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Original Research

The effect of power losses for agricultural tractor on tractive efficiency

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ABSTRACT:

The present study was conducted to determine the effect of depths of plough at the farm by tractor on tractive efficiency and operation costs. The studied variables were two depths of plough (16-20 and 21-24cm), three equipment plough (disk, chisel and sweep) and five different forward speeds. The average soil moisture content was (18.61%) and the soil texture was found to be silt-clay. The study was focused on the rate of power losses, fuel consumption, pull ratio, tractive efficiency and operation costs. The experiment was carried out by using split-split plot with complete randomized block design, three replicates. The obtained results, for the range of tests, showed that the use of disk plough superposed the chisel plough and sweep plough, in recording lowest rate of fuel consumption (16.016 l/h). While the sweep plough superposed the chisel plough and disk plough, in recording lowest rate of power losses (10.13 kW) and higher rate of tractive efficiency (75.17%). The forward speed (8.14 km/h) superposed in recording higher rate of pull ratio (0.482) and lowest rate of operation costs 23592 ID/ha. While the first forward speed (2.72 km/h) was superior on other forward speed in recording lowest rate both of fuel consumption (13.80 l/h) and power losses (1.99 kW), and higher rate of tractive efficiency (75.49%), in the meantime, the depths of plough (16-20cm) recorded lowest rate of fuel consumption (16.97 l/h), power losses (9.64 kW), operation costs 23903ID/ha and higher rate both of tractive efficiency (75.36%) and pull ratio (0.441).

Keywords:

Costs, Chisel, Plough, Power, Sweep.

Abbreviation: **FS:** Forward speed (km/h); **FC:** rate of fuel consumption (l/h); **A:** Rolling resistance for the working unit (kN); **B:** The recording pull by using implement (kN); **Ndp:** Net drawbar pull (kN); P_d**:** Drawbar power (kW); P_{sl}**:** Power consumed by slip (kW); P_{dp}**:** Drawbar power (kW); P_{rr}**:** Rolling resistance power (kW); T_t**:** Cost per hour of operation (ID/h); **Efc:** Effective Field capacity (ha/h); **Oc:** Operation costs (ID/ha).

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INTRODUCTION

The farm tractor is the key source of power on the farm, which meets these requirement of the required power but there are diversity and significant difference of existing tractors in the agricultural field in many countries of the world, including Iraq. The efficiency and capacity of the agricultural tractor is determined according to the type and nature of the work (towing, loading) with the various agricultural machines in a number of well-studied calibrations in accordance with the suitability of the tractor and the nature of the agricultural land according to its dimensions on the ground; and also on the basis of the agricultural equipments associated with it. This in turn encourages states to expand the use of units of agricultural mechanization to provide human capital and raising the quality of agricultural products, but the development did not seem obvious unless in the current century. Drawbar work is known through pull force and speed. Therefore, the tractor cannot convert the full energy of fuel into useful work at the drawbar. Virtually, most of the potential energy is lost in transforming chemical energy into mechanical energy, along with losses from the engine through the drivetrain and finally through the tractive device. Research showed that about "20% to 55%" of the available tractor energy is exhausted at the tractive device (Wulfsohn, 1988). Efficient traction of tractors includes; maximizing the fuel efficiency of the engine and propulsion system, maximizing the tractive priority of the traction devices, and selecting an optimum forward speed for a given tractor-implement system (Zoz and Grisso, 2003).

Al-Aridhee (2011) found that fuel consumption may fit directly proportional with increasing depth, and attributed that to the increased depth requiring, more work and more fuel consumption. Aday *et al*. (2008) concluded that higher tractor forward speed may give the least amount of fuel consumption per unit area because high speed leads to a reduction in the period of time to complete the unit area as well as losing the tractor ability optimally in the slow speeds. Tillage speed has significant impact on the traction force and increasing tillage speed lead to the increase of traction force, and on this, the foundation of the primary speed recorded 3.35 km/h as the least traction force, reaching 6.149 kN while third speed reached 6.55 km/h and the highest traction force, reached to 7.821 kN. The reason attributed to that increase accelerated tillage led to further accelerate in soil compounds and increase the energy given to the soil as a result of increased speed (Hilal, 2010). High tractive efficiency was obtained at a lower of slip in the range of 10–20%. Higher tractive efficiency occurred at a pull ratio of 0.40–0.50. Abbaspour *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. Younis *et al*. (2010) indicated that the performance of drawbar test has measured the following data: forward speed, fuel consumption, the equivalent forward speed and drawbar pull. This research was conducted to facilitate the task of selecting the suitable tractor with the implement. The study aims at evaluating the impact of the traveling speed and depths of plough on tractor performance parameters, namely power losses, tractive efficiency and fuel consumption.

