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Forward Speed and Draught Requirement of a Semi-Automatic Cassava Planter under Different Wheel Usage

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Abstract—Five varying 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 to determine the effects of forward speed on the draught requirement of a semi-automatic cassava planter under pneumatic wheel and rigid wheel usage on a well-prepared sandy clay loam soil. The soil draught was electronically measured using an on-the-go soil draught measuring instrumentation system developed for the purpose of this research. The results showed an exponential relationship between forward speed and draught in which draught ranging between 24.91 and 744.44 N increased with an increase in forward speed in the rigid wheel experiment. This is contrary to the polynomial relationship observed in the pneumatic wheel experiment in which the draught varied between 96.09 and 343.53 N. It was observed in the experiments that the optimum speed of 1.5 km/h had the least values of draught in both the pneumatic wheel and rigid wheel experiments with higher values in the pneumatic experiment. It was generally noted that the rigid wheel planter with the less value of draught requires less energy requirement for operation. It is therefore concluded that operating the semi-automatic cassava planter with rigid wheels will be more economical for cassava farmers than operating the planter with pneumatic wheels.

Keywords—Cassava planter, planting, forward speed, draught, wheel type.

I. Introduction

In the mechanics of tractor-implement performance, especially in the area of pulling, an important parameter to consider is the horizontal force which is technically known as the 'draught' to move the implement. This force varies depending on the type of implement, its size, the forward speed, the type and condition of the soil, and other factors. It is equal and opposite to the forces that result from the operation that the implement is doing. The implement draught is expressed as a force, usually in kN. It may also be in terms of parameters that take into account the size of the implement or the magnitude of work that is being done [1]. It was reported that draught increased from 0.5 kg to 14 kg as the forward speed increased from 1.05 to 3.6 km/h and remained constant with further increase in forward speed [2]. Draught increased with an increase in forward speed in separate studies by [2] and [3]. A polynomial relationship was observed between forward speed and the values of draught in a study in which a mouldboard plough was used as the tillage tool by [4]. For field performance evaluation, three traveling speeds (1.7, 2.0 and 2.4 km/h) were used in a study on the design and development of a cassava planter with no significant difference in the efficiency of the planter as it increased in forward speed [5]. Forward speed between 2.97 and 4.2 km/h were used by [6] in a study on the development and performance evaluation of a cassava planter. Field efficiency increased with an increase in forward speed with a low coefficient of determination r^2 of 0.775. Forward speed from 2.16 to 3.12 km/h were used in the development of a metering device for a two-row single feeder cassava planter [7]. But 2.16 to 2.64 km/h were reported as the convenient speed of operation without skipping of stems. The study showed that skipping of stems occurs at a speed higher than 2.64 km/h. 1.5 km/h and 2 km/h forward speed were respectively recommended for 1 or 2-row picker-pin planter and 1 or 2-row hand fed planter [8].

It has been noted by most scientific information sources that about 20-55% of the available tractor power is wasted at the tire-soil interface. This energy consumes the tires and causes soil compaction to a degree that may be destructive to growth and development [9]. Effective operation of agricultural tractors involves selecting an optimum operating speed for a given tractor-implement unit; optimizing the tractive advantage of the traction devices, and reducing the drive wheel slippage [10].

Soil physical properties play a vital role in the performance of farm machinery especially in planting and tillage machinery as related traction. Study by [11] revealed a correlation between tractor wheel and soil moisture content. It was indicated that increasing soil moisture content from 12 to 22% led to an increase in wheel slippage from 10% to 20%. Similar results were reported by [12] and [13] and the results from [14] indicated an inverse relationship between tractor wheel slippage and soil moisture content in which the soil moisture increased from 7% to 15% and the wheel slippage decreased from 20 to 16%. The different results as reported by [14] was due to changes in working conditions like soil structure, tillage speed and type of the implements. As soil varies from one place to another and draught requirement varies with implement type and size, this study was therefore on the effects of tractor forward speed on the draught requirement of a semi-automatic cassava planter under different wheel usage.

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II. Materials and Methods

Experimental Site

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.

