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Note

Effect of ploughing depth on average and instantaneous tractor fuel consumption with three-share disc plough

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A b s t r a c t. There are many parameters in tillage operations that affect the fuel consumption of a tractor. Also there are several methods for measuring tractor fuel consumption. In this study tractor fuel consumption was measured by flowmeter sensors. The measurement system was installed on the engine of a 72.3 KW John Deer 3140 tractor because it is one of the useful tractors, with long service life and high efficiency in Iran. A three-share disc plough was used for studying the effect of plough depth variations on tractor fuel consumption. Results showed that the tractor with the disc plough attached at depths of 15, 23 and 30 cm consumed 19.667, 24.715 and 28.646 l of fuel per hectare, respectively. Increasing plough depth from 15 to 23 and 23 to 30 cm increased fuel consumption by 25 and 15.9%, respectively. The average fuel consumption was 24 l ha^{-1} at the common plough depth of 15 to 30 cm. Instantaneous fuel consumption during operation of mouldboard plough at three depths increased when working depth increased. In farm experiments, only the working depth of plough was changed, but variations in time-consumption diagram showed that there are other factors affecting draft and thereby fuel consumption during operation, although depth variations had a more pronounced effect than others on fuel consumption.

K e y w o r d s: tillage, disc plough, ploughing depth, fuel consumption

INTRODUCTION

In Iran, disc plough is one of the tillage implements used in fields where mouldboard ploughs do not have good performance. Also John Deere 3140 tractor is one of useful tractors, with long service life and high efficiency in Iran. Ashtiani *et al*. (2007) studied the service life of some kind of tractors and reported that John Deere 3140 had fairly long service life. Ajabshirchi *et al*. (2007) reported that, when determining a mathematical model of maintenance cost for tractors, John Deere 3140 had fairly low maintenance costs. Another advantage of John Deere 3140 is high traction efficiency that Shaker (1996) has reported. Maleki *et al*. (2008) conducted a study to determine the maximum authorized time for driving a tractor and specified that maximum authorized time for driving was for John Deere 3140. In Iran the service life of tractors was determined 13 years, however John Deere 3140 tractors work powerful and useful in the farmlands till now (ABS, 2009). There are many parameters in tillage operations affecting fuel consumption of a tractor, such as type and structure of soil, climate, relative humidity, tractor type (two or four wheel drive), tractor size, and the tractor-implement relationship. Therefore, tractor fuel consumption in different methods of measurement is not constant and varies from one to another (Nielsen and Sorensen, 1993). A method for measuring fuel consumption of tractor is the use of high accuracy flowmeter sensors on the tractor. The measurement system should be connected in such a way that no problem occurs when fuel enters the system, so measurement accuracy does not decrease (Nielsen, 1987).

Research has been conducted for measuring fuel consumption of tractors using flowmeter sensors in tillage operations. Possibility of fuel savings and reduction of CO_2 emissions in soil tillage in Croatia was studied by Filipovic *et al.* (2006). In this research, fuel consumption was measured by applying a volumetric system. Kheiralla *et al*. (2007) measured tractor fuel consumption at various depths and speeds by using oval flowmeter sensor. So far, there have been no researches on instantaneous fuel consumption in tillage operation by disc plough. In addition, there are no detailed studies in Iran related to consideration of tractor fuel consumption in tillage operations using disc plough.

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In this research, tractor fuel consumption was measured at different ploughing depths of disc plough using a special system designed for measuring tractor fuel consumption. Flow-time diagram of fuel consumption was displayed when disc plough attached to the tractor, because the application of instantaneous fuel consumption diagram can be useful and effective for determining transient loads on engine and instantaneous variation of fuel consumption.

MATERIALS AND METHODS

The experiments were performed in the educational farm of agriculture faculty of Tehran University located in Karaj during October 2008. Texture of soil of this farm was loam-clay and all over the farm had the same condition (Dehroyeh, 2005). Air temperature was 16-18°C during the test period. For measuring bulk density, three soil samples from different parts of the land were collected using a cylindrical core sampler. Collected samples were immediately put in plastic bags to conserve moisture during transferring to the laboratory. Bulk density and moisture content were determined by standard methods.

