

# The use of variable weights on rear wheels in the evaluation performance of ploughing operation

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### ABSTRACT

The aims of this study were to investigate the performance characteristics of a farm tractor during ploughing (chisel plough) using variable weights from (0 to 500 kg) on the rear tractor wheels, and different traveling speeds from (3.58 to 5.68 km/h). The ploughing depths were (15-20 cm), and the average moisture content was (20.15 %). The soil texture was found to be a (Silty clay). The rear tier sizes of the tractor and inflation pressure were 16.9/14-38 and 150 kPa, respectively. The study was concentrated on the rate of fuel consumption, specific energy, drawbar pull, tractor wheel slippage, tractive efficiency and field efficiency. The obtained results, for the range of tests, showed that the use of 500 kg weight on the tractor rear wheel at 3.1 km/h traveling speed produced the highest value (74.4 %) of tractive efficiency, and (in the meantime) the wheel slippage, field efficiency, fuel consumption, required power, specific energy were 7.46 %, 80.22%, 15.11 l/h, 46.58 kW, and 43.13 kW.h/fed, respectively. In general, the traveling speed and the weight on the rear tractor wheels were the most important factors that affecting the drawbar pull and the specific energy.

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### Introduction

Improving tractors performance on the field to reduce fuel consumption. Reducing fuel consumption reduces energy consumed. The hub of agricultural mechanization as it can be used to operate the agricultural implements and its power on farm will continue to be an absolute necessity for increasing agricultural production. It is useful for field work, materials handling, and processing operation on farm. The amount of energy consumed for chisel plough operation depend on soil and operating conditions. So that it must increase operation efficiency of farm tractor. Abbaspour-Gilandeh et. al. (2007) reported that the agricultural tractors consume about 20 percentage of total energy, required for a farm. Therefore optimizing performance of agricultural tractors could bring energy losses down. Lyasko M.I. (2010) Indicated that the soil conditions significantly affect on tractive performance of off-road wheeled and tracked vehicles. Mehta et al (2010) Indicated that the tractor is used for various field operations. Therefore, it is recommended that the field operations which are the most time sensitive or that require the highest power should be taken into consideration for determining the power of tractor. Sahay and Tewari (2004) mentioned that the satisfactory performance of the tractor-implement system is dependent upon the stability of the operation, power of the engine and traction developed. Mostafa et. al. (1993) indicated that the slippage resistance power increases as the traveling speed increases. The may be due to the variation in the different between traveling speed without load and effective traveling speed under load. The fuel consumption increases by increase of traveling speed, where the fuel consumption increased from 13.65 l/h to 14.5 l/hr by increasing traveling speed from 4.38 to 4.75 km/hr. The fuel consumption was

measured during the field experiments. El-Ashry et. al. (2003) carried out field experiments to evaluate the tractive performance at different levels of ballast conditions (0, 60 and 90 kg) in ploughed and unploughed soils. They concluded that the tractive efficiency increased up to a certain value of ballast conditions (from 0 kg to 60 kg) beyond which it decreased with an increase in ballast conditions (from 60 kg to 90 kg) in tilled and untilled soil conditions. Narang and Vershney (2006) summarized the results as the following main points: 1- The wheel slip increased with the increase in draft of the tractor; 2- The drawbar power increased by 0.170 and 0.139 kW at rated speed and three fourth rated speed of two wheel tractor, with the mounting of 40 kg wheel ballast; and 3- The fuel consumption increased by about 19% with the mounting of 40 kg wheel ballast. Younis et al. (2010) indicated that the performance of drawbar test has been measured the following data: traveling speed, fuel consumption, the equivalent traveling speed and drawbar pull. The maximum drawbar power affected by drawbar pull as showed (62.31 and 62.58 kW) at highest traveling speed of (6.72 and 7.7 km/hr), respectively. Dahab and Al-Hashem (2002) studied the effect of tractor speed working on clay loam soil on drawbar pull. The results showed that the increases in tractor speed had a highly effect on drawbar pull. The increases in tractor speed from 5 km/h to 9 km/h increased pull by 39% for tractor had 53.2 kW rated power. Abu-Hamdeh (1998) reported that the operation of farm tractors near their maximum tractive efficiency increases tractor productive output and results in fuel savings. However, operating condition in the field affected on performance of tractors, fuel consumption and physical properties of soil. Bashford (1984) said that the tractive efficiency is a parameter that defines the percentage of

