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Effect of Forward Speed and Drive Wheel on the Performance of a Semi-Automatic Cassava Planter

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Abstract

An experiment to determine the effects of the forward speed and type of wheel on the performance of a semi-automatic cassava planter was carried out at the Federal University of Technology Akure, Nigeria. Tractor forward speeds of 1.5, 1.8, 2.1, 2.3 and 2.6 km/h were used at a constant soil depth of 100 mm on a well prepared sandy clay loam soil. The field performance of the planter was determined using standard equations. A quadratic relationship was observed between the forward speed and germination percentage varying between 77.78 and 85.19%. It was also found that the effective field capacity increased with an increase in the forward speed in the pneumatic and rigid wheel experiments. The efficiency decreased with an increase in the forward speed in the two experiments at 100% cutting efficiency at all the forward speeds. Field performance of 97.20% field efficiency was achieved at a forward speed of 1.5 km/h and when the planter was operated with rigid wheels. The effect of the forward speed on the performance of the planter is significant ($P<0.05$). The results suggest that the planter should be used with the rigid wheels at an optimum forward speed of 1.5 km/h.

Keywords: Forward speed, wheel type, cassava stem planter, planting, performance

1.0 Introduction

Various soil types and ecologies support the growth of cassava. According to Oliver *et al.* (2017), cassava originated in Brazil and Paraguay. It can be grown either on its own or together with a variety of other crops, including maize, groundnuts, vegetables, and rice. According to Anike (2018), cassava stakes may be planted on unploughed land 1–2 m apart using a minimum tillage technique. Cassava roots can be harvested 9 – 18 months after planting. A yield record between 8 and 15 tonnes of cassava roots per hectare of land planted exclusively with cassava under traditional farming practices (FAO, 2013a). According to reports, Nigeria produces 46 million tonnes of cassava, making it the world's largest producer (FAO, 2013b).

Cassava has long played the role as a famine-reserve crop due to its ability to withstand infertile soils, drought, and uncertain rainfall, coupled with the possibility to delay harvest of tubers until needed (James and David, 2021). Cassava starch is an ingredient in the manufacture of dyes, drugs, chemicals, carpets and coagulation of rubber latex (Adetunji *et al.,* 2013).

Cassava grows well in various soil types and ecologies. It can be grown either on its own or together with a variety of other crops, including maize, groundnuts, vegetables, and rice. Cassava cultivation from land preparation to harvesting requires about 75 – 125 persons per hectare. Cassava production depends on a supply of quality stem cuttings. Production of cassava is dependent on a supply of high-quality stem cuttings. When compared to grain crops that are propagated by seeds, planting materials have a very low rate of multiplication (IITA, 2009). It was reported by Tarawali *et al*. (2013) that mechanical planting is faster and 50 % less expensive than planting by hand.

Majority of planting is done by hand in a slanting position at an angle of 45^o when the soil is fairly dry to promote the formation of compactly arranged roots; in a horizontal position when the soil is dry to increase stem production and in vertical position when planting is done during the wet season to produce deeper lying storage roots for anchorage, making sure that at least two-thirds of the cutting length is buried or covered with soil (Oyedeji *et al*., 2011). Correct application of production inputs for sustainability of agricultural production is a key requirement to successful crop production (Soyoye, 2020). Horizontal planting of cassava produces more yields when compared to the vertical planting of cassava and minimizes the production cost when it comes to harvesting (Danao *et al*., 2015).

Soyoye (2018) developed and evaluate the performance of a self-propelled instrumented motorized multi-grain crop with planter with field efficiency and field capacity of 98 % and 0.28 ha/hr. Ale and Manuwa (2020) developed a semi-automatic cassava planter that was found suitable at a functional efficiency of 94.5% for stem picking, stem cutting as well as planting in a single operation. The development of the planter was aimed at reducing the cost of planting by eliminating the extra labour required behind the tractor by the presently available commercial cassava planter. A rotary dibble-type cassava planter operating at 0.5 m/s and planting rate of 95% was developed by Fengguang *et al*. (2021).