Land Preparation and the Drive System

The experiment was carried out on a well-prepared soil. The soil was appropriately ploughed and harrowed in preparation for the experiment. The drive system (Fig. 1) is a New Holland TT55 tractor. It is a 36 kW and 4 wheel drive tractor.

Fig. 1 The Planter as coupled to the Tractor

Soil Measurement and Analysis

For the purpose of soil measurement and analysis, soil samples were collected from the depth of 0-5, 5-10 and 10-15 cm by the use of a core sampler of 5.8 cm diameter and 5 cm height. The soil sample was collected by driving the core sampler into each depth of the soil and the soil sample collected was kept in an air tight polythene bag to prevent moisture loss. The collected sample was dried and weighted using electrical oven and a digital weighing scale. The soil was allowed to cool for one hour before the necessary measurements. The value of 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 moisture meter at the soil depth of 5, 10 and 10 cm.

Experimentation and Instrumentation System

Tractor forward speeds of 1.5, 1.8, 2.1, 2.3 and 2.6 km/h were used at the constant furrow depth of 100 mm and other parameters presented in Table I for both pneumatic wheel and rigid wheel experiments. The speed was made constant for each experiment by using the hand throttle to fix it to the desired speed before the operation. At each of the forward speed, the soil draught was electronically measured using the on-the-go soil draught measuring instrumentation system (Figs. 2 and 3) developed for the purpose of this research.

The data acquisition system consists of the load cell amplifier that performs the function of amplification of electronic signal as sensed by the load cells; opto-coupler module for light emitting; micro-controller for precise motion control; LCD display for electronic digital display of values as measured by the system; SD-card shield for data storage and cable for wire connection between the system and the tractor. The system was designed to be powered by the battery of the tractor. The load cell was installed on the frame of the cassava planter by the use of brackets as presented in Fig. 4. The schematic representations of the pneumatic and rigid wheels are given in Figs. 5 and 6.

TABLE I
Parameters Used during the Experiment

Parameter	Value
Soil Textural Class	Sandy clay loam
Soil Moisture Content	15 %
Soil Depth	100 mm
Cassava Variety	TME 419
Stem Girth(diameter)	35 mm
Spacing	1 m
Tractor Forward Speed	1.5, 1.8, 2.1, 2.3 and 2.6
Land Preparation	Ploughing and harrowing

Fig. 2 Load Cell

Fig. 3 Data Acquisition System

III. Results and Discussions

Effect of Tractor Forward Speed on the Draught Requirement of the Planter

The experiment showed that different behaviors were observed from the pneumatic wheel and rigid experiments as presented in Fig. 7. In the rigid wheel experiment, draught increased with an increase in tractor forward speed. This is in conformity with [2] in which the influence of forward speed of planter and operating depth on land wheel speed was carried out. The result was also similar to [3]. But it was contrary to [4] which reported that the values of draught increased with an increase in operating speed and later decreased with further increase in speed in a draught measurement study. The power regression model that described the relationship as presented in Fig. 7 is with coefficient of determination r^2 of 0.9377. But this is contrary to [15] which reported that draught-speed regression varied from linear to quadratic.

