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Determination and Analysis of Gross Power Losses for the Farm Tractor using Prediction Equations during Field Operations

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ABSTRACT

Investigation was carried out to study the effect of the forward speed and tire inflation pressure of the farm tractor on gross power losses, and tractive efficiency. The studied variables are the equipment (moldboard plough, disk plough and disk harrow), tire inflation pressure (80, 140 and 160 kPa) and five different forward speeds (3.86, 4.18, 4.76, 5.82 and 7.21 km/h). The ploughing depths were (15-20 cm) and average soil moisture content (14.56 %). the soil texture was found to be a (Clay). The study was focus on the rate of drawbar pull, drawbar specific fuel consumption, travel redaction (slip), tractive efficiency and gross power losses. The experiment was carried out by using *split-split plot with complete randomized block design in three replicates*. The obtained results, for the range of tests, showed that the use of 80 kPa tire inflation pressure superposed the (140 and 160 kPa), in recording lowest rate of slip (6.31 %), and higher rate of drawbar pull (16.097 kN). The forward speed (3.86 km/h) superposed in recording lowest rate of gross power losses (5.29 kW), and higher rate of tractive efficiency (74.017 %) and drawbar specific fuel consumption (0.98 l/kW.h). While the fifth forward speed (7.21 km/h) was superior on other forward speed in recording higher rate of drawbar pull (17.12 kN), in the meantime the moldboard plough recorded higher rate of tractive efficiency (75.37 %) and drawbar pull (20.69 kN), While the use of disk harrow recording lowest rate of slip (4.898 %) and power losses (7.40 kW). The relationship fits the experimental data on studying the effect of tire inflation pressure (I.P) and forward speed (FS) on reduce of gross power losses (L_{power}) by prediction regression equations.

Introduction

In general, the forward speed, tire inflation pressure and soil moisture content were the most important factors that affecting the drawbar pull and the fuel consumption, to reduce power losses should be improve operating efficiency, optimizing engine fuel efficiency, maximizing the tractive performance of the traction device, appropriate matching, selection of the forward speed for given tractor implement system. High tractor power than the implement-needed causes a soil compaction and lower operation efficiency due to the increase of the tractor weight, power losses, fuel consumption and also high fixed cost compared with the matched tractor, low tractor power than the implement needed causes a power loss and tire wearing because of the slippage. Baloch et. al. (1991) concluded that the tractive performance may be evaluated by means of a pull-slip test. The tractor must ensure to be efficiently utilized through implement draught. The effects of draught on the performance of different tillage tools and implements in different countries have been investigated (Shrestha et al., 2001; gratton et al., 2003; Mclaughlin and Campbell, 2004). All these researchers observed that draught varies with variations in soil conditions, tool design and operational parameters. Younis et al. (2010) indicated that the performance of drawbar test has been measured the following data: forward speed, fuel consumption, the equivalent forward speed and drawbar pull.

Nomenclature	
MC	Soil moisture content (dry basis), %
W_w	wet soil mass, gm
W_d	dry soil mass, gm
FS	Forward speed, km/h
x	Traveling measured distance, m
t	Traveling measured time, sec.
FC	rate of fuel consumption, l/h
V	volume of consumed fuel in glass bulb, ml
t	time, s
A	Rolling resistance for the working unit, kN
B	The recording pull by using implement kN
Ndp	Net drawbar pull, kN
W.S	wheel slip, %
FS_1	Forward speed without load km/h.
FS_2	Forward speed with load km/h.
D_p	Drawbar pull, kN
P_{dp}	Drawbar power, kW
P_{rr}	Power consumed by rolling resistance, kW
D.s.fc	Drawbar specific fuel consumption, l/kW.h
P_{sl}	power consumed by slip, kW
η_{TE}	Tractive efficiency. %
L_{power}	Power Losses, kW
I.P	inflation pressure, kPa
R^2	Regression of determination.
SE	Standard Error
Rr	rolling resistance, kN

