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The Performance of Pivot-Type Trailer for Fresh Fruit Bunches Transport Equipment Using Two-Wheeled Tractors in Oil Palm Fields

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ABSTRACT

Poor farmers in Indonesia still transport palm fruit bunches manually, so they require a lot of manpower and many of them are transported for a long time, reducing quality. Oil palm farmers have two-wheeled tractors that are used for processing rice fields that can be used for towing trailers. The existing conventional trailers do not work optimally in oil palm fields, so it is necessary to design a pivot type trailer. The purpose of this study was to see the performance of the pivot type trailer for transporting oil palm fruit bunches, the pivot type trailer and the conventional one that was tested directly on the farmers' oil palm fields involving 3 operators. The results show that the pivot type trailer has an advantage over conventional trailers and is easy to operate properly, this is reflected in its very small turning radius of 260 cm unloaded and 280 cm loaded, and has a larger working capacity.

1. INTRODUCTION

The traditional transportation that is often used to transport oil palm by farmers in Indonesia is wheelbarrow, but this type of transportation is often constrained by the difficulty of mobilizing on sloping land. Freight using wheelbarrow has a smaller capacity and the movement is fully human. The research to develop a calculation model which can be used as a base of transportation truck management system, especially truck departure has been carried out by Krisdiarto *et al.* (2019) and Nasution (2018), stated that there was not correlation between FFB (fresh fruit bunch) weight and load transportation time, so this method may be used as a decision support system in optimizing FFB transportation. Effectiveness is determined by the transport capacity, the transport load approaching the capacity of the conveyance is more efficient than the load carried less than the carrying capacity (Rifaldi *et al.*, 2018).

Hand tractors or two-wheeled tractors are very widely used by farmers in Indonesia for land cultivation in lowland rice cultivation because of several advantages including the low price so that it is affordable for farmers, easy operation because it is in accordance with the anthropometry of the average farmer's body, and the operating costs are not too high because of its relatively smaller oil consumption (Dhafir *et al*., 2021). The use of two-wheeled tractors for land cultivation for lowland rice plants is only done twice a year and is used only for two months in a year so that two-wheeled tractors do not spend much time. Two-wheeled tractor power can be used for other purposes such as towing haul trailers. The use of two-wheeled tractors as trailer towers has begun to be carried out but its use for the transportation of oil palm fresh fruit bunches (FFB) is still not done because the operation of an ordinary trailer-towed two-wheeled tractor is very difficult, especially in the turning process and on sloping land (Nafchi *et al*., 2011; Raskarowana, 2016). Transport of FFB on sloping land is a very common problem for Indonesian oil palm farmers, so that farmers in some cases will leave the oil palms on valley land for a long time.

The problem of transportation on sloping land can be overcome by designing a transport tool that is suitable for the designation on sloping land that is able to move dynamically and stably in an inclined position (Cebro, 2019). Research by Dhafir et al. (2019) regarding the design and application of a pivot-type trailer on two-wheeled tractors to make it easier. In operating it, the operators have made transportation tools on sloping land by utilizing two-wheeled tractors which have only been used for plowing the fields (Hermawan *et al*., 2001; Idkham *et al*., 2018), while when the work in the fields ends, the two-wheeled tractors are mostly idle or not in use. The design of this transport tool is very suitable for transporting FFB on sloping land because the original design was for this purpose.

This pivot type trailer has never been tested directly on oil palm land, so its performance is not known and any problems that may arise in the field. The purpose of this study was to analyse the performance of a two-wheeled tractor coupled with a pivot-type trailer in transporting fresh palm fruit bunches both on flat land and on sloping land, another goal is to see the problems that occur during the operation of a pivot-type trailer in oil palm land.

2. MATERIALS AND METHODS

This research was conducted from March to December 2020, making a prototype of a pivot type trailer at the Workshop Laboratory of the Agricultural Engineering Study Program, Syiah Kuala University. Tool testing was carried out at smallholder oil palm plantations in Aceh Besar District, Aceh Province. Meanwhile, data processing is carried out at the Laboratory of Agricultural Equipment and Machinery, Universitas Syiah Kuala.

