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Effect of Tillage Depth and Tractor Forward Speed on Some Technical Indicators of the Moldboard Plow

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Abstract – Due to the lack of many in-depth studies on the moldboard plow in the conditions of the Republic of Yemen before, this research was conducted with the aim of finding the effect of forward tractor speed and depth of tillage on the slippage percentage, field capacity, field efficiency and fuel consumption. The experiment was carried out in the farm of the Agriculture and Veterinary Medicine, Thamar University in the year 2015. The Massey Ferguson 275 tractor (MF 275) 67.43 hp (50.3 kW) with moldboard plow was used. Three replicates were used for each experiment, the experiment included three depths (10 cm, 20 cm, 30 cm) and three speeds (4.24, 5.54 and 6.75) (km / h) for each repeat, and the experiment included 27 identical experimental pieces. The results showed that increasing depth from 10 cm to 20 cm and 30 cm lead to increased slippage percentage (from 11.55 to 19.79 and 25.39 %), and fuel consumption (from 18.97 to 23.00 and 26.27 l/ha), but decreased field capacity (from 0.324 to 0.294 and 0.272 %) and field efficiency (from 59.39 to 53.80 and 50.04 %). Increasing speed from 4.24 to 5.54 and 6.75 km/h lead to increased slippage percentage (from 13.52 to 20.16 and 23.06 %) and field capacity (from 0.246 to 0.296 and 0.348 %) but decreased field efficiency (from 57.54 to 53.49 and 51.56 %) and fuel consumption (from 26.87 to 22.57 and 18.8 %). The first depth (10 cm) with first speed (4.24 km/h) gave the lowest slippage percentage rate (8.49 %) and the highest rate of field efficiency (61.08 %). The third speed (6.75 km/h) with first depth (10 cm) gave the highest rate of field capacity (0.381 ha/h) and les rate of fuel consumption per unit area (15.5 l/ha). The third depth (30 cm) with third speed (6.75 km/h) gave highest rate of slippage percentage (30.37 %). While the third depth (30 cm) with first speed (4.24 km/h) gave the highest rate of fuel consumption per unit area (30.8 l/h). We recommend the use of third speed (6.75km/h) and first depth (10 cm) because it recorded the highest rate of the field capacity and the lowest rate of fuel consumption per unit area (15.5).

Keywords – Slippage, Filed capacity, Field efficiency, Fuel consumption, tillage.

I. INTRODUCTION

The tillage processes areis considered one of themost important processes in agriculture, as it gives suitable conditions for root growth, which in turn supports the growth of plants, as it reduces soil resistance, increases the ventilation process and eliminates weeds (El-Shebrawy and El-Hanafy, 1997). Conservation tillage plays an important role in reducing production costs, reducing runoff, increasing soil organic matter and water infiltration rate (Roozbeh and Khani, 2020). Availability of tillage and harvesting equipment varies from region to region nationwide. Small and medium farmers usually rent farm equipment, and the costs of renting farm equipment are directly related to the price of diesel and the availability of farm machinery. As for the process of producing grains in agricultural terraces, they depend on draft animals, due to the difficulty of using tillage and mechanical harvesting equipment in these areas. Hindey, et al., (1998) Indicated that tillage is the traditional method that farmers have used to provide conditions favourable to crop growth. The chisel plow, moldboard plow and disk plow are commonly used for primary tillage in seedbed preparation. They found that using the combined tillage unit