Average field capacity and field efficiency of 0.135 ha/h and 65.3%; average germination percentage of 90% and Fuel consumption between 19.9 and 24.2 L/ha were recorded in field performance evaluation of a cassava planter developed by Lungkapin *et al*. (2009) when three forward speeds of 1.7, 2.0 and 2.4 km/h were used. The study by Oyedeji *et al*. (2011) revealed that a cassava planter operated at a forward speed of 4.24 km/h gave a field capacity of 0.28 ha/h and a field efficiency of 73.1%. Forward speed ranging between 2.16 and 3.12 km/h were used by Kamal and Bamgboye (2019) in the development of a metering device for a two-row single feeder cassava planter, but operating speed ranging between 2.16 and 2.64 km/h were reported as the convenient speed of operation that did not result to skipping of stems. Forward speed between 1.5 km/h and 2 km/h were respectively recommended for 1 or 2-row picker-pin planter and 1 or 2-row hand fed planter for optimum performance by Ademosun (1986). No influence was found by Bellé *et al*. (2014) and Gassen *et al*. (2014), when evaluating hoe-type openers for soil scarification. Francetto *et al*. (2015) did not also find any influence of operating speed when analyzing the performance of furrow openers of planters.

The majority of scientific information sources have noted that the tire-soil interface wastes between 20 and 55 percent of the tractor power that is available. This energy depletes the tyres and compacts the soil to an extent that could be harmful to crop growth. (Algirda *et al*., 2018). Efficient operation of agricultural tractors include selecting an optimum operating speed for a given tractor-implement unit; maximizing the tractive advantage of the traction devices, and reducing the drive wheel slippage (Moitzi *et al*., 2013). As the performance of soil engaging machines like planters varies with operating parameters like the forward speed, drive wheel and soil characteristics and the soil itself differs from one place to another, this study therefore focused on the relationship between tractor forward speed, drive wheels and the performance of a cassava planter.

2.0 Methods and Procedures

2.1 Experimental Location

The experiment was carried on the Teaching and Research Farm of Federal University of Technology, Akure, Nigeria located on latitude 7°10' N and longitude5°05' E. The soil of the study area is a sandy clay loam soil according to USDA textural classification of soil.

2.2 The Semi-Automatic Cassava Planter

The components of the cassava planter as presented in Figure 1 include a hopper, a roller-picker, cutting unit, a belt conveyor for metering, a double-disc furrow opener, a double-disc furrow coverer, a transmission system, the frame and the land wheels. The planter is powered by a 41-horsepower (30.6 kW) tractor.

Figure 1: The Semi-Automatic Cassava Planter Coupled to the Tractor

1. Tractor Operator
2. Tractor
3. Hopper
4. Chain & Sprocket
5. Frame
6. Land Wheel
7. Furrow Closing Device

2.3 Land Preparation and Soil Measurements

The soil was well ploughed and harrowed in preparation for the evaluation test. The drive system is a 36 kW and 4 wheel drive tractor. Soil samples were collected from the depth of 0-5, 5-10 and 10-15 cm by the use of a core sampler of 5.8cm diameter and 5cm height. The core sampler was driven into each depth of the soil and the soil sample collected was kept in an air tight polythene bag to prevent moisture loss. The soil sample was weighed using an electonic weighing balance (Superior Mini-Digital Platform Scale- China). The bulk density was determined using the standard equation; the soil textural classification(particle size) was determined using hydrometer method while the moisture content of the soil was taken using a soil moisturemeter at the soil depth of 5, 10 and 10 cm.

2.4 Evaluation Test

The evaluation test to determine the effect of the tractor forward speed and the type of wheel on the performance of the planter is presented in 2.3.1 and 2.3.2.

2.4.1 Determination of the Effect of Tractor Forward Speed on the Field Performance of Cassava Planter

To determine the effect of forward speed of the tractor on the field performance of the cassava planter, five forward speeds of 1.5, 1.8, 2.1, 2.3 and 2.6 km/h were used to drive the planter on the tilled soil at the furrow depth of 100 mm for rigid wheel (Figure 2) and pneumatic wheel experiments (Figures 3). The tractor speeds were selected as required of a cassava planter (Ademosun, 1986). The planter was operated to plant cassava along a row of 39 m and the time taken to cover the said distance was taken using a stop watch. The field performance of the planter which are the Theoretical Field Capacity (TFC), the Effective Field Capacity (EFC), the Field Efficiency (FE) and Cutting Efficiency are determined using Equations 1, 2, 3 and 4 as expressed by Mohamed *et al.* (2017) and Ikejiofor and Okwesa (2013).

