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A Comparative Study of Actual Fuel Consumption and the Predicted Fuel Consumption of the Tractor with Chisel Plow

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***Abstract**:*

A field experiment was conducted during December 2019, at the Demonstration Farm of the Faculty of Natural Resources and Environmental Studies, University of Alsalam. The objective was to compare the actual fuel consumption and the predicted fuel consumption of tractor with chisel plow. Randomized complete block design with three replications was used in this study. Three operating speeds of 3.41 km/h, 5.52 km/h and 8.4 km/h were set as treatments. Three methods of calculating fuel consumption were used namely, refilling (direct) method, first estimation and second estimation methods. The effective field capacity and field efficiency were also determined. The results showed there was a significant difference ($P \leq 0.05$) between refilling method and first estimation method in the first speed. The first estimation method showed an increase the rate of fuel consumption by 33% over the refilling method. However, in the second speed, the difference was a significant between the refilling method and the second estimation method. The rate of fuel consumption was increased by 28% over the refilling method. In the third speed, the difference was significant among the methods of calculating fuel consumption. The second estimation method increased the rate of fuel consumption by 14% over the refilling method, while the first estimation method decreased the rate of fuel consumption by 49%.The results showed that increasing in the operating speed resulted in increase the rate of fuel consumption in refilling and second estimation methods. However, in the first estimation method the rate of fuel consumption remained constant in all operating speeds. The results also showed increasing in the operating speed led to a significant increase in effective field capacity and field efficiency. It can be concluded that the second estimation method could be used because it gave closer results to the refilling method at different operating speeds.

***Keywords:** Fuel consumption; predicted fuel consumption; refilling method; estimation method*

Introduction

With increasing concern for fuel conservation and energy management, farmers may wish to estimate the amount of fuel required to perform specific farming operations. By knowing the amount of fuel needed, farmers can select the best conservation practices to manage farm equipment.

Fuel consumption is considered most important factor for research in agricultural operations, testing and assessing the performance of the machines. Fuel consumption of tillage operations is an essential parameter for selecting the appropriate machines. It is needed for developing strategies for operating machines under various field conditions. Energy used in tillage operations depends on many factors such as soil type, soil condition, depth of tillage, speed of operation and hitch geometry. Fuel consumption is measured by the amount of fuel used during a specific time period. Ability to predict tractor fuel consumption is very useful for budgeting and proper management. Several methods have been used for fuel consumption prediction, some of these methods are generally based on power requirements and others are for individual engines, which require extensive

engine testing to verify the amount of consumption. Grisso *et al*., (2004) developed a general model to predict fuel consumption for full and partial loads and for reduced throttle conditions using data from Nebraska Tractor Test Lab (NTTL) in U.S.A. for a specific tractor models. Estimating fuel consumption for a specific operation developed by (ASABE, 2015b).Using mathematical equations which make it possible to predict fuel savings for different operating and loading tractor conditions (Grisso *et al*., 2008).

Tractor fuel consumption is tightly related to power. Howard (2010), Howard et al. (2013), and Smith (2015) indicated that there was also an effect of travel speed on tractor fuel consumption. According to Hanna (2001) and Thakare and Deshmukh (2009), fuel consumption is affected by a number of factors such as soil types and moisture, the users, tractor design (two wheels or four wheels), tractor size, equipment width, working depth and speed of operation.

Fuel consumption plays a significant role in the selection and management of tractors and equipment used in agriculture, so better estimate and comparison of the fuel consumption for different operating and loading conditions is highly needed. Therefore, the main objective of this study is to compare the actual fuel consumption and the predicted fuel consumption of tractor with chisel plow as well as to determine the technical performance of the tillage implement (effective field capacity and field efficiency).

Materials and methods

Study area

The experiment was carried out in the Demonstration Farm of the Faculty of Natural Resources and Environmental Studies, Alsalam University, Elfula, West Kordofan State (latitude$10^{o}50^{'}$ -$12^{o}30^{'}$ N and longitudes $27^{o}40^{'}$ - 29^{o}E) during season 2019. The soil type is sandy loam characterized relatively by high content of sand; the soil moisture content was 3.5%

Experimental design and experimental procedures

A randomized complete block design was laid out with three replications. Three fuel consumption calculation methods were used namely, the refilling (direct) method, first estimation method (equation) and second estimation method (equation). Three operating speeds of 3.41 km/h, 5.52 km/h and 8.4 km/h were used. An experimental block of 90 m long and 1.53 m wide was used for each treatment.
The tractor Tafe 8502 (80.5 hp) was used in this study, as well as the chisel plow with two rows and five shanks (two front and three back) was used. Depth of tillage was constant in all treatments ranging from 18- 20 cm.