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inseedbed preparation resulted in many of imporoved paramiters from which: higher effective field capacity, higher field efficiency and lower fuel consumption. Taieb, (1998) indicated that the primary ojectives and fundamental purposes of tillage are to prepare a suitable seedbed, to destroy competitive weeds and to improve the physical condition of the soil. Albani and Mohren,(1998) studied the effect of the dipth of tillage and the height of ridging on the quickness of flowering of paper. The results indicated that the flowering increase by increasing the tillage depth and redging height. Alshuhiri, et al., (2011) studied the economic impact of using plowing implements on yield of Mango crop. The results showed that cultivator treatment was of the highest economic return and lower cost comparing with the others treatments. Fartoot, Aalshuhiry and Mosharra, (2010) studied the effect of ploughing on yield of millet. The results showed that ploughing using disc and moldboard ploughs increase the yield of millet and improve farmer's income comparing with chisel plough and zero tillage. Gomaa, (1998) studied and evaluate the effect of blade distribution of three different types of chisel plough (two rows, three rows and v-chisel) on ploughing operation and soil properties. The result indicated that, the three rows of chisel plough gave the lowest rate of fuel consumption in L/h and L/Faddan. Taha (2011) found that increasing of tillage depth from 12.5 to 17 and 24 cm caused an increasing in fuel consumption, slippage percentage and decrease in practical productivity. Increasing ground speed of tractor from 3.06 to 4.68 and 6.68 km/h caused an increasing in fuel consumption, slippage percentage and practical productivity. According to Al-Badri and Al-Hadithy, (2011) increasing speed from 3.21-3.27 km/h lead to increased slippage percentage, practical productivity but decreased fuel consumption. Increased depth represents 10-20-30 cm lead to increased slippage percentage and fuel consumption but decreased practical productivity. Abdul-Munaim and Abdul-Razak, (2006) found that increasing plowing depth was increased the slipage percentage and decreased practical productivity. According to Al-Rajabo and Al-Taee, (2013) the plowing depth (10-12) cm gave significant reduction in the value of slippage rate and fuel consumption comparing with depth (16-18) cm. Abdul-Munaim and Al-Hadidy, (2008) indicated that whin the speed increased, it caused an increase in field capacity. Al-Jubory, et al., (2012) concluded that the increase in the depth of tillage led to an increase in the slippage percentage characteristics in%, the volume of the raised soil m^3 / h, and the fuel consumption in liters / ha, with a decrease in the value of practical productivity in donum / h. Whereas, increasing the front speed of the tractor led to an increase in the characteristics of slipage percentage %, practical productivity in donums / h, and volume of raised soil m^3 / h, with a decrease in the value of fuel consumption in liters / ha. They also recommended that tillage be carried out at low depths and at high speed. Man worked since ancient times on plowing and agitating the soil, where he used axes (haggling) to dismantle the surface layers for the purpose of irrigation and cultivation, then the process evolved into using animals to pull the municipal plow, which is still used today in many developing countries, including our country, and pointed out that the use of the plow appropriate and appropriate conditions are considered a catalyst to provide good germination conditions and good crop growth, which is reflected in the increase in crop productivity (Nagib and Fartoot, 2007). Al-Talabani, (2010) found that increasing plowing depth from 15 to 22 cm gave highest slippage precentage range of 24.805 to 40.22% with a soil distubed volume of 391.47 to 437.97 m^3/h and decreased practical productiviy from 0.279 to 0.223 ha/h and also decreased the field efficiency of practical productivity from 59.772 to 47.682 %. Al-Jubory (2011) found that the field capacity is increased by 68.9% when increased the practical speed to all the depth. And the field capacity gave the best performance when the depth is decrease; while the slipage percentage was less 15% to all the speed and depth within the permissible limits. Rawdhan, (2012) found that increasing the depth of tillage led to high in the percentage of slip, fuel consumption, capacity and traction. But down deep tillage led to the low percentage of slip, fuel consumption and towing capacity and drag force. Jebur and Alsayyah, (2017) found that with an increase in speed, the ratio of slip and field capacity increases and they recommend using low speed to reduce slip and high speed to increase productivity. From previous studies, it is clear that there are no in-depth studies on the moldboard plow in the conditions of the Republic of Yemen, and what is mentioned is only about the relationship of plowing with the crop and not the effect of the speed of the tractor and the depth of plowing on the technical indicators of the performance of the plow with the agricultural tractor. This research was carried out with the aim of investigating the effect of depth of tillage and forward tractor speed on some technical indicators of the performance of the moldboard plow with the Massey Ferguson 275 (MF 275) tractor.

II. Material and Method

2.1. Soil analysis

The soil sample was analyzed in the soil laboratory of the Agricultural Research and Extension Authority (AREA), where a sample was taken at a depth of (0 - 50) cm to find out the soil texture. The Massey Ferguson 275 tractor (MF 275)

67.43 hp (50.3 kW) was used. The experiment was carried out in the farm of the Agriculture and Veterinary Medicine, Thamar University in the year 2015. The test was carried out by operating the machinery unit (the tractor with the moldboard plow) in the field of experiment and without plowing, and the plow almost touched the ground to calculate the theoretical time for a distance of 50 meters, noting that a distance of 10 meters was left from the beginning of the working line to reach stability in the speed of the tractor. Three replicates were used for each experiment, the experiment included three depths (10 cm, 20 cm, 30 cm) and three speeds (4.24, 5.54 and 6.75) (km / h) for each repeat, and the experiment included 27 identical experimental pieces.