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tractor axle power that is transformed into drawbar power. It is influenced by the traction ratio, rolling resistance, and the wheel slip. Jain and Philip (2003) mentioned that the power requirement of a tractor for different field operations can be calculated after getting the preliminary details regarding land holding, total available working time, soil conditions and type of operations.

The present study aims to investigate, test and evaluate the relationships between power, weight, drawbar pull and traveling speed of farm tractor during ploughing and sowing operations using chisel plough and seed drill, respectively, with the use of different weights on the rear tractor wheels and different traveling speeds through the following specific objectives:

1. Determination the wheel slippage.
2. Determination the drawbar pull.
3. Determination the tractive efficiency.
4. Determination the fuel consumption, required power and specific energy.
5. Determination the effective field capacity and field efficiency

### Materials and Methods

The experimental work was carried out in El-Gemmaiza Agriculture Research Station, El-Garbia Governorate Egypt during the summer of 2012. The soil type was Silt clay and the average soil moisture content during working time was 20.15% (dry basis), at ploughing depths (15-20) cm. The variable weights (from 0 to 500 kg) on the rear tractor wheels and travelling speeds (from 2.78 to 5.68 km/h) were used. The mechanical analysis of the soil is shown in table (1).

**Table 1. Mechanical analysis of the experimental soil.**

Soil fraction				CaCo <sub>3</sub> , %	Soil textural class
Clay, %	Silt, %	Fin sand %	Coarse sand, %		
46.35	35.15	17.30	1.20	2.62	Silt clay

The following materials and methods were used

### A- descriptions of tractors and implements

#### 1- Tractors

Two tractors (New Holland 110- 90) were used. The specifications of the used tractors are:

Type	New Holland
Engine HP at R.P.M	90 at 2500
Engine type	IVECO
Fuel type and No. of cylinders	Diesel, 6 cylinders
Bore and stroke (mm)	104 × 132
P.T.O. - (rpm)	540-2200
Tire size front, rear	7.50-20, 16.9/14-38
Capacity (cm <sup>3</sup> )	6728
Cooling system	Water
Weight (kg)	4930

#### 2- Chisel plough:

The specifications of the Chisel plough are:

A local manufactured RAU "Behera Co", rear mounted, Share spacing (25cm), Total width (175cm), Mass (500kg), Without wheel depth control and With 7 tines arranged in two rows as 3 and 4 from front to rear.

#### B- Measuring instruments:

- 1- Spring dynamometer;
- 2- Fuel consumption apparatus;
- 3- 50 m tape; and
- 4- Stop watch.

### C- Parameter measurement and determination

#### 1- Soil moisture content (MC)

Soil moisture content was determined by using the standard oven methods. Soil samples were taken at depths (from 0 to 20 cm) by screw auger. They were weighted, and then dried at 105 °C for 24h in electric oven. The moisture content was calculated according to (Black et. al. 1965) as:

$$MC = \left( \frac{W_w - W_d}{W_d} \right) \times 100$$

Where:

MC= Soil moisture content (dry basis) %

W<sub>w</sub>= wet soil mass, gm

W<sub>d</sub>= dry soil mass, gm

#### 2- Traveling speed (TS)

It was calculated as follows

$$TS = \frac{x}{t} \times 3.6$$

Where:

TS = traveling speed, km/h

x= traveling measured distance, m

t= traveling measured time, s

#### 3- Fuel consumption (FC)

Fuel consumption per unit time was determined by measuring the volume of consumed fuel during ploughing or sowing time. It was calculated as follows:

$$FC = \left( \frac{V}{t} \right) \times 3.6$$

Where:

FC : rate of fuel consumption, l/h

V : volume of consumed fuel, cm<sup>3</sup>

T : time, s

#### 4- Tractive force:

The tractive force of the tractor was measured by using a spring dynamometer and two tractors. One of the two tractors was towed by the other. The rear (towed) tractor (Newholland 110-90) is used as an implement carrier whereas the front one (Newholland 110-90) is, thus, used as a prime mover. A horizontal chain with the spring dynamometer linked the two tractors. The rear tractor which pulled the implement (chisel plough or seed drill) is being in neutral gear but with implement in the operating position. The tractive force was recorded in the measure distance of 50 m as well as the time taken to transverse it. On the same field the implement was lifted out of the ground and the rear tractor was pulled to record the rolling resistance (A), then the drawbar pull (B) was calculated as follow:

During the operation the following measurement were obtained:

A = rolling resistance for the working unit (tractor + plough or seed drill).

B = the recording pull by using plough or seed drill.

Net drawbar pull (kN) = Tractive force (kN) - Rolling resistance (kN)

#### 5- Wheel slip (S):

The slippage percentage was measured by using the following formula:

$$S = \frac{TS_1 - TS_2}{TS_1} \times 100$$

Where:

- S : wheel slip, %
- TS<sub>1</sub> : traveling speed without load km/h.
- TS<sub>2</sub> : traveling speed with load km/h.

**6- Drawbar power (P<sub>db</sub>):**

Drawbar Power (kW) = Net drawbar pull (kN) × traveling speed (km/h)/3.6

**7-Power consumed by rolling resistance (P<sub>rr</sub>):**

Rolling resistance power (kW) = rolling resistance (kN) × traveling speed (km/h)/3.6

**8- Power consumed by slip (P<sub>sl</sub>):**

$$P_{sl} = [P_{db} + P_{rr}] \times \frac{S}{100 - S}$$

(Jebur, 2015)

Where:

- P<sub>sl</sub> = Power consumed by slip (kW)
- P<sub>db</sub> = Drawbar power (kW)
- P<sub>rr</sub> = rolling resistance power (kW)
- S = Slip in percent (%)

**9- Tractive efficiency (TE):**

Tractive efficiency is defined as:

$$TE = \frac{\text{Output Power}}{\text{Input power}} \times 100 \Rightarrow \frac{\text{Drawbar Power}}{\text{Axle power}} \times 100$$

(Sharma and Mukesh, 2010)

where TE = tractive efficiency %

**10- Effective Field capacity (E<sub>fc</sub>)**

$$\text{Theoretical field capacity} = \frac{\text{Machine width(m)} \times \text{speed(km/h)}}{4.2} \dots \text{fed.h}^{-1}$$

$$\text{Effective field capacity} = \frac{1}{\text{effective total time in hours required per feddan}} \dots \text{fed.h}^{-1}$$

**11- Field efficiency (η<sub>f</sub>):**

$$\eta_f = \left( \frac{E_{f.c}}{T_{f.c}} \right) \times 100$$

Where:

- η<sub>f</sub> : field efficiency, %
- E<sub>fc</sub> : effective field capacity, fed/h.
- T<sub>fc</sub> : theoretical Field capacity, fed/h.