The fuel consumption was determined as follows:
Refilling (direct) method:
the fuel tank of the tractor was filled up to full capacity before testing, after testing the fuel tank of the tractor was refilled up to the same fuel capacity with 1000 ml graduated cylinder, the total quantity of fuel needed to refill the tractor tank was recorded. The fuel consumption per hour was calculated by using the following equation:

$$\text{Fuel consumption (liter/hour)} = \frac{Fuel\ consumption\ (liter)}{Time\ of\ operation\ (h)} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(1)$$

Estimated methods:
First method: Fuel consumption was estimated by using the following formula suggested by ASABE Standards (2006, 2009):

$$Q_{avg} = 0.044 \times P_{pto} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(2)$$

Where:

Q_{avg} = average fuel consumption of a diesel tractor, gal/h.

P_{pto} = rated PTO power, hp.

Second method: In this method fuel consumption was estimated by using the following formula suggested by ASABE Standards (2011):

$$QF = (0.0434X + 0.019) \cdot P_{PTO} \quad \text{.....(3)}$$

Where

QF = diesel fuel consumption at partial load and full throttle (gal/h),

X = fraction of equivalent PTO power available (decimal).

$X = P / P_{RATED}$

Where

P = equivalent PTO power required by current operation (hp),

P_{PTO} = rated PTO power available (hp)

The performance parameters which measured include the following:

Forward speed was calculated as the ratio of a distance (m) to the time required by the machine to travel this distance. The distance travelled (m) was determined using a measuring tape. The time taken (s) to distance travelled (m) during operation was determined using a stopwatch. Then the forward speed of tractor (km/h) was calculated by the following equation:

$$S = \frac{D_T}{t} \times 3.6 \quad \text{.....(4)}$$

Where,

S = speed (km/h).

D_T = travelled distance (m).

t = time (sec).

The Theoretical field capacity (ha/h) was calculated using the following equation ASABE (2006).

$$TFC = \frac{W \times S}{C} \quad \text{.....(5)}$$

Where:

TFC = Theoretical field capacity, (ha/h).

S = Speed, (km/h).

W = Width of implement, (m).

C = Constant, (10).

The effective field capacity (ha/h) was calculated using the following equation ASABE (2006).

$$EFC = \frac{A \times 3600}{T \times 10000} \quad \text{.....(6)}$$

Where:

EFC = Effective field capacity, (ha/h).

A = Plot area, (m^2).

T = Total plot time, (sec).

Field efficiency is defined as the ratio of effective field capacity to theoretical field capacity. It was calculated using the following equation suggested by Kepner *et al.*, (1982):

$$FE = \frac{EFC}{TFC} \times 100 \quad \text{.....(7)}$$

Where:

FE = field efficiency, %.

EFC = effective field capacity, ha/h.
TFC = theoretical field capacity, ha/h.

The data were analyzed using Statistix 8 software program for analysis of variance and means separation.

Results and discussion

1- Fuel consumption calculation methods:

The effect of forward speed on the fuel consumption calculated by refilling method showed in Fig 1. The fuel consumption significantly increased when forward speed increased. The speed 8.4 km/h recorded the highest value of fuel consumption 23.5 l/h, while the lowest value of 9 l/h obtained at speed 3.41 km/h. This could be attributed to the increasing in forward speed that increased engine speed and this in turn led to increase of the fuel consumption. The result was in agreed with Taha (2011) results.

The effect of forward speed on the fuel consumption (estimation methods) also showed in Fig 1. In the first estimation method the fuel consumption was remained constant in all speeds at 12 l/h. While in the second estimation method the fuel consumption significantly increased when forward speed increased. Where the speed 8.4 km/h recorded the highest value of 26.8 l/h followed by speed 5.52 km/h and 3.41 km/h were 16.8 l/h and 10 l/h, respectively Fig 1.

Regarding the difference between the refilling method and two estimation methods at different speeds the results revealed that there was significant difference between refilling method and first estimation method in the first speed, which led to increase fuel consumption over the refilling method by 33%. However, there was no significant difference between the refilling method and the second estimation method at the same speed.

In the second speed, the statistical analysis showed that there was no significant difference between the refilling method and the first estimation method. But the difference was significant between the refilling method and the second estimation method. Where, it increased the fuel consumption over the refilling method by 28%.

In the third speed, the difference among the methods of calculation fuel consumption was significant. The second estimation method increased the fuel consumption over the refilling method by 14%, while the first estimation method decreased it by 49 %. Estimated fuel consumption using the first estimation method gave fuel consumption based on the assumption that the tractor was operated under the same load pattern for equal time. Therefore, this method used for estimating average fuel consumption by a tractor for a whole year, not for estimating consumption for a particular operation. The fuel consumption estimated using the second estimation method was found slightly higher than the refilling method. The results were agreed with those of Grisso et al., (2010).