Theoretical field capacity, TFC (ha/h)

$$TFC = \frac{Forward\ Speed\ \times\ Width\ of\ the\ lanter}{10} \qquad (1)$$

Effective field capacity, EFC (ha/h)

$$EFC = \frac{Area\ Covered}{Time} \qquad (2)$$

Field efficiency, FE (%)

$$FE = \frac{EFC}{TFc} \times 100 \qquad (3)$$

Cutting efficiency, E$_{f}$ (%)

$$E_f = \frac{T - X}{T} \times 100 \qquad (4)$$

Where T is the total number of stakes cut and X is the number of non-viable stakes

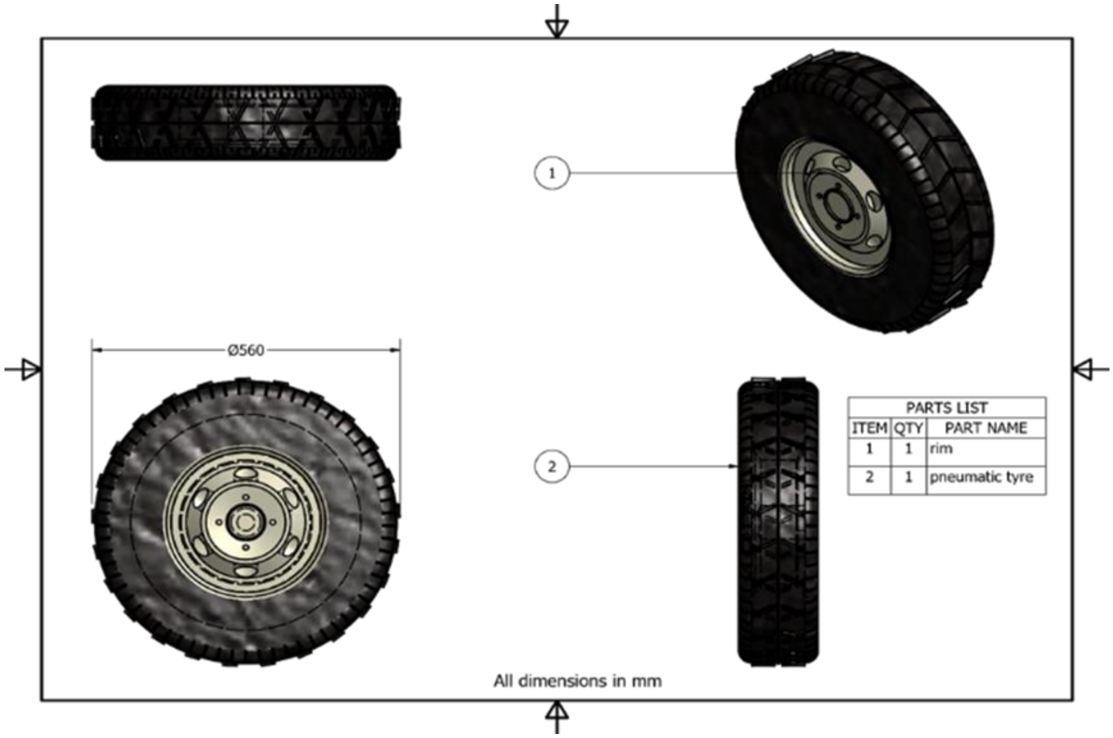

Figure 2: Schematic View of the Pneumatic Wheel

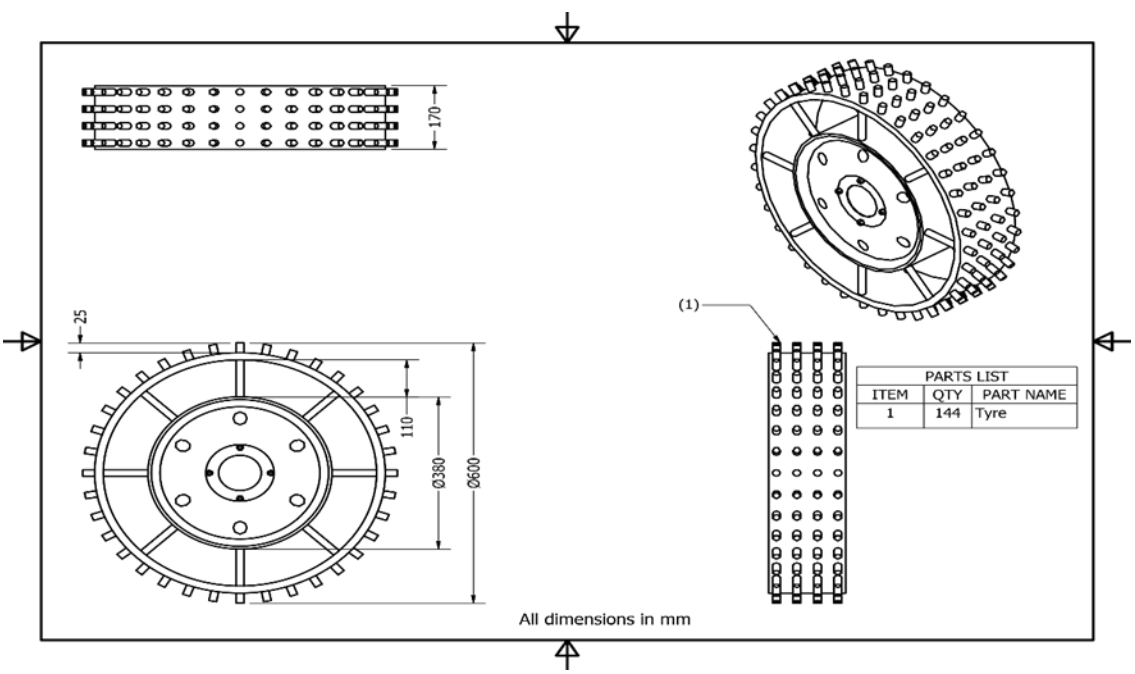

Figure 3: Schematic View of the Rigid Wheel

2.3.2 Determination of the Effect of Tractor Forward Speed on the Germination Percentage

The number of stakes planted was counted based on the number of stems used per row. The number of stakes that germinated was also counted after thirty days of planting. The points at which there was no germination was noted. The germination percentage was therefore determined using Equation 5 as adapted from Agidi *et al*. (2017). This procedure was used for all the forward speeds (1.5, 1.8, 2.1, 2.3 and 2.6 km/h) used for this evaluation test.

Germination percentage Gp (%)

$$G_p = \frac{S_g}{S_p} \times 100 \qquad (5)$$

Where;

S_g is Number of germinated stakes (number),

S_d is Number of planted stakes (number).

3.0 Results and Discussion

3.1 Effect of Tractor Forward Speed on Germination Percentage

The percentage of germination was determined thirty days after the planting operation and the evaluation test revealed as presented in Figure 4 that the germination percentage increased with an increase in the forward speed of the tractor but later decreased with further increase in the forward speed. This polynomial relationship with coefficient of determination r^2 of 0.9555 also indicated that the average germination percentage of 83.33%, 85.19%, 85.19%, 84.61% and 77.78% did not depend on the tractor forward speed because the variations in the result were not so much significant. This is in conformity with Lungkapin *et al*. (2009) in the study on the design and development of a cassava planter. The germination percentage was affected by termite infection of the soil in the location of the experiment.