2.2. Studied traits

2.2.1. Slippage percentage

For the purpose of calculating the slippage, the theoretical and practical speed of the machinery unit was calculated, as the theoretical speed was calculated by running the tractor and the plow almost touching the ground along the transaction distance of (50) m to measure the theoretical time and calculate the theoretical speed from the following equation (Jasim and Madlol, 2012):

$$V_t = \frac{S_t}{T_t} \times 3.6 \ (km/h) \qquad (1)$$

Whereas:
V_t = theoretical speed (km / hr).
S_t = theoretical distance (m).
T_t = theoretical time (s).

In the same way, after the two plowshares are lowered into the ground, the practical time is measured, and then the operational velocity is calculated from the following treatment (Jasim and Madlol, 2012):

$$V_p = \frac{S_p}{T_p} \times 3.6 \left(\frac{km}{h}\right) \qquad (2)$$

Whereas:
V_p = practical speed (km / h).
S_P = Operation distance (m).
T_p = practical time (s).
3.6 = constant for converting speed from m / s to km / h
Slippage percentage was calculated using the following (Jasim and Madlol, 2012):

$$S = \frac{V_t - V_p}{V_t} \times 100 \quad (\%) \qquad (3)$$

Whereas:
V_p = practical speed (km / h).
S_P = Operation distance (m).
T_p = practical time (s).

2.2.2. Field capacity

After measuring the actual working width of the plow using a tape measure for each treatment separately, the following equation was used to estimate the field capacity of the plow operation (Jasim and Madlol, 2012):

$$P_p = 0.1 \times B_p \times V_p \times F_t \quad (ha/h) \qquad (4)$$

Whereas:
P_p = practical productivity of the plow (ha / h).
B_p = theoretical width of the plow (m).
F_t = coefficient of time utilization, and the moldboard plow has the limits of 0.67 (The previous reference)
0.1 = constant for converting practical productivity to ha / h.

The design proposal of the plow was also found in order to find the theoretical productivity of it and then the field efficiency, so the design width of the plow was (1) m. It was measured with a tape measure. The design width is the distance from the right end to the left end of the working part of the plow. The theoretical productivity of the plow was calculated for the purpose of extracting the field efficiency according to the following equation (Jasim and Madlol, 2012):

$$P_t = 0.1 \times B_t \times V_t \quad (ha/h) \qquad (5)$$

Whereas:
Pt = theoretical productivity of the plow (ha / h).
Bt = theoretical width of plow (1) m.
Vt = theoretical speed (km / hr).

2.2.3. Field efficiency of the plow

The field efficiency was calculated from the following equation (Jasim and Madlol, 2012):

$$F_e = \frac{P_p}{P_t} \times 100 \quad (\%) \qquad (6)$$

Whereas:
Fe = field efficiency (%).
Pp = practical productivity of the plow (ha / h).
Pt = theoretical productivity of the plow (ha / h).

2.2.4. Fuel consumed

The fuel consumed was calculated from the following equation AL-Jubory, et al., (2012):

$$F.c = \frac{f*10000}{W*S*1000} \qquad (7$$

Whereas:
F.c = fuel consumed (l / ha).
f = the fuel consumed during the transaction (ml).
W = width of the plow (m).

S = length of distance plowed (m)

III. Result and Discussion

3.1. Soil analysis

The results of the soil analysis test conducted during the tillage experiments are showed in Table 1. The results showed that the soil is loamy soil. The total sand is 70%, the silt 21% and the clay is 9%.

Table 1 Soil analysis test in the farm of Faculty of Agriculture

Soil texture	%
Total sand	70
Silt	21
Clay	9
Classification	loamy

3.2. Effect of depth of tillage on slippage percentage, field capacity, field efficiency and fuel consumption

Table 2 and figures from 1 to 4 show effect of depth of tillage on slippage percentage, field capacity, field efficiency and fuel consumption. From this table, it was observed that slippage percentage and fuel consumption increased with increase in tillage depth. While the field capacity and field efficiency decreased with increase in depth of tillage. Increasing the tillage depth from 10 cm to 20 cm and to 30 cm the slippage percentage and fuel consumption were increased from 11.55 to 19.79 and 25.39 % and from 18.97 to 23.00 and 26.27 l/ha respectively, while the field capacity and field efficiency were decreased from 0.324 to 0.294 and 0.272% and from 59.39 to 53.80 and 50.04 l/ha respectively. This is in agreement with Abdul-Munaim and Abdul-Razak, (2006), Al-Rajabo and Al-Taee, (2013), Al-Jubory, et al., (2012), Al-Talabani, (2010) and Rawdhan, (2012).

