100	852±6.69	3.50±3.72
	4	100	87.7±2.5	0	0	100	855±8.22	5.58±4.49
2	1	100	80.6±4.2	0	0	100	856±7.13	4.90±3.61
	2	100	85.2±2.5	0	0	100	854±9.61	2.00±2.91
	3	97	84.6±3.2	0	0	100	854±6.89	2.57±2.41
	4	100	81.5±1.6	0	0	100	851±9.00	4.83±2.97
3	1	100	87.5±2.1	0	0	100	854±3.82	3.86±3.76
	2	100	86.4±2.3	0	0	100	855±3.50	5.67±4.31
	3	100	87.3±1.6	0	0	100	853±6.98	4.43±3.52
	4	97	86.9±1.8	0	0	100	859±6.88	4.50±2.62
	No. of samples	90	90	-	-	-	90	90
	95% CI	99.25±0.28	86.04±0.29	0	0	100	855±4.14	4.55±0.24

Table 4. Pulling force of planted seedling with machine system

Parameter	No. of Sample	95% CI
Pulling Force	20	380.8±23.72

Table 5. Average heart beat rate and human energy

Activity	Energy, Kcal $min^{-1}man^{-1}$	Average Heart Rate, beat min^{-1}	Category of work
Driver of machine system	1.66	94	Light
Operator of machine system	6.24	111.31	Moderate

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