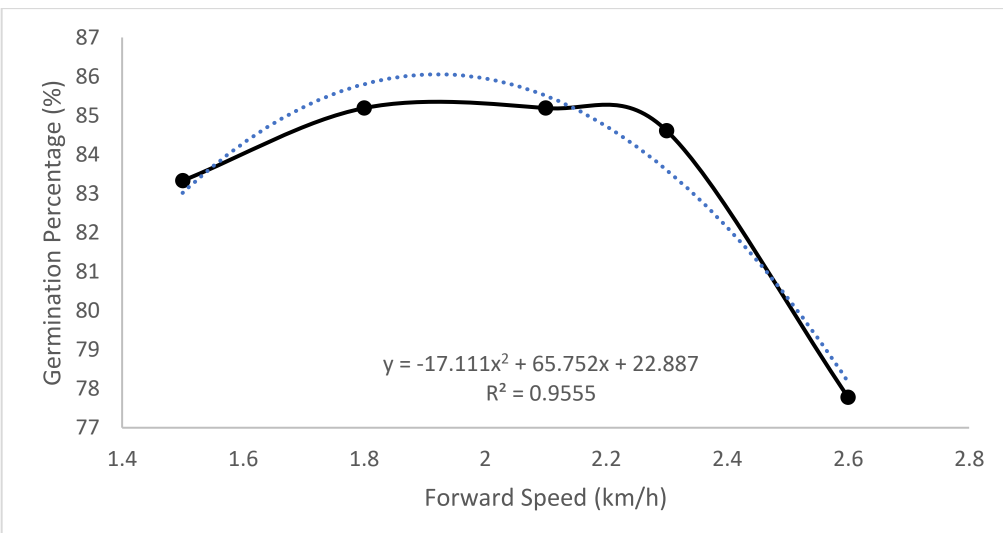

Figure 4: Effect of Tractor Forward Speed on Germination Percentage

3.2 Effect of Tractor Forward Speed on Field Capacity of the Planter

The effect of tractor forward speed is presented in Figure 5. The result of the evaluation test showed that the effective field capacity which is the actual field capacity increased with an increase in the tractor forward speed in both the pneumatic and the rigid wheel experiments in a linear relationship with respective coefficient of determination r^2 of 0.9969 and 0.9688 for the rigid and pneumatic wheel experiments. This is in agreement with Lungkapin *et al*. (2009) and Mohamed *et al.* (2017). As presented in Figure 5, higher effective field capacity was recorded in the rigid wheel experiment than the pneumatic wheel. The average effective field capacity of the planter varied from 0.1182 to 0.1608 ha/h in the rigid wheel experiment and 0.1122 to 0.1405 ha/h in the pneumatic wheel experiment at the forward range of 1.5 km/h to 2.6 km/h.

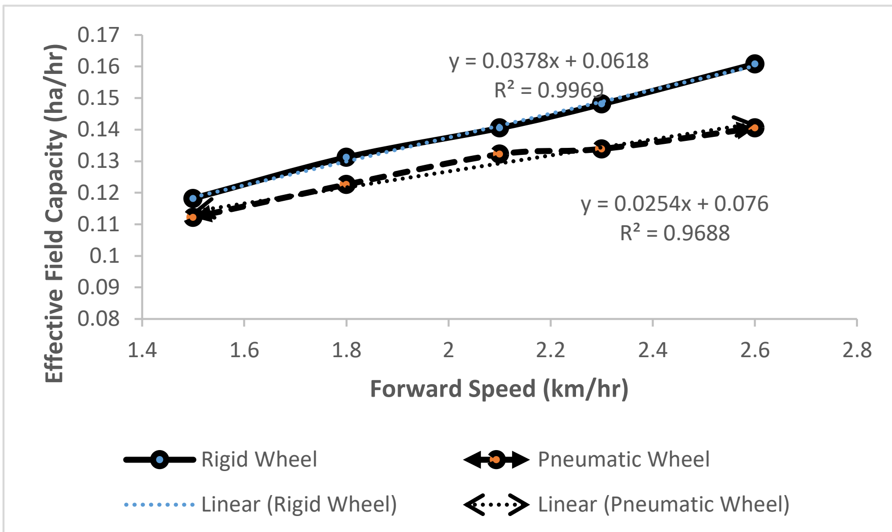

Figure 5: Effect of Tractor Forward Speed on Field Capacity of the Planter

3.3 Effect of Tractor Forward Speed on Field efficiency of the Planter

The strong relationship between the tractor forward speed and the field efficiency of the cassava planter is presented in Figure 6 which showed that the field efficiency decreased with an increase in forward speed of the tractor in the pneumatic wheel and rigid wheel experiments with respective coefficient of determination r^2 of 0.9913 and 0.9959. This speed-efficiency relationship is stronger than Oyedeji *et al.* (2011) that reported a linear relationship with a lower coefficient of determination r^2 of 0.775. Higher values of the efficiency were recorded in the rigid wheel than in the pneumatic wheel. The average efficiency varied from 77.31 to 97.20% in the rigid wheel experiment and 67.55 to 92.27% in the pneumatic wheel experiment at the tractor forward speed ranging from 1.5 to 2.6 km/h.

3.4 Effect of Tractor Forward Speed on Efficiency of the Cutting System of the Planter

Figure 7 shows the effect of forward speed of the tractor on the cutting efficiency of the planter. 100% cutting efficiency was recorded at the forward speeds of 1.5, 1.8, 2.1, 2.3 and 2.6 km/h as no damage of stake was recorded both in the rigid wheel and pneumatic wheel experiments. This is higher than the 89.91% cutting efficiency reported by Lungkapin *et al.* (2009).