Table 2 Effect of depth of tillage on slippage field capacity field efficiency and fuel consumption

Depth of tillage (cm)	Slippage (%)	Field capacity (ha/h)	Field Efficiency (%)	Fuel Consumption (l/ha)	Mean
10	11.55	0.324	59.39	18.97	22.56
20	19.79	0.294	53.80	23.00	24.22
30	25.39	0.272	50.04	26.27	25.49
Mean	18.91	0.297	54.41	22.75	24.09

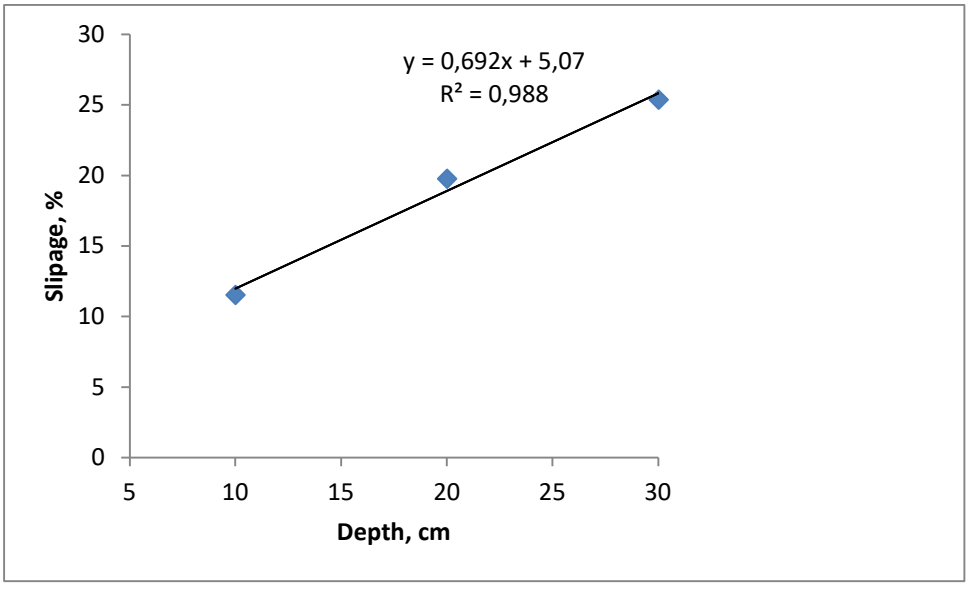

Figure 1 Effect of depth on slippage percentage

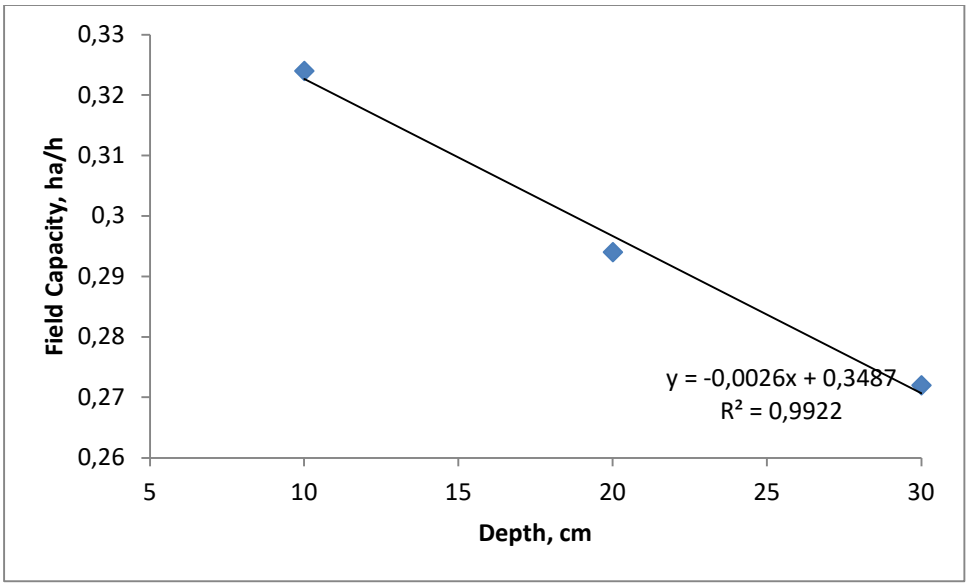

Figure 2 Effect of depth on field capacity