**12- Required engine Power (R.E.P):**

The required engine power was determined for each operation by using the following equation (Embaby, 1985).

$$R.E.P = \left( F_c \times \frac{1}{3600} \right) \times \rho_f \times L.C.V \times 427 \times \eta_{th} \times \eta_m \times \frac{1}{75} \times \frac{1}{1.36}$$

Where:

- R.E.P : Power Requirements from Fuel consumption; kW.
- F<sub>c</sub> : Fuel consumption rate; L/h
- ρ<sub>f</sub> : Density of the fuel; kg/L (for diesel fuel = 0.85 kg/L)
- L.C.V : Lower calorific value of fuel Kcal/Kg; (average L.C.V of diesel fuel is 10<sup>4</sup> kcal/kg)
- 427 : Thermo – Mechanical equivalent; kg m/ kcal;
- η<sub>th</sub> : Thermal efficiency of the engine (assumed to be 40% for diesel engine);

η<sub>m</sub> : Mechanical efficiency of the engine (assumed to be 80% for diesel engine).

**13- Specific Energy (SE):**

The specific energy (kW.h/fed) for a particular operation was calculated as follows:

$$SE = \frac{R.E.P}{E_{f.c}}$$

Where:

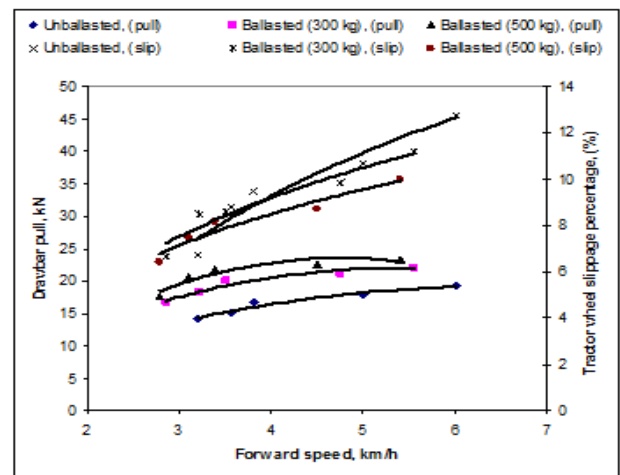
- SE : specific energy, kW.h/fed.
- R.E.P : power required for a particular operation, kW,
- E<sub>fc</sub> : effective field capacity, fed/h.

**Results and Discussion**

All the obtained results are in range of the tests and for the specified soil type and soil moisture content that were mentioned in the materials and methods section, and should not be used below or above the test range and the soil conditions.

**1.Drawbar pull and wheel slip:**

Results presented in fig. (1) Show the effect of traveling speed and the weight on the rear tractor wheels on the drawbar pull and wheel slip. It is obvious that both of the drawbar pull and wheel slip increased with the increase of the traveling speed. The drawbar pull and the wheel slip increased by an average (12.15 and 25.4 %) with increasing the traveling speed (from 3.1 to 5.43 km/h). Fig. (1) Also show that the increase in drawbar pull and the decrease in wheel slip with increasing the weight on the rear tractor wheels at the given speed.



**Fig 1. Effect of traveling speed and different weights on drawbar pull and wheel slip.**

**2.Tractive efficiency**

Results illustrated in fig (2) show the effect of traveling speed and the weight on the rear tractor wheels on the tractive efficiency during the field operation of the chisel plough. It is clear that the tractive efficiency decreased by increasing the traveling speed. With the use of 500 kg weight on the rear tractor wheels, the tractive efficiency decreased by an average 7.58 % with the increase of the traveling speed (from 3.1 to 5.43 km/h). This may be due to the losses in output power that come from both travel reduction, which is also referred to slip or pull losses. Fig. (2) Also show that the increase of tractive efficiency with increasing the weight in the rear tractor wheels at the given traveling speed. This could be due to the use of the correct tire size and inflation pressure with the sufficient weight allows the tractor tires to operate at

its design deflection ratio where optimum performance was obtained. Within the speed range of the tests, data showed that the highest value of the tractive efficiency, with the use of 500 kg weight on the rear tractor wheels, were 76% as the speed of 2.78 km/h.