Fig. 4 Load Cell and Bracket as Installed on the Planter

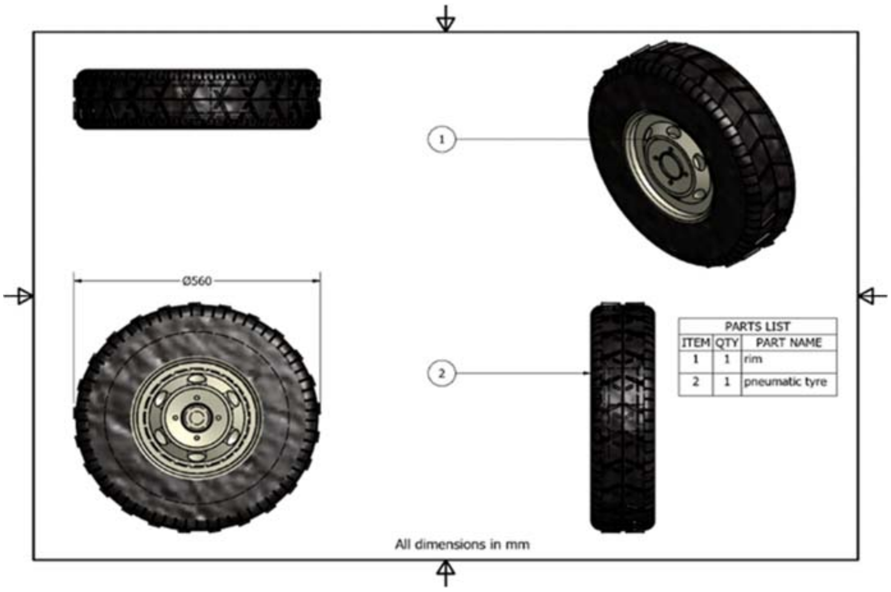

Fig. 5 Schematic View of the Pneumatic Wheel

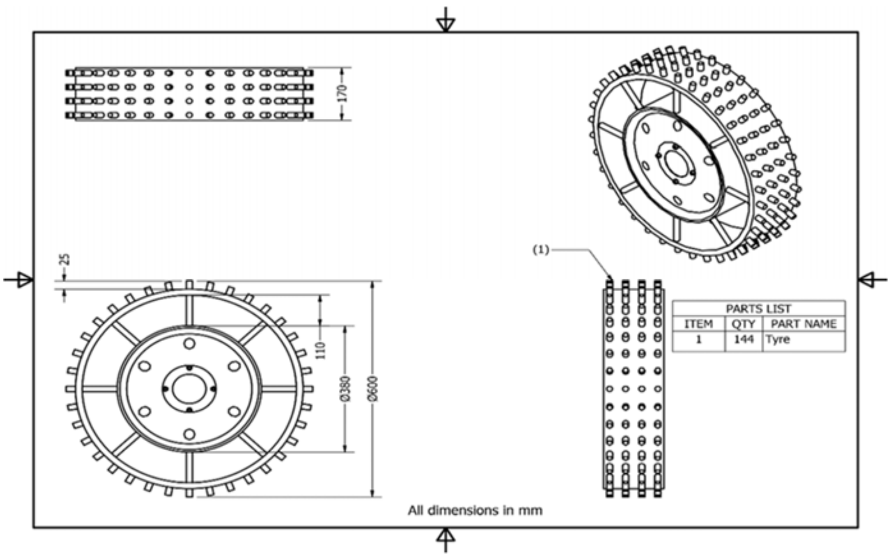

Fig. 6 Schematic View of the Rigid Wheel

In the pneumatic wheel experiment, a polynomial relationship was observed between the tractor forward speed and the values of draught. The values of draught decreased with an increase in forward speed and later increased with further increase in forward speed. This behavior disagreed with most of the studies on the draught-speed relationship of farm machinery, but the quadratic regression model of the relationship is supported by [15]

There was an increase in the average value of draught from 24.91 N to 744.44 N as forward speed increased from 1.5 to 2.6 km/h in the rigid wheel experiment. In the pneumatic wheel experiment, the least value of draught (96.09 N) was recorded at forward speed of 2.3 km/h and the highest value of draught (343.53 N) was at the forward speed of 1.5 km/h. This disagreement in behavior observed in the two experiments was due to the difference in the soil resistance during soil deformation process by the furrow opener and the difference in the vertical loads of the wheels.