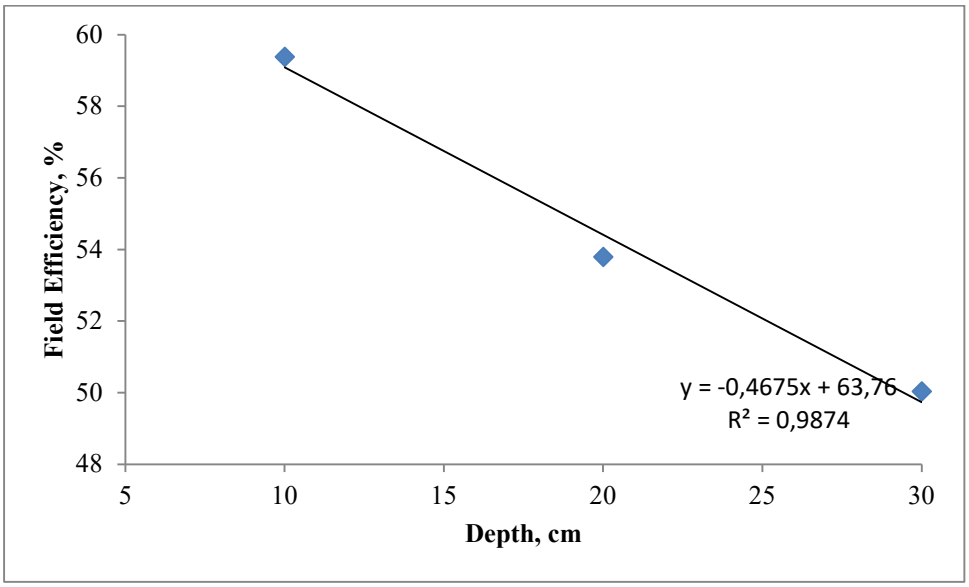

Figure 3 Effect of depth on field efficiency

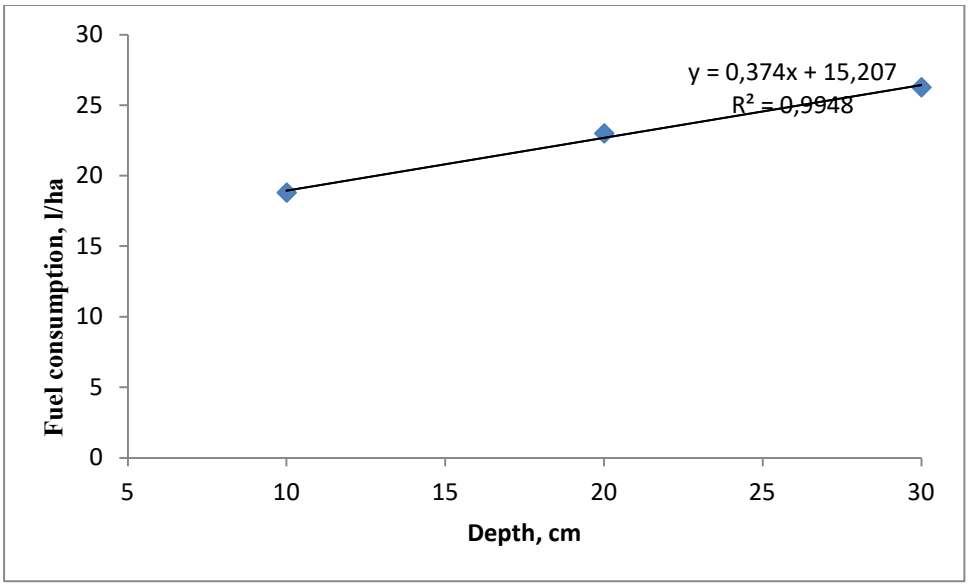

Figure 4 Effect of tillage depth on fuel consumption

The results of the regression equations obtained from the analysis for moldboard plow on clay loam soil is presented in Table 3. From this table, it was observed that the coefficient of determination values R^2 obtained from all the equations was very high which would make the equations suitable for predictive purposes.