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The maximum drawbar power affected by drawbar pull as showed (62.31 and 62.58 kW) at highest forward speed of (6.72 and 7.7 km/hr), respectively. Studies have demonstrated that reduction in soil compaction, coefficient of rolling resistance and sinkage, obtained through decreasing the wheel load are not as significant as those obtained by decreasing tire pressure (Popescu & Ene, 2007). Benefits from lower inflation pressure could include decreased soil-tire interface pressure, increased tire performance and decreased soil compaction (McAllister, 1983). El-Ashry et. al. (2003) carried out field experiments to evaluate the tractive performance at different levels of inflation pressure (75, 100 and 125 kPa) and ballast conditions (0, 60 and 90 kg) in ploughed and unploughed soils. They concluded that the tractive efficiency decreased as the inflation pressure increased from 75 to 125 kPa in the tilled and untilled to soil. Al-Hamed et. al. (2001) studied the effect of rear tire inflation pressure (on the front wheel assist tractor performance in sandy loam soil). They found that the lower rear tire inflation pressure the better tractive performance. Abu-Hamed and Al-Widyan. (1998) operation of agricultural tractors near their maximum tractive efficiency increases tractor productive output and results in fuel savings. However, operating condition in the field affect on performance of tractors, fuel consumption and physical properties of soil. Wiley et. al. (1992) showed that inflation pressure and dynamic load are important factors that affect the performance of tractor tires. Efficient use of agricultural tractors includes optimizing engine fuel efficiency, maximizing the tractive performance of the traction device, and appropriate matching and selection of the forward speed for a given tractor-implement system Jenane & Bashford (2000). The drawbar pull and wheel slip increased by increasing the forward speed, also the amount of energy consumed during chisel plough and seed drill operations depend on soil and operating conditions Jebur et. al (2013). 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.. Dahab & 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. The purpose of this study was to test and evaluate the effect of tire inflation pressure and soil moisture content on tractor performance parameter, namely; tractive efficiency, drawbar pull, slip, power losses and drawbar specific fuel consumption during field operations: ploughing and harrowing.

Materials and Methods

Field tests were carried out in Meet El-Deeba Rice Mechanization Center, Kafr El-Sheikh Governorate, Egypt. This paper presents the results of evaluation of the effect of tire inflation pressure and different forward speeds on traction parameters and performance of an agricultural tractor, under field working conditions, in clay soil. The variable inflation pressure (80, 140 and 160 kPa) and forward speeds (from 3.86 to 7.21 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				CaCo3, %	Soil textural class
Clay, %	Silt, %	Fin sand %	Coarse sand, %		
53.11	16.64	29.05	1.20	1.3	clay

The following materials and methods were used

A- Descriptions of tractors and implements

1- Tractors

Two tractors were used in the experiment, namely, Dutz tractor model DX 6.30 (4×4), 115 hp (85.8 kW) with an engine rated speed of 2400 rpm, and Ford tractor model 7610 (76 hp-59.7 kW).

2- Moldboard plough

A three blades mounted moldboard plough was used in this experiment. It was manufactured by Behera Company.

3- Disk plough

Model D-326A, made in Romania, type mounted three point hitch, Number of disks (3), Type of plate (standard), disk diameter 66 cm, distance between disks 60 cm, total working width of cut (90 cm) and total weight (535 kg).

4- Disk harrow

A total width of 330 cm, it has four groups of disks, two groups in front and the others in the rear, the disks in the rear groups are completed edges, but the groups in front are notched, the average measured disk's diameter are 59 cm, the measured distance between each two disks in each group were 23 cm.

B- Measuring instruments

Strain gauge dynamometer, data logger (Daytronic system 10), portable computer, Fuel consumption apparatus, 3- 50 m tape and 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 two depths 0-10 cm and 10-20 cm by screw ouger. 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:

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

The soil moisture content of the area at two depths is given table (2).

Table (2). Soil moisture content

Replications	Depth of soil sample, cm		Average
	0-10	10-20	
Soil moisture content (14.56 %)			
1	13.9	15.5	14.70
2	12.8	15.7	14.25
3	14.3	15.2	14.75
Average			14.56

2- Forward speed (FS)

It was calculated as follows

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

3- Fuel consumption (FC)

The fuel consumption is one of the most important measurements of any research and tractor test as it represent the power required for any operation.