MATERIALS AND METHODS

The experimental study was carried out at the college of agricultural-University of Baghdad. This

Table 1. Mechanical analysis of the experimental soil

S. No	pH	Electrical conductivity (ds/m)	Soil penetration resistance (kPa)	Porosity (%)	Bulk density (gm/cm^3)	Soil type	Soil texture (%)		
							Clay	sand	silt
1	7.52	8.69	4.88	41.35	2.56	S.C.L	31.7	58.1	2.10

paper presents the results of evaluation of the effect of depths of plough and different forward speeds on traction parameters and performance of an agricultural tractor, under field working conditions, in silt-clay loam soil. The variable depths of plough (16-20 and 21-24cm and forward speeds (from 2.72 to 8.14 km/h) were used. The mechanical analysis of the soil is shown in Table 1. The following materials and methods were used

A. Descriptions of tractors and implements:

Tractors

New Holland tractor model WD2*80-66 s NH, 80 hp-59.66 kW), and IMT-285 tractor (75 hp-55.93 kW).

Sweep plough

A local manufacture (1 board).

Disk plough

A local manufacture "State company for mechanical industries", Model PAM, type mounted three point hitch, Number of disks (3), Type of plate (standard), total working width of cut (90cm) and total weight (380 kg).

Chisel plough

A local manufacture "State company for mechanical industries", total width of 170cm, 9 boards.

B. Measuring instruments

Spring dynamometer and Fuel consumption apparatus.

C. Parameter measurement and determination:

Forward speed (FS)

The forward speed was calculated as follows:

$$FS = \frac{x}{t} \times 3.6$$ (Macmillan, 2002)

Fuel consumption (FC)

The fuel consumption was calculated as follows:

$$FC = \left(\frac{V}{t}\right) \times 3.6$$ (Macmillan, 2002)

Pull force

The draft force of the tractor was measured by using a spring dynamometer. The attached with a horizontal chain between two tractors to measure the draft force. Two wheel drive tractor (IMT-285), was used as a rear (towed) on which the implement was mounted; whereas the front tractor (New Holland) was used to pull the towed tractor with the attached implement through the spring dynamometer. The towed tractor was working on the neutral gear while the implement that was in the operating position. 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:

Drawbar power:

P_{dp} = NDP ×FS /3.6 (Younis and EL-Said, 2009)

Power consumed by rolling resistance (P_{rr}):

P_{rr} (kW) = rolling resistance (kN) ×FS (km/h)/3.6

Pull ratio:

$$Pull\ ratio = \frac{Net\ drawbar\ pull\ (kg)}{Weight\ on\ rear\ wheel\ (kg)}$$

(Zoz and Grisso, 2003)

Power consumed by slip (P_{sl}):

$$P_{si} = [P_{db} + P_{rr}] \times \frac{S}{100 - S}$$ (Younis and EL.Said, 2009)

Tractive efficiency

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

(Sharma and Mukesh, 2010)

Effective Field capacity (E_{fc})

$$Effective\ Field\ Capacity = \frac{1}{\substack{effective\ total\ in\ hours \\ required\ per\ feddan}} \ldots ha.h^{-1}$$

(Liljedahl *et al*., 1989)

Operation costs

$$T_t = \left(\frac{C}{h}\right)\left(\frac{1}{L} + \frac{i}{2} + a + r\right) + (1.2\,P.S.f) + \frac{m}{144} \quad \ldots I.D/h$$

(Awady, 1987)

So equation becomes. Cost per unit work (Oc) = Hourly cost "T_t" / Effective Field capacity (E_{fc}).