A strip of land with length of 50 m was chosen for the test. Disc plough with given working width was used for tillage. Depth and acquiring tractor rpm were adjusted uniformly and stabilized in an area with length of 10 m before the target land. Start button was pressed when the tractor entered the land and stop button was pressed when the plough reached the final point. Three replications were considered for every plough depth for measuring the effect of ploughing depth on tractor fuel consumption.

In the fuel measuring system, an electronic board was used to receive and save digital pulses sent by the flowmeter sensors. In this system, a battery (as power supply), a monitoring unit, a keyboard (for controlling the operation of system), a memory (for recording data in fields where sampling and transferring data directly to computer is not possible), a connector for serial port (for adapting voltage level of micro controller to computer) and the main controller which was an AVR Atmega16 were used.

The flowmeter used for measuring input fuel value to injector pump was turbine type (VISION2000) and 6900 pulses were sent for the passage of one litre of fuel. Some specifications of this sensor were: working range: 0.1-3.0 l m^{-1}, length: 55 mm, weight: 15 g, and accuracy: 0.8% (Fathollazadeh *et al*., 2007). A sensor of turbine type (model RS256-225) was used to measure returning fuel from injectors and injector pump to the tank (Bedri and Al-Hashem, 2006).

The measurement system was installed on diesel engine of a 72.3KW John Deer 3140 (3998 kg). A three-share disc plough with working width of 1.4 m operating at 3 km h^{-1} speed was used for studying the effect of plough depth variations on tractor fuel consumption. The reason for using that tractor and disc plough was because of their popularity in Iran. The experiment was conducted at three ploughing depths of 15, 25, 30 cm.

In addition to the sensor installed where fuel enters the injector pump, a flowmeter was located where the fuel returns to the tank (Alimardani, 1987). Total engine fuel consumption over a given distance of operation was calculated by subtracting the readings from the two sensors and the result was saved in memory. Also, consumption amount per second was measured by the measurement system in order to consider instantaneous consumption. The related data were displayed by monitoring unit and saved. Duncan's multiple range test at 5% probability was performed to compare the means of different treatments by using the computer software SPSS 12.0 (Version, 2003).

RESULTS AND DISCUSSION

Tractor fuel consumption was measured during ploughing at depths of 15, 25 and 30 cm with 18.35% soil moisture and 1.106 g cm^{-3} bulk density. Operating the disc plough required 19.667 (SD: 1.941), 24.715 (SD: 1.256) and 28.646 (SD: 1.662) litres of fuel per hectare for depths of 15, 25 and 30 cm, respectively. Results of Duncan's test indicate significant differences between fuel consumption values at the three depths. As expected, the fuel consumption increased when ploughing depth increased.

Figure 1 shows the linear relationship between fuel consumption and working depth of disc plough represented as:

$$Fc = 0.599h + 10.75 \ (R^2 = 0.998),$$

where: Fc – fuel consumption (l h^{-1}), h – working depth (cm).

The results showed that with increasing depth from 15 to 23 cm (8 cm increase) fuel consumption increased by 25%. When ploughing depth increased from 23 to 30 cm (7 cm increase), fuel consumption increased by 15.9% (Fig. 2).

Instantaneous fuel consumption during operation of disc plough at three depths of 15, 23 and 30 cm is shown in Fig. 3. The diagram shows the increase of instantaneous fuel consumption when working depth increases. In the farm experiments, only working depth of plough was changed as one of the effective factors in fuel consumption rate, but variations in time-consumption diagram of disc plough at approximate speed of 3 km h^{-1} show that there are other factors affecting draft and thereby fuel consumption during operation, such as soil texture, moisture content, soil compression ratio, plant residue and bulk density (Srivastava, 1993). Fuel consumption maps can be developed using this technique, indicating spatial variations resulting from topography and soil conditions (McLaughlin, 1993).