The two-wheeled tractor used is the Yanmar model YZC-L, TF 105-di power 8.5 HP, dimensions 2640 mm long, 765 mm wide, 1060 mm high, 251 kg trailer weight and 840 mm tractor tread distance. The trailer used is a conventional trailer assembled with a length of 1200 mm, a width of 900 mm, a height of 800 mm, a trailer wheel distance of 1080 mm and a pneumatic wheel size of 175/70 R13, a cage wheel with a wheel tread of 70 cm, a groud clearance of 20. cm, wheel diameter 60 cm. The prototyping of the pivot type trailer was carried out in the workshop with the necessary materials, namely ASTM 36 hollow iron, S45C shaft iron, ASTM 36 iron, ST 37 angle iron, bolts and nuts. Tests use instruments and measuring instruments such as: camcorders, meters and calipers, as well as an 18 MP digital camera.

2.1. Pivot Type Trailer Prototype

The prototype pivot type trailer is shown in Figure 1. The main components are: a) the front link frame is made of hollow box steel, b) operator footrest, c) operator seat, d) auxiliary wheel equipped with spring mechanism, and e) connecting pivot.

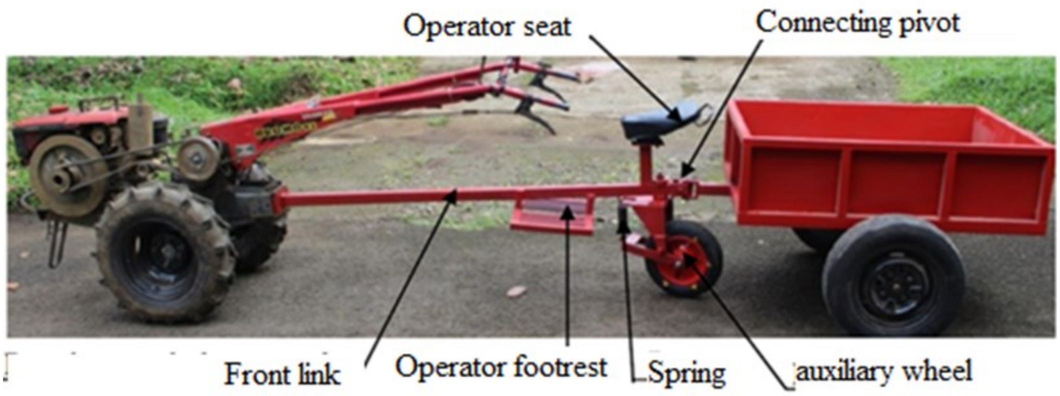

Figure 1. Pivot type trailer prototype

2.2. Pivot Type Trailer Functional Testing

The results of functional testing show that each component of the coupling system is functioning properly according to the planned mechanism (Table 1) and method of Nugroho (2013). However, some modifications are required for sloping land as follows:

Table 1. Functional performance of each component of the trailer coupling system

No.	Component Name	Functional Mechanism
1	Pivot system	Good
2	Trailer connection frame	Good
3	Operator's seat	Good
4	Operator's footrest	Good
5	Auxiliary wheel	Good
6	Spring	Good
7	Hook and pin holes	Good

Modification-1

At the beginning of the test, on the sloping land the trailer is at risk of overturning, especially with extreme slopes, therefore a tilt barrier that is not dangerous to the operation is needed. Modifications made are adding a holding system to the pivot so that the tipping of the trailer is limited to safe conditions (Figure 2).

Modification-2

From several tests, it is found that the turning ability of wheeled tractors using a pivot type trailer on a sloping land still has limitations under certain conditions. Therefore we need a mechanism to assist the deflection. The mechanism that can be done is by sliding / moving the auxiliary wheel with the operator's feet. The second modification that can be made is to add a control rod to the auxiliary wheel, this control rod functions to control the assist wheel when the tractor and trailer are operated using the operator's feet (Figure 3).