Table 2. Effect of the forward speed, depths of plough and equipment on fuel consumption (l/h)

S. No	Characters studied		Fuel consumption (FC), l/h					
	Transactions		Interaction between, depths, equipment and speed					
	Equipment of plough	Depths of plough (cm)	Forward speed km/h					Average depths of plough (cm)
			8.14	6.43	4.31	3.23	2.72	
1	Disk	16-20	19.130	17.110	14.730	13.130	12.520	16.97
2	Chisel		19.363	17.730	15.120	13.630	12.820	
3	Sweep		21.233	18.120	15.640	14.750	13.930	
1	Disk	21-24	20.850	18.540	15.216	14.623	14.230	17.29
2	Chisel		21.250	19.112	16.920	15.327	14.422	
3	Sweep		21.662	19.653	16.851	15.841	14.846	
	L.S.D = 0.05		0.0243±0.001					0.0032
	Average of speed		20.58	18.38	15.75	14.55	13.80	
	L.S.D = 0.05		0.0053±0.0004					
	Average equipment of plough							
			Sweep		Chisel		Disk	
			17.252		16.569		16.016	
	L.S.D = 0.05		0.0032±0.0001					

RESULTS AND DISCUSSION

This experiment was conducted in the field in order to evaluate a precision performance the tractor and implements, and also to determine the best working engineering performance parameters for the machine unit.

Fuel Consumption (FC) l/h

Results illustrated in Table 2 shows the effect of forward speed, depths of plough and equipment and their overlaps on the fuel consumption and is illustrate in Table 2. As seen from the table, the increase of the forward speed (2.72, 3.23, 4.31, 6.43 and 8.14 km/h), increased FC (1380, 18.38, 15.75, 14.55 and 20.581/h) respectively with an average of 32.94%. The reason is that the tractor ability does not show optimally at slow velocities. Therefore, waste exists in energy. These results are consistent with the ones obtained by Kassar (2011) and Jebur (2016). The high velocities need a short time period to complete unit area according to the results of Khalilian *et al*. (1988). The same table shows that increasing depths of plough has increased the fuel consumption with the ratio of 1.85%. This is because the increase in depth leads to increasing rolling resistance to penetrate and wheel slip; therefore, the tractor consumes more fuel to overcome this influence. These results are consistent with Khorshid (2016). Also the results in the Table 2 illustrated that the use of disk superposed the chisel plough and sweep plough, in recording lowest FC (16.016 l/h). The reason may be because of consuming less amount of power. These results are consistent with the ones obtained by Khader (2008). So the Table 2 indicate that the interaction between equipment, forward speed and depths of plough were significant on the FC, whereas the triple overlap between the forward speed 2.72 km/h, disk plough and depths of plough 16-20cm led to obtain the lowest FC and was found to be12.52 l/h, while the highest FC was 21.662 l/h resulting from the overlap of the sweep plough, depths of plough 21-24cm and traveling speed 8.14 km/h as.

Table 3. Effect of the forward speed, depths of plough and equipment on pull ratio

S. No	Characters studied		Pull ratio					
	Transactions		Interaction between, depths, equipment and speed					
	Equipment of plough	Depths of plough (cm)	Forward speed km/h					Average depths of plough (cm)
			8.14	6.43	4.31	3.23	2.72	
1	Disk	16-20	0.533	0.497	0.457	0.419	0.392	0.441
2	Chisel		0.475	0.429	0.389	0.377	0.328	
3	Sweep		0.475	0.417	0.382	0.372	0.313	
1	Disk	21-24	0.483	0.471	0.423	0.384	0.349	0.399
2	Chisel		0.473	0.413	0.406	0.357	0.341	
3	Sweep		0.449	0.441	0.398	0.367	0.285	
	L.S.D = 0.05		0.0948±0.003					
								0.0356
	Average of speed		0.482	0.445	0.409	0.378	0.335	
	L.S.D = 0.05		0.0389±0.001					
	Average equipment of plough							
			Sweep		Chisel		Disk	
			0.390		0.403		0.417	
	L.S.D = 0.05		0.0386±0.002					