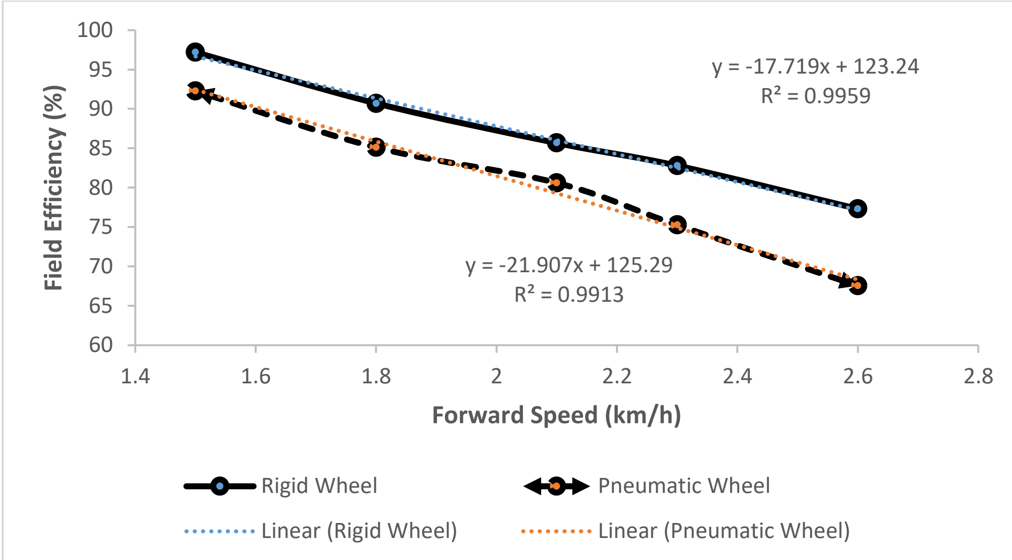

Figure 6: Effect of Tractor Forward Speed on Field Efficiency of the Planter

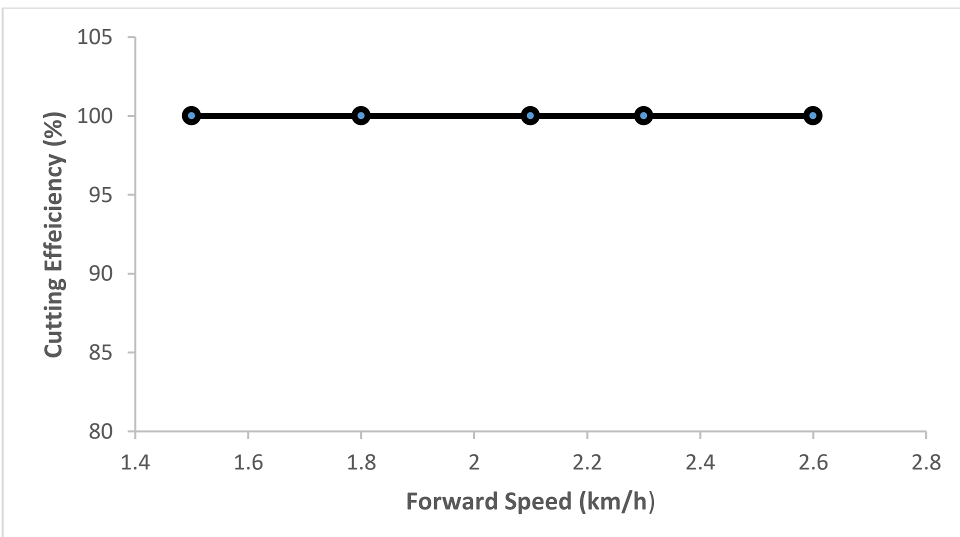

Figure 7: Tractor Forward Speed on the Efficiency of the Cutting System of the Planter

4.0 Conclusion

The following conclusions were drawn from this research;

i. Optimum field performance of 97.20% field efficiency was achieved at the optimum forward speed of 1.5 km/h when the planter was operated with rigid wheels. There was also no record for damage of stakes at all the forward speeds used in this study.

ii. The planter when operated with rigid wheel performed better than when it was operated with pneumatic wheels for all the forward speeds with effective field capacity varying between 0.1182 and 0.1608 ha/h.

iii. Forward speed has a strong correlation with field efficiency and field capacity. It was also found that germination percentage was a not function of the forward speed as the variability of the germination percentage when operated at varying speeds was not so much significant.

iv. The compaction caused by the rigid wheels is negligible and it can be corrected by minimum tillage.

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