Figure 2. Pivot modification

Figure 3. Modification of auxiliary wheels

The two modifications have made the pivot type trailer design performance better. In the operation of trailer coupling on a two-wheeled tractor, when the operation becomes more stable and the trailer does not tumble again and the auxiliary wheel turns properly.

The subjects used in this study were two-wheeled tractor operators consisting of 3 (three) adult males. The selected operator sample (Table 2) is close to secondary anthropometric data from Indonesian society, these samples can also represent the three percentile operators, namely the 5, 50 and 95 percentiles. The operating conditions of the trailer in this study are (1) trajectory: flat, sloping 10^{O}, sloping 30^{O}; (2) operation: straight, turn 45^{O} and turn 90^{O}; (3) trailer load: empty and full load; (4) tractor forward speed: 4 and 6 km/h. The performance tests carried out are as follows:

a) Two-wheel tractor and trailer stability. Observations were made by taking videos of the operation of two-wheeled tractors and trailers, namely (1) on the track conditions: flat, 10^{O} inclined, 30^{O} inclined; (2) under operating conditions: go straight, turn 45^{O} and turn 90^{O}; (3) when the trailer load is empty and full, the forward speed of the tractor is 4 km/h (slow) and 6 km/h (fast) (McAtamney & Corlett, 1993).

b) Turning radius is the smallest circle radius that can be made by two-wheeled tractor and trailer when turning. The radius is measured from the center of the axle of the tractor to the center of the curve of the two-wheel tractor when turning (Setyanto *et al*., 2015, Syuaib *et al*., 2015 and Syuaib, 2015). Setiawan have designed a power train that is useful for transporting agricultural products on poor road conditions. The smallest 180° turning radius is 3.5 m at 3500 rpm engine speed which occurs when the vehicle is not loaded (Setiawan *et al*., 2019).

c) Work Capacity, measured by how much FFB the trailer can carry in each unit of time. Work capacity is the ability of a tool to do its work. The higher the working capacity, the better the tool performance. The effective capacity of the tool is the amount of weight transported in the time required to carry the load (Fadhil & Lubis, 2015).

Table 2. Dimensions and weight of oil palm FFB in the test plantations

Notation	Clarification
A1, B1, C1	Trailer Pivot, flat ground, empty load and low speed
A2, B2, C2	Trailer Pivot, flat ground, empty load and high speed
A3, B3, C3	Trailer Pivot, flat ground, full load and low speed
A4, B4, C4	Trailer Pivot, flat ground, high speed full load
A5, B5, C5	Trailer Pivot, 10^o slope, empty load and low speed
A6, B6, C6	Trailer Pivot, 10^o slope, high speed empty load
A7, B7, C7	Trailer Pivot, 10^o slope, full load and low speed
A8, B8, C8	Trailer Pivot, 10^o slope, high speed full load
A9, B9, C9	Trailer Pivot, 30^o slope, empty load and low speed
A10, B10, C10	Trailer Pivot, 30^o slope, high speed empty load
A11, B11, C11	Trailer Pivot, 30^o slope, full load and low speed
A12, B12, C12	Trailer Pivot, 30^o slope, high speed full load
AA1, BB1, CC1	Conventional Trailer, flat ground, empty load and low speed
AA2, BB2, CC2	Conventional Trailer, flat ground, empty load and high speed
AA3, BB3, CC3	Conventional Trailer, flat ground, full load and low speed
AA4, BB4, CC4	Conventional Trailer, flat ground, high speed full load
AA5, BB5, CC5	Conventional Trailer, 10^o slope, empty load and low speed
AA6, BB6, CC6	Conventional Trailer, 10^o slope, high speed empty load
AA7, BB7, CC7	Conventional Trailer, 10^o slope, full load and low speed
AA8, BB8, CC8	Conventional Trailer, 10^o slope, high speed full load
AA9, BB9, CC9	Conventional Trailer, 30^o slope, empty load and low speed
AA10, BB10,CC10	Conventional Trailer, 30^o slope, high speed empty load
AA11, BB11, CC11	Conventional Trailer, 30^o slope, full load and low speed
AA12, BB12, CC12	Conventional Trailer, 30^o slope, high speed full load

Note: A is operator A, B is operator B and C is operator C

3. RESULTS AND DISCUSSION

3.1. Land Conditions

The research was carried out on smallholder oil palm lands with a land area of 50 ha. This land was chosen as the test site because it has various land conditions that represent the conditions of oil palm land in the Indonesian community. so that testing of the tool can be carried out on various land conditions on flat land, a slope of 10^o, and a slope of 30^o.