Pull ratio

Results illustrated in Table 3 shows the effect of forward speed, depths and equipment and their overlaps on the pull ratio are illustrate in Table 3. As seen from the table, the increase of the forward speed (2.72, 3.23, 4.31, 6.43 and 8.14 km/h), increased pull ratio (0.335, 0.379, 0.409, 0.445 and 0.482) respectively. The same table shows that the increasing depths of plough, the pull ratio has decreased. Also the results in the Table 3 illustrate that the use of disk plough superposed the moldboard and chisel plough, in recording higher pull ratio (0.417). Also Table 3 shows that the interaction between equipment, forward speed and depths of plough were significant on the pull ratio, whereas the triple overlap between the forward speed 8.14 km/h, disk plough and depths of plough 16-20cm led to obtain the highest pull ratio was 0.533%, while the lowest pull ratio 0.285% resulting from the overlap of the sweep plough, depths of plough 21-24cm and traveling speed 2.72 km/h.

Power losses (kW)

The effect of forward speed, depths of plough and equipment, and their overlaps on the power losses are tabulated in Table 4. As seen from the table, the increase of the forward speed (2.72, 3.23, 4.31, 6.43 and 8.14 km/h), increased power losses (1.99, 4.43, 8.25, 14.75 and 22.54 kW) respectively with average of 91.17%. The reason may be attributed to the fact that one of the factors involved in the calculation of speed that led to increase of power losses. These results are consistent with the results obtained by Madlol and Jebur (2014). The same table shows that increasing of the depths of plough the power losses has increased from 9.64 to 11.15 kW, with a ratio of 13.54%. The reason is that the increase of depths of plough led to the increase of load on the tractor consequence increased energy consumption. These results are consistent with the re-sults obtained by Zedan (2006). Also the results in the

Table 4. Effect of the forward speed, depths of plough and equipment on power losses (kW)

S. No	Characters studied		Power losses (kW)					
	Transactions		Interaction between, depths, equipment and speed					
	Equipment of plough	Depths of plough (cm)	8.14	6.43	4.31	3.23	2.72	Average depths of plough (cm)
1	Disk	16-20	22.27	13.90	7.64	4.09	1.84	9.64
2	Chisel		20.97	13.26	7.35	3.85	1.70	
3	Sweep		21.93	12.56	7.81	4.23	1.79	
1	Disk	21-24	25.17	17.34	9.37	4.90	2.43	11.15
2	Chisel		22.87	16.32	8.63	4.61	2.01	
3	Sweep		22.59	15.14	8.75	4.88	2.18	
	L.S.D = 0.05				1.2397±0.02			0.3736
	Average of speed		22.54	14.75	8.25	4.43	1.99	
	L.S.D = 0.05				0.5600±0.04			
	Average equipment of plough							
			Sweep		Chisel			Disk
			10.13		10.16			10.89
	L.S.D = 0.05				0.0628±0.005			

Table 4 illustrate that the use of sweep plough superposed the disk plough and chisel plough, in recording lowest power losses (10.13 kW). So Table 4 indicate that the interaction between equipment, forward speed and depths of plough were significant on the power losses, whereas the triple overlap between the forward speed 2.72 km/h, disk plough and depths of plough 16-20cm led to obtain the lowest power losses i.e., 1.84 kW.

Tractive efficiency (η_{TE})

Table 5 showed the effect of forward speed, depths of plough and equipment and their overlaps on the tractive efficiency. As seen from the table, the increase of the forward speed (2.72, 3.23, 4.31, 6.43 and 8.14 km/h), decreased tractive efficiency (75.49, 75.24, 74.33, 73.77 and 73.10%) respectively. This may be due to the losses in output power that come from both slip and rolling resistance. These results are consistent with the results obtained by Jebur (2015). The same table showed that with the increasing depths of plough, the tractive efficiency has decreased from 75.36% to 73.41%. This may be due to the increased power losses. Also the results in the Table 5 illustrate that the use of sweep plough superposed the chisel and disk plough, in recording highest tractive efficiency (75.17)%. The reason may be because of recording highest average of drawbar power. So the Table 5 indicate that the interaction between equipment, forward speed and depths of plough were significant on the tractive efficiency, whereas, the triple overlap between the forward speed 2.72 km/h, sweep plough and depths of plough 16-20cm led to obtain the highest tractive efficiency of 77.22%, while the lowest tractive efficiency was 70.67% resulting from the overlap of the disk plough, depths of plough 21-24cm and traveling speed 8.14 km/h.