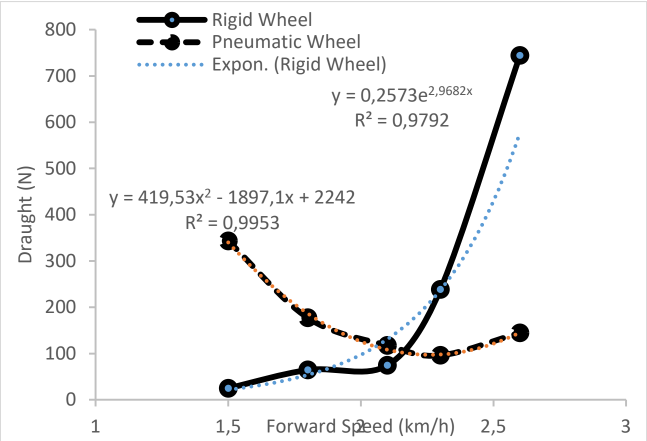

Fig. 7 Effect of Tractor Forward Speed on Draught Requirement of the Planter

Effect of Type of Wheel on the Compaction Characteristics of the Soil

Negligible differences in the values of compaction characteristics (penetration resistance) as presented in Fig. 8 were recorded in the compaction test of the soil affected by the passage of the wheels used in this experiment. The mean penetration resistance of the soil before the experiment was 943.30 kPa, while the mean penetration resistances of the disturbed soil after the experiment were 995.00 and 1065.00 kPa for the pneumatic and the rigid wheel experiments respectively. The difference in values recorded was due to the weight difference. The compaction difference between the pneumatic wheel and the rigid wheels can be corrected by a minimum tillage. This is in conformity with [16].

The physical properties of the soil as presented in Table II revealed that the experimental soil is sandy clay loam with soil moisture content varying between 14 and 15% and varying bulk density of 1.17 to 1.21 g/cm^3. The chemical properties of the soil as presented in Table III revealed that the pH of the soil varied from 4.68 to 4.70; organic carbon from 1.30 to 1.44%; organic matter (2.25 to 2.48%); nitrogen (0.30 to 0.36 mg/kg); phosphorus (6.53 to 7.08 mg/kg); potassium (1.10 to 1.16 mg/kg); sodium (1.13 to 1.18); calcium (3.60 to 4.40 cmol/kg) and magnesium (1.70 to 2.00 cmol/kg)

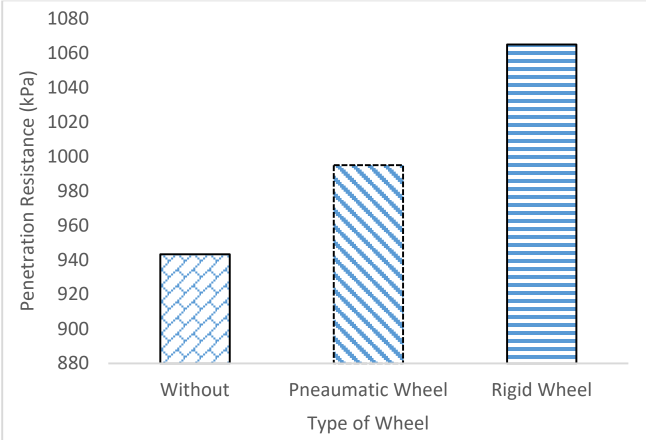

Fig. 8 Effect of Type of Wheels on the Penetration Resistance of Soil

TABLE II
PHYSICAL PROPERTIES OF THE EXPERIMENTAL SOIL

Soil sample	M.C	B.D	Particle size %			Textural Class
			Sand	Clay	Silt	
A	15	1.17	53.00	27.00	20.00	Sandy clay loam
B	14	1.21	57.00	27.00	16.00	Sandy clay loam
C	15	1.18	53.00	27.00	20.00	Sandy clay loam

TABLE III
CHEMICAL PROPERTIES OF THE EXPERIMENTAL SOIL

Soil Sample	pH	OC	OM	N	P	K^+	Na^+	Ca^{2+}	Mg^{2+}
			%	mg/kg	mg/kg			cmol/kg	
A	4.70	1.36	2.34	0.36	6.53	1.13	1.13	3.60	1.7
B	4.69	1.30	2.25	0.30	7.08	1.10	1.13	3.70	1.70
C	4.68	1.44	2.48	0.34	7.00	1.16	1.18	4.40	2.00

IV. CONCLUSIONS

The following conclusions were drawn from this research;

1. Different relationships were observed between the forward speed and the draught requirement of the planter from the pneumatic wheel and rigid wheel experiments.
2. Forward speed has a strong correlation with draught requirement of the planter in both the pneumatic wheel and rigid wheel experiments.
3. The compaction caused by the rigid wheels is negligible and it can be corrected by minimum tillage.

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