Table 3 Regression equations showing effect of depth on studied treatments

Regression	Regression equation	R^2
Slippage percentage	S= 0.6925d+5.06	0.9878
Field capacity	F.c=-0.0026d+0.3487	0.9922
Field efficiency	F_e=-0.455d+63.437	0.9897
Fuel consumption	F.c.=0.374d+15.207	0.9948

3.3. Effect of forward speed of tractor on slippage percentage, field capacity, Field efficiency and fuel consumption

Table 4 and figures from 4 to 8 show effect of speed on the slippage percentage, field capacity field efficiency and fuel consumption. Increasing ground speed of tractor from 4.24 to 5.52 and 6.75 km/h caused an increasing in slippage percentage from 13.52 to 20.16 and 23.06% and field capacity from 0.246 to 0.296 and 0.348 ha/h. This is in agreement with Al-Jubory (2011), Abdul-Munaim and Al-Hadidy, (2008), AL-Badri and Al-Hadithy, (2011), Jebur and Alsayyah, (2017). This Increasing in speed lead to decreased field efficiency from 57.54 to 53.49 and 51.56% and fuel consumption from 26.87 to 22.57 and 18.80 l/ha respectively. This is not in agreement with AL-Badri and Al-Hadithy, (2011), Al-Jubory, et al., (2012), Jasim and Madlol, (2012). The reason for the increase in field capacity by increasing the speed is due to the fact that speed is one of the vehicles included in the equation to calculate field capacity.

Table 4 Effect of speed of tractor on slippage field capacity efficiency and fuel consumption

Speed (km/h)	Slippage (%)	Field capacity (ha/h)	Field Efficiency (%)	Fuel Consumption (l/ha)	Mean
4.24	13.52	0.246	57.54	26.87	24.54
5.54	20.16	0.296	53.49	22.57	24.13
6.75	23.06	0.348	51.56	18.8	23.44
Mean	18.91	0.297	54.21	22.75	24.04