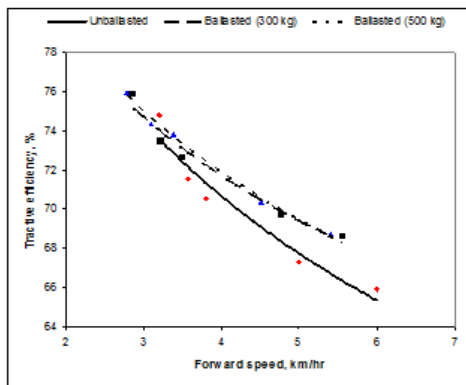


Fig 2. effect of traveling speed and different weights on tractive efficiency during ploughing.

3.The effective field capacity and field efficiency

The relation between the traveling speed and both the effective field capacity and field efficiency of the chisel plough operation with the use of different weights on the rear tractor wheels are presented in fig. (3). In general, the results showed that the effective field capacity increased by increasing the traveling speed for both implements, but the field efficiency decreased with the increase of traveling speed which may be due to the increase in the theoretical field capacity. With the use of 500 kg weight on the rear tractor wheels and traveling speed (from 3.1 to 5.43 km/h), the effective field capacity increased by 44.04%, while the field efficiency decreased by 3.76%. The highest value of the effective field capacity was 1.93 fed/h at 5.43 km/h traveling speed.

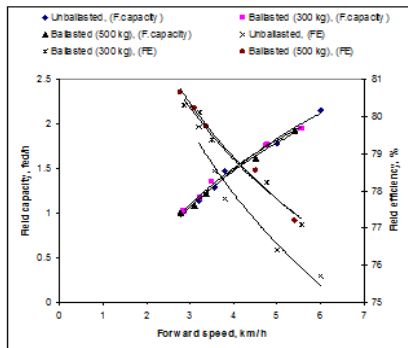


Fig 3. Effect of traveling speed and different weights on effective field capacity and field efficiency.

4.Required engine power and specific energy

Fig. (4) Show the effect of traveling speed and the weight on the rear tractor wheels on the required power (kW) and the specific energy (kWh/fed) of the chisel plough operation. It's obvious that by increasing the traveling speed, the required power was increased, while the specific energy was decreased with the use of 500 kg weight on the rear tractor wheels the required power was increased by (22.03%) and the specific energy was decreased by (28.24%) when the traveling speed increased (from 3.1 to 5.43 km/h). The highest value of the required power was 59.74 kW at (5.43 km/h) traveling speed, in the meantime the specific energy was (30.95 kW.h/fed).

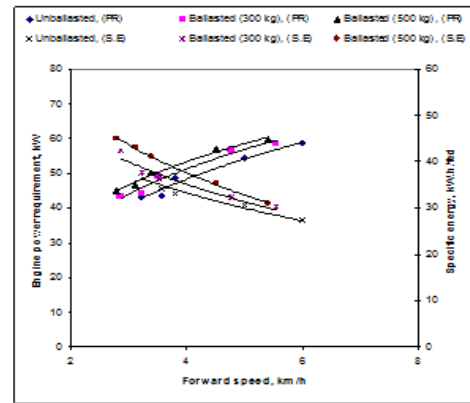


Fig 4. effect of traveling speed and different weights on power requirement and specific energy.

Conclusion

The results of the present study led to the following conclusions:

- 1- The traveling speed and the weight on the rear tractor wheels were the most important factors that affecting the drawbar pull and the specific energy.
- 2- The wheel slip increased with the increase in the traveling speed, while decreased by increasing the weight on the rear tractor wheels.
- 3- The drawbar pull increased by increasing the traveling speed or the weight on the rear tractor wheels.
- 4- The use of 500 kg weight on the tractor rear wheel at 3.1 km/h traveling speed produced the highest value (74.4 %) of tractive efficiency, and (in the meantime) the wheel slippage, filed efficiency, fuel consumption, required power, specific energy were 7.46 %, 80.22%, 15.11 l/h, 46.58 kW, and 43.13 kW.h/fed, respectively.

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