Operation costs (ID/ha)

Table 6 showed the effect of forward speed, depths of plough and equipment and their overlaps on the operation costs. As seen from the table, the increase of the forward speed (2.72, 3.23, 4.31, 6.43 and 8.14

Table 5. Effect of the forward speed, depths of plough and equipment on tractive efficiency (%)

S. No	Characters studied		Tractive efficiency (%)					
	Transactions		Interaction between, depths, equipment and speed					
	Equipment of plough	Depths of plough (cm)	8.14	6.43	4.31	3.23	2.72	Average depths of plough (cm)
1	Disk	16-20	73.624	74.231	74.856	75.431	75.843	75.36
2	Chisel		74.226	74.451	75.331	76.251	76.561	
3	Sweep		74.763	75.061	75.912	76.621	77.223	
1	Disk	21-24	70.670	71.456	71.810	73.583	73.647	73.41
2	Chisel		71.970	73.370	73.893	74.273	74.370	
3	Sweep		73.303	74.047	47.157	75.280	75.297	
	L.S.D = 0.05		0.0249±0.001					0.3736
	Average of speed		73.10	73.77	74.33	75.24	75.49	
	L.S.D = 0.05		0.00623±0.0002					
	Average equipment of plough							
			Sweep		Chisel		Disk	
			75.17		74.47		73.51	
	L.S.D = 0.05		0.0521±0.005					

Table 6. Effect of the forward speed, depths of plough and equipment on operation costs (ID/ha)

S. No	Characters studied		Operation costs (ID/ha)					
	Transactions		Interaction between, depths, equipment and speed					
	Equipment of plough	Depths of plough (cm)	8.14	6.43	4.31	3.23	2.72	Average depths of plough (cm)
1	Disk	16-20	20745	23232	24365	26545	27745	23903
2	Chisel		20114	22851	24121	25654	27321	
3	Sweep		18684	21524	23654	25153	26841	
1	Disk	21-24	28117	29543	30126	30523	31724	29313
2	Chisel		27346	28258	29652	30325	31154	
3	Sweep		26548	27823	28563	29567	30434	
	L.S.D = 0.05		1145.4±15.5					936.23±26.3
	Average of speed		23592	25538	26747	27961	29203	
	L.S.D = 0.05		1126.16±33.2					
	Average equipment of plough							
			Sweep		Chisel		Disk	
			25879		26680		27266	
	L.S.D = 0.05		961.31±62.3					

25538 and 23592 ID/ha) respectively. The reason may be attributed to the fact that increasing of practical speed led to increase of effective field capacity. Therefore, the tractor costs decreased as a result of the reverse km/h), decreased operation costs (29203, 27961, 26747, relationships between effective field capacity and tractor costs. These results are consistent with the results obtained by Mayfield *et al*. (1981). The same table shows that increasing depths of plough and operation costs have decreased from 23903ID/ha to 29313ID/ha. This may be due to the increased fuel consumption, therefore the operation costs increased. These results are consistent with those obtained by Al-Janobi (2000) and Jabour, (2010). Also the results in the Table 6 illustrate that the use of sweep plough superposed the chisel and disk plough, in recording lowest operation costs 25879 ID/ha. So the Table 6 indicate that the interaction between equipment, forward speed and depths of plough were significant on the operation costs, whereas the triple overlap between the forward speed 8.14 km/h, sweep plough and depths of plough 16-20cm led to obtain the lowest operation costs i.e., 18684ID/ha, while the highest operation costs was 31724ID/ha resulting from the overlap of the disk plough, depths of plough 21 -24cm and traveling speed 2.72 km/h.

CONCLUSION

Increasing the forward speed in an increase in fuel consumption, power losses per unit area and a significant decrease in tractive efficiency, pull ratio and operation costs. Also increasing the depths of plough in a significant increase in power losses, operation costs and fuel consumption. The use of depths of plough 16-20cm produced the highest value (75.36%) of tractive efficiency, while the lowest value of tractor costs was 29313ID/ha. The sweep plough recorded highest value (75.17%) of tractive efficiency and lowest value (25879 ID/ha) of operation costs.

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