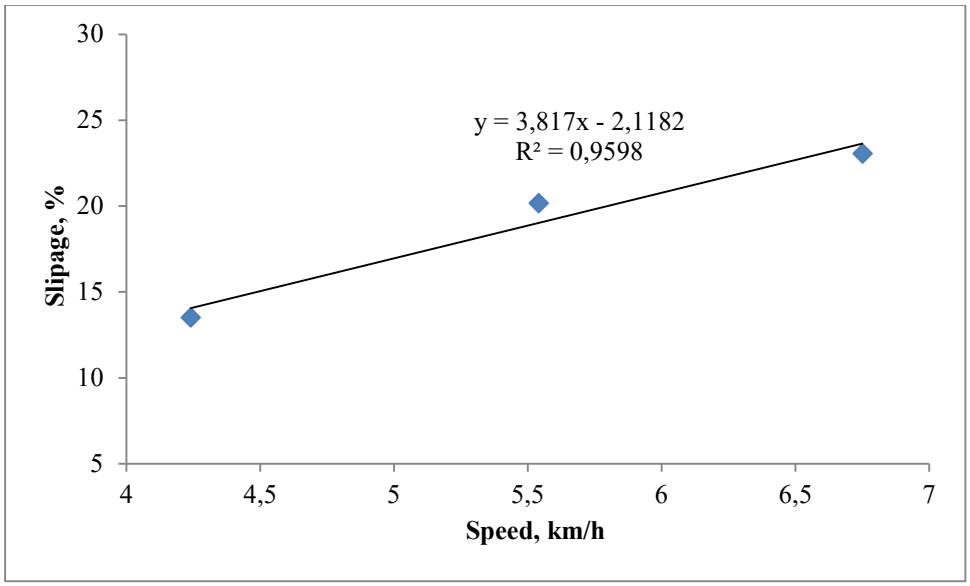

Figure 5 Effect of speed on slippage

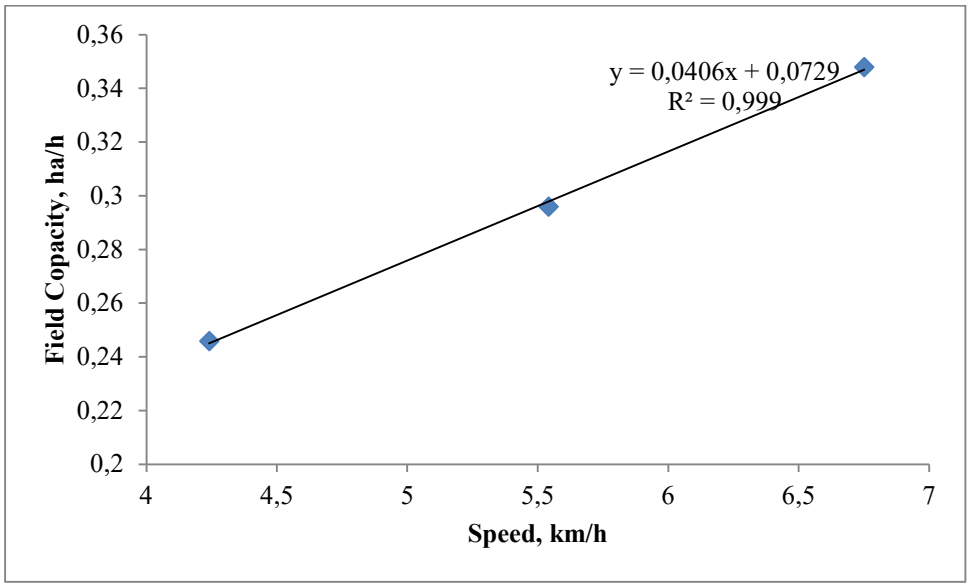

Figure 6 Effect of speed on field capacity

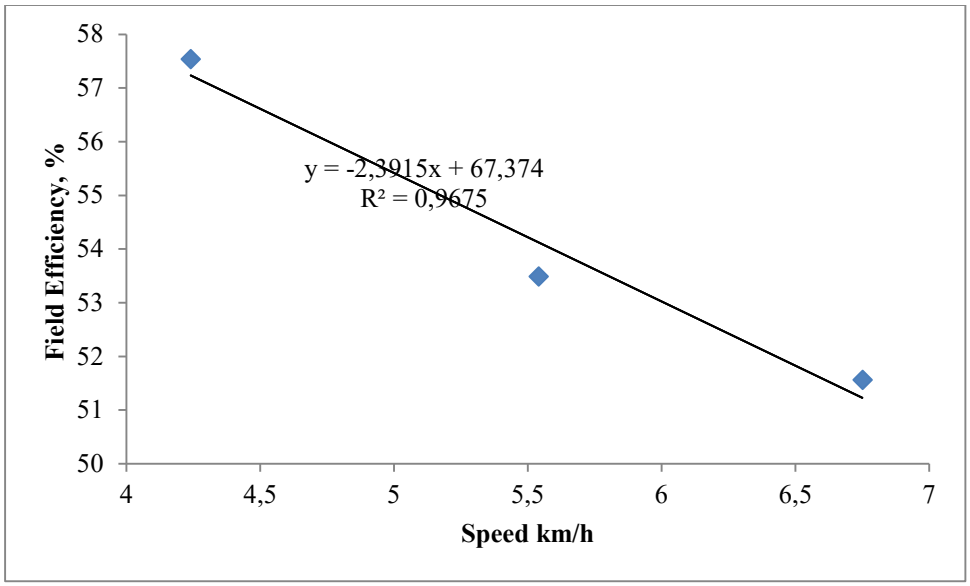

Figure 7 Effect of speed on field efficiency

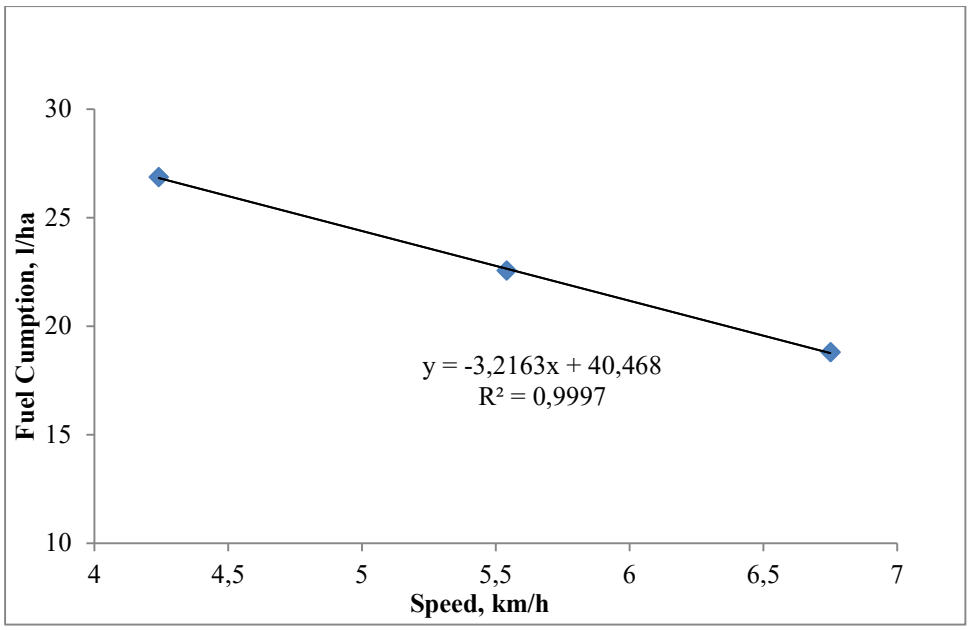

Figure 8 Effect of speed on fuel consumption

The results of the regression equations obtained from the analysis for moldboard plow on clay loam soil is presented in Table 5. From this table, it was observed that the coefficient of determination values R^2 obtained from all the equations was very high which would make the equations suitable for predictive purposes.

Table 5 Regression equations showing effect of speed on studied treatments

Regression	Regression equation	R^2
Slippage percentage	S= 2.0935s+8.7737	0.9985
Field capacity	F.c=0.0213s+0.1933	0.9304
Field efficiency	F_e=-1.4007s+61.114	0.9986

3.4. The effect of the interaction between depth of tillage and tractor speed

Table 6 shows the interaction between tillage depth and tractor speed. It is noticed from Table 4 that all the traits were affected by this interaction. Tillage depth 10 cm and speed 4.24 km/h gave the lowest slippage percentage of 8.49 % and the highest field efficiency of 61.08 %. The interaction between tillage depth 10 cm and speed 6.75 km/h gave the highest field capacity of 0.381 and lowest fuel consumption of 15.50 l/ha. Tillage depth 10 cm and 4.24 km/h gave the highest fuel consumption of 30.80 l/ha, while tillage depth 30 cm and speed 6.75 km/h gave the highest slippage percentage of 30.37%. This is in agreement with Jasim and Madlol (2012) and Al-Jubory et al. (2012).

Table 6 Effect of the interaction between tillage depth and tractor speed

Depth of tillage (cm)	Speed (km/h)	Slippage (%)	Field capacity (ha/h)	Field Efficiency (%)	Fuel Consumption (l/ha)	Mean