3.2. Characteristics of Palm Fresh Fruit Bunches

The planting age of the oil palm plantations used in testing this conveyance is 10 years, the average weight of FFB is around 17 kg, the fruit is smaller in size because some of it is produced from embedded plants in the planting process because someone died. The average dimensions and weight of oil palm FFB produced in the tested plantations can be seen in Table 3.

Table 3. Dimensions and weight of oil palm FFB in the test plantations

No	Diameter (m)	Length (m)	Volume (L)	Volume (m^3)	Weight (kg)
1	0.3	0.4	28.3	0.0283	25.3
2	0.2	0.31	9.2	0.0092	7.9
3	0.18	0.3	7.5	0.0075	5.1
4	0.22	0.35	15.1	0.0151	22.4
5	0.2	0.34	14.2	0.0142	21.5
6	0.25	0.37	22.5	0.0225	23.3
7	0.26	0.37	24.1	0.0241	24
8	0.2	0.28	13.7	0.0137	12
9	0.22	0.3	15.4	0.0154	14
10	0.2	0.27	11	0.011	9
11	0.21	0.37	17.2	0.0172	15
12	0.17	0.28	12.3	0.0123	13
13	0.16	0.3	13	0.013	14

3.3. Pivot Type and Conventional Trailer Performance Testing

Performance tests have been carried out in oil palm fields using pivot type trailers and conventional trailers (Figure 4) in flat and sloping land conditions, each with three different operators. The test is also carried out on a straight and a turn (Figure 5).

(a) (b)

Figure 4. Testing using tire wheels: (a) pivot type trailer, (b) conventional trailer

(a) (b)

Figure 5. Testing on the track: (a) straight, (b) turn

3.4. Turning Radius

The results of the two-wheel tractor turning radius test with a conventional and pivot-type trailer system for tire wheels can be seen in Figure 6 and notation in Table 2. It can be seen that the pivot-type trailer system can shorten the turning radius of a two-wheeled tractor for various variations of speed and load. From the test results, the turning radius at slow speed for conventional trailers can be obtained a turning radius of 405 cm for empty loads and 410 cm for full loads. Furthermore, in the test turning radius at speed 2 (fast) can be seen in Figure 7, for conventional trailers the turning radius can be 370 cm for empty loads and 435 cm for full loads. Then the turning radius test at slow speed for the pivot trailer can be 260 cm at empty load and 280 cm at full load. And finally testing the radius of turning at full speed at 265 cm for empty loads and 275 cm for full loads. With the shorter turning radius on the pivot-type trailer, the coupling system can be more agile and easy to traverse in fairly sharp or narrow turns. According to Dhafir *et al*., (2019), testing on flat land and agricultural land shows that the turning radius of a two-wheel tractor with a pivot type trailer is 2.18 m – 2.82 m, better than the conventional system, which is 3.72 m – 4.03 m, Radzi stated that a shorter turning radius can improve the maneuverability of tractors and trailers, which are capable of maneuvering in sharp and narrow turns (Radzi *et al*., 2020).