2- The performance variables:

i- Effective field capacity:

Table 1 shows there was significant difference ($P \leq 0.05$) in field effective capacity between the third speed and first speed and between third speed and second speed. But the difference was not significant ($P > 0.05$) between the first speed and second speed. The third speed obtained the highest value of effective field capacity was 1.1 ha/h followed by the second speed of 0.55 ha/h and first speed 0.43 ha/h. It is clear that effective field capacity showed an increase with speed increase, and this could be attributed to the positive relationship between them. Similar findings were observed by Muhsin (2017) and Al-jubory (2010).

ii- Field efficiency:

The effect of tractor forward speed on the field efficiency is given in Table 1. There was significant difference ($P \leq 0.05$) in field efficiency between the third speed and first speed and between third speed and second speed. But the difference between the first speed and second speed was not significant ($P > 0.05$). The third speed scored the highest field efficiency 68.5%, while the first speed obtained lowest value of 61.4%. This because

the increasing of the operating speed which in turn led to increase the effective field capacity. This agreed with the observation of Muhsin (2017).

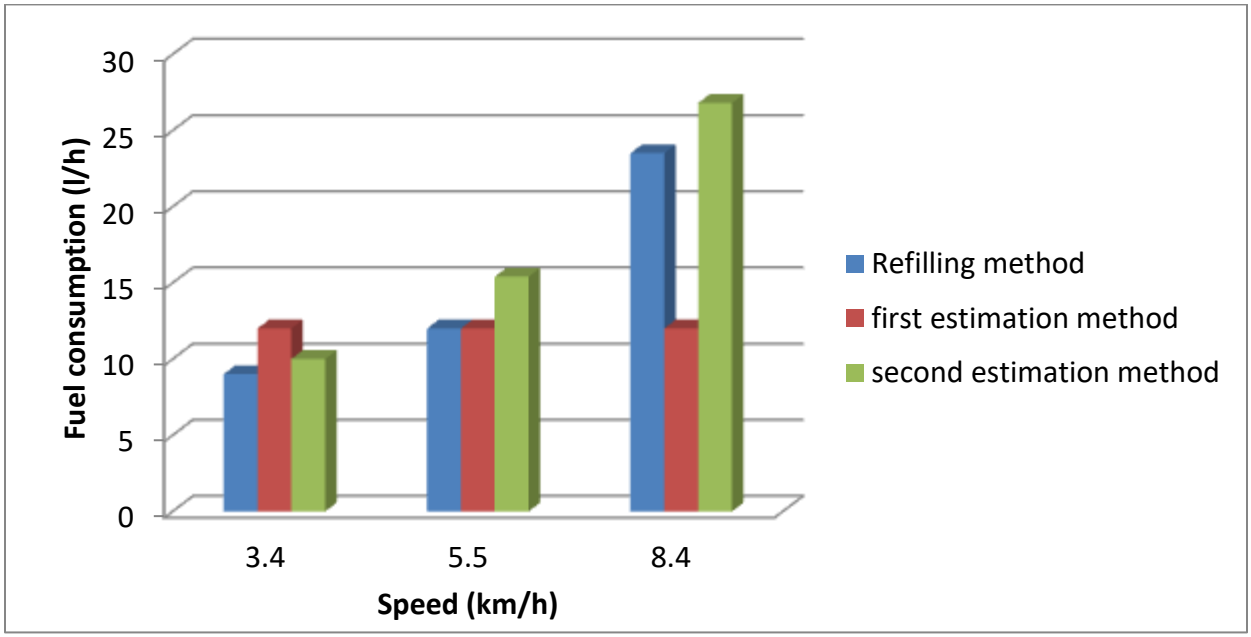

Fig 1 Effect of speed on the rate of the fuel consumption as measured by the refilling method and two estimation methods

Table 1 Effect of operating speed on effective field capacity and field efficiency

Treatments Speed (km/h)	Effective field capacity (ha/h)	Field efficiency (%)
3.4	0.43 [b]	61.4 [b]
5.5	0.55 [b]	62 [b]
8.4	1.1 [a]	68.5 [a]
L.S.D 0.05	0.41	1.7

Means share same superscript letter are not significantly different as separated by LSD test at 0.05 level of significance.

Conclusion:

It can be concluded that when comparing estimated and actual fuel consumption at different operating speeds, the fuel consumption estimated using the second method was close to the actual measured fuel consumption. The measured fuel consumption and estimated fuel consumption using the second method were significantly increased with increase in speed. Fuel consumption estimated using first method remained constant without change at different operating speeds. Both effective field capacity and field efficiency were significantly increased with increase in speed.

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