10	4.24	8.49	0.259	61.08	22.60	23.11
	5.54	10.47	0.332	59.92	18.8	22.38
	6.75	15.70	0.381	56.44	15.5	22.01
20	4.24	14.62	0.243	57.31	27.20	24.84
	5.54	21.66	0.291	52.53	22.50	24.25
	6.75	23.11	0.348	51.56	19.30	23.58
30	4.24	17.45	0.235	55.43	30.80	25.98
	5.54	28.34	0.266	48.01	26.400	25.75
	6.75	30.37	0.315	46.67	21.60	24.74
Mean		18.91	0.297	54.33	22.74	24.07

IV. Conclusion

Field experiment was performed to determine the effects of tillage depth and forward speed on the slippage percentage, field capacity, field efficiency and fuel consumption. The soil test from the field showed that the soil classification is loamy soil. Increase in slippage percentage and fuel consumption was observed with an increase in tillage depth. While the field capacity and field efficiency was decreased with an increase in tillage depth. Increase in slippage percentage and field capacity was observed with an increase in forward speed. While the efficiency and fuel consumption was decreased with an increase in forward speed. From the interaction between tillage depth and forward speed we can concluded that the low tillage depth with low speed gave the lowest slippage percentage rate and the highest rate of field efficiency. The high speed with low tillage depth gave the highest rate of field capacity and les rate of fuel consumption per unit area. The high tillage depth with high forward speed gave higher rate of slippage percentage. The high tillage depth with low forward speed gave the highest rate of fuel consumption per unit area. The very high values of coefficient of determination would make the equations suitable for predictive purposes. We recommend the use of high speed and low depth because it recorded the highest rate of the field capacity and the lowest rate of the fuel consumption per unit area.

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