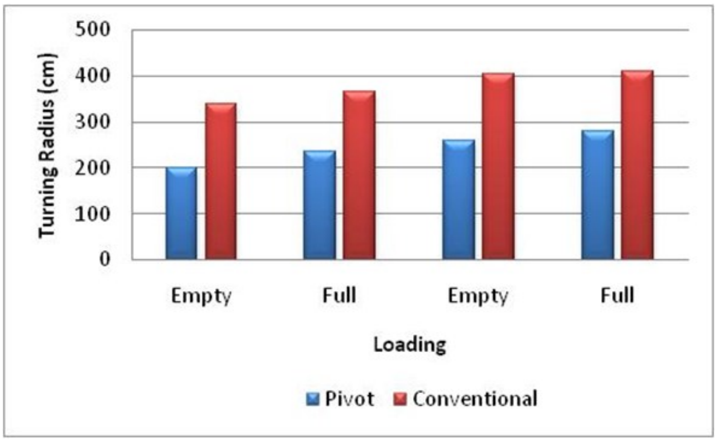

Figure 6. Slow speed tire wheel turning radius

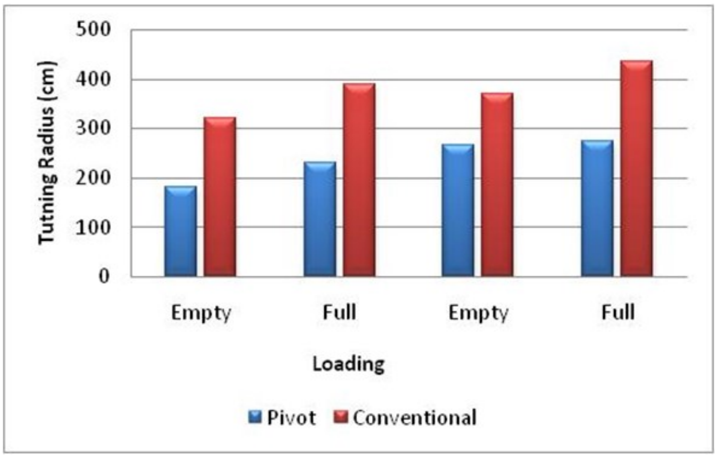

Figure 7. Fast speed tire wheel turning radius

In conventional trailers the operator's ability to control the turning operation is very limited, while in pivot type trailers the operator's ability to control is better during turning. This results in a smaller turning radius on the pivot type trailer compared to the conventional type trailer at both full and empty loads and at slow speeds and fast speeds.

3.5. Working Capacity

Work capacity is the ability of a tool to do its job. The higher the working capacity, the better the performance of the tool. The full load on the tested trailer has a total weight of 206.5 kg or as much as 13 pieces of palm FFB. The results of the tool work capacity testing on the transport of palm FFB are shown in Figure 8.

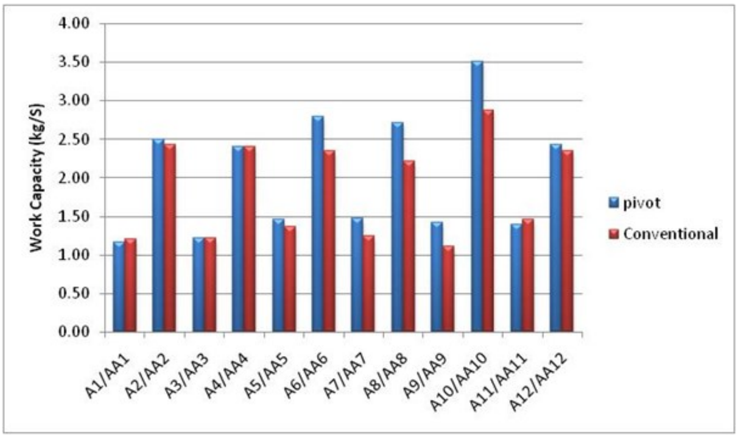

Figure 8. The working capacity of pivot and conventional trailers on various slopes of land with operator A.