There is a related study that shows the effect of ploughing depth with disc plough on the average value of tractor fuel consumption. Kheiralla *et al*. (2007) measured fuel consumption for a disc plough with three shares attached to a 64 kw MF3060 tractor in various conditions. They reported fuel consumption values of 20.6 and 22.7 for 17.4 and 23.4 cm depths, respectively. Although the conditions were different, average fuel consumption values obtained in this study

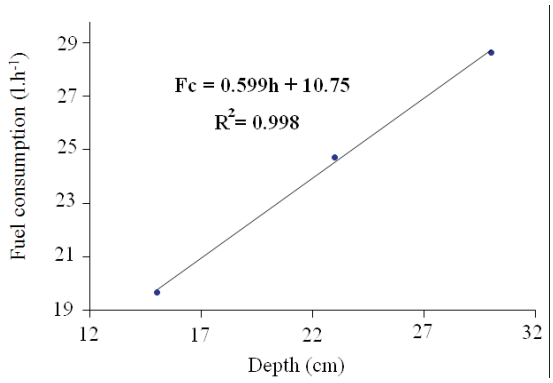

Fig. 1. Tractor fuel consumption as a function of working depth of disc plough.

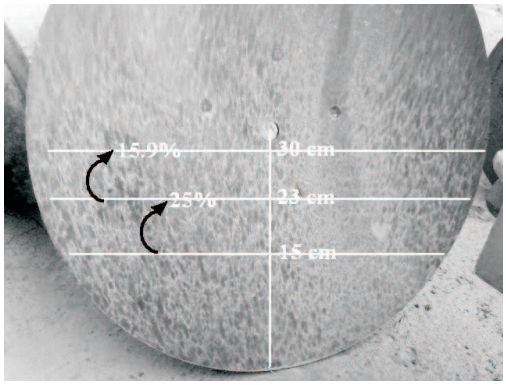

Fig. 2. Effect of depth increase on fuel consumption.

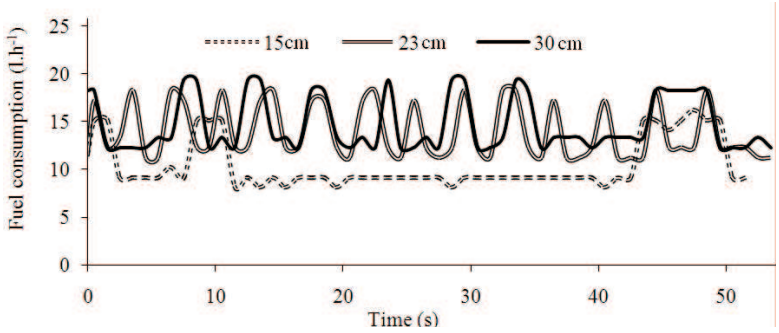

Fig. 3. Instantaneous fuel consumption by tractor engine.

are close to those reported by Kheiralla *et al*. (2007). Also there are some other studies on fuel consumption in tillage operations. Filipovic *et al*. (2006) in Croatia did a research on fuel consumption value for each applied implement in various tillage systems. They used a mouldboard plough for common tillage system attached to a 92 kW four wheel drive tractor. Results showed that mouldboard plough in tillage operation (for planting wheat and soybean) consumed 28.16 and 34.45 l of diesel fuel per hectare. They did not measure tillage depth and fuel consumption value and they only studied common tillage operation. Yalcin and Cakir (2006) studied tractor fuel consumption when using a mouldboard plough in dry and wet soils. The tractor used in their experiments was a 40 kW FIAT 54C. They reported that the tractor consumed 30 and 23 l ha^{-1} in wet and dry soils, respectively. Weideman and Meeusen (2000) reported some of their results about fuel consumption of various implements. They used a mouldboard plough with three shares attached to a 60 kW tractor when slip and working rate were 13.2% and 0.564 ha h^{-1}, respectively. Fuel consumption was reported as 32 l ha^{-1}. Koga *et al*. (2003) report that a 59 kW tractor operating with a mouldboard plough consumed 29.8 litre of fuel per hectare. Their operating system was common tillage system.

CONCLUSIONS

1. Studying of central parts of Iran showed that a tractor with three-share disc plough attached, operating at depths of 15, 23 and 30 cm, usually consumes 19.667, 24.715 and 28.646 l h^{-1}, respectively. Increasing plough depth from 15 to 23 and 23 to 30 cm increases fuel consumption by 25.0 and 15.9%, respectively. The average fuel consumption is 24 l h^{-1} in the common plough depth of 15 to 30 cm.

2. Flow-time diagram showed that some of important and effective factors of instantaneous fuel consumption during tillage operations vary continuously in the farm. Some of these factors that can be mentioned are soil texture, moisture content, soil compression ratio, plant residue and bulk density. Fuel consumption map can be developed using instantaneous fuel consumption data and a positioning system.

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