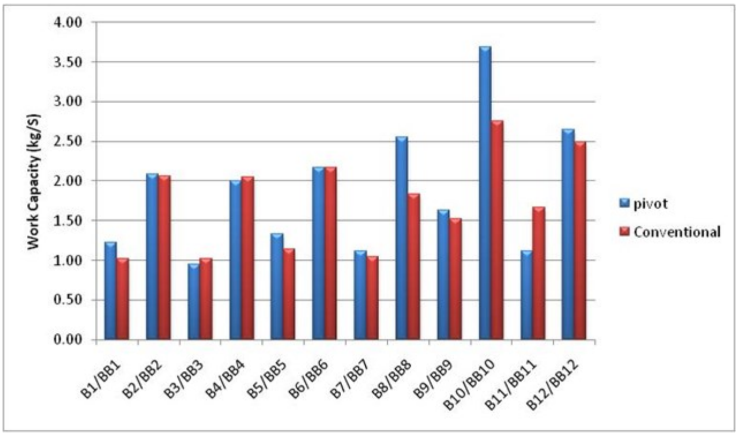

Figure 9. The working capacity of pivot and conventional trailers on various slopes of land with operator B

The average working capacity generated by the pivot trailer controlled by operator A shows a better trend compared to conventional trailers, this is due to the less time required to operate the pivot type trailer, which is made possible by the smaller turning radius which results in capacity better pivot trailers. Then the test controlled by operator B has the same trend as operator A. Figure 9 shows that the average working capacity generated by the pivot trailer is also better than that of conventional trailers.

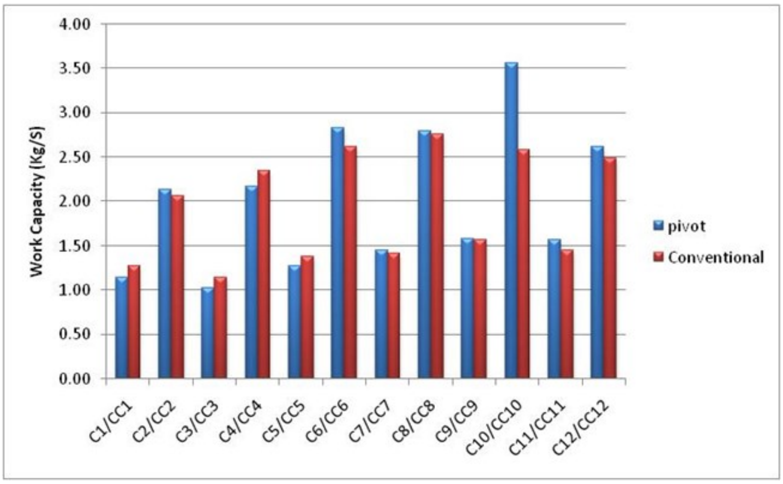

Figure 10. Working capacity of pivot and conventional trailers on various slopes of land with operator C

Furthermore, Figure 10 shows that the test controlled by operator C have the average working capacity generated by the pivot trailer is also better than that of conventional trailers, except in the condition of the pivot trailer full load (full) flat land and sloping land 30^0. The results show that the performance of the pipet-type trailer looks better than the conventional trailer, as said by Nugraha, (2013) telah merancang angkong bermesin untuk pengangkutan TBS sawit, hasil menunjukkan bahwa penggunaan angkong bermesin telah meningkatkan kapasitas pengangkutan dan kecepatan maju angkong dibandingkan dengan tanpa bermesin.

4. CONCLUSION

1. The average weight of oil palm FFB in oil palm plantations with a plant age of 10 years is 17 kg with an average volume of 0.02 m3. The condition of the contours of the oil palm plantations where the test was conducted was varied with a slope of 5 degrees to 45 degrees and some parts were flat.
2. Two-wheel tractors with pivot-type and low-speed mating systems have a turning radius of 260 cm for empty and 280 full loads while conventional low-speed trailers have a turning radius of 405 for empty and 410 cm full. At high speed the turning radius of the pivot type trailer is 265 at empty load and 275 at full load while conventional trailers have a turning radius of 370 at empty load and 435 at full load, the resulting turning radius on the cage wheel shows the same tendency where the pivot type trailer has a radius smaller turns which means pivot type trailers show better performance in turning and turning.
3. The working capacity controlled by the three operators using tire wheels at high speed or low speed for the pivot trailer is better than conventional trailers, this is because the time needed to operate the pivot trailer is less.

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