Measurement and calculation of fuel consumption for tractor engine was performed on the basis of volume under different operation by using diesel fuel .the system depends on the measurement of a given volume of fuel consumed in the operation of the engine during certain period of time where it is determined by using stopwatch. The device shown in fig (10) consists of a secondary tank installed on the dashboard, the bottom of this tank is equipped with a control valve that allows the fuel to pass during operation by hose which is connected to a glass bulb tube to show the volume of fuel passing and having capacity of 30 ml. through, the glass tube was connected to the fuel supply system at inlet of the fuel filter directly and being linked to the fuel line return from injectors by transparent hose.. It was calculated as follows:

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

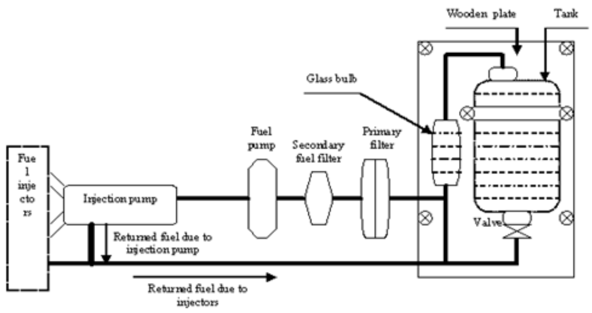


Fig (1). Sketch of the fuel meter connected with the tractor fuel system

4- Tractive force

The tractive force of the tractor was measured by using a Strain gauge dynamometer and two tractors. Strain gauge dynamometer, 10 ton, fig. () was attached with a horizontal chain between two tractors to measure the draft force. Two wheel drive tractor (Ford model 7610), was used as a rear (towed) on which the implement was mounted; whereas the front tractor (Dutz model DX 6.30 was used to pull the towed tractor with the attached implement through the Strain gauge dynamometer. The towed tractor was working on the neutral gear while the implement was in the operating position; the draft force was recorded and saved on the portable computer. 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:

NDp = B – A

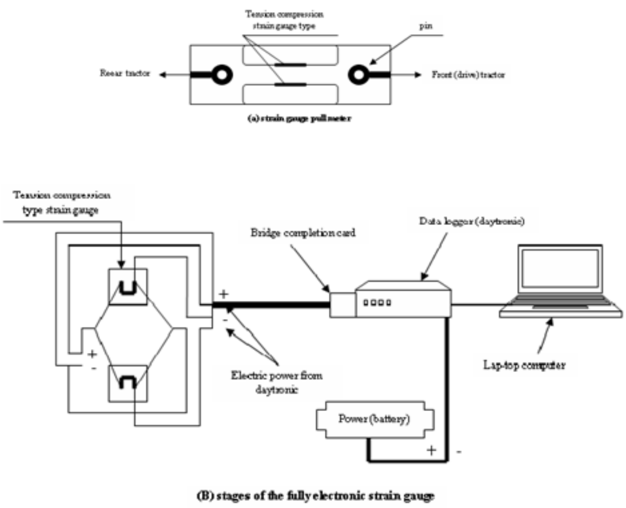


Fig (2). A diagram of device to measure strain explains how to measure the traction

5- Wheel slip (S)

The slippage percentage was measured by using the following formula:

$$S = 1 - \frac{FS_2}{FS_1} \times 100$$

(Barger et. al. 1963)

6- Drawbar power

P_{dp} = NDP × FS /3.6

7-Power consumed by rolling resistance

P_{rr} = Rr × FS / 3.6

(Younis & EL.Said, 2009)

8- Power consumed by slip (P_{sl})

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

(Younis & EL.Said, 2009)

9- Power losses (L_{power})

L_{power} = P_{sl} + P_{dp}

10- Drawbar specific fuel consumption

$$D.S.FC = \frac{F.C(L.h^{-1})}{p_{dp}(kW)}$$

11- Tractive efficiency (η_{TE})

Tractive efficiency is defined as:

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

(Sharma and Mukesh. 2010)

Results and Discussion

To achieve the objectives of this study, the effect of tire inflation pressure and forward speed on tractor performance parameter, namely tractive efficiency, Drawbar specific fuel consumption, drawbar pull, power losses and Wheel slip during different field operations: ploughing (Moldboard plough, Disk plough) and harrowing (disk harrow). All the obtained results are in range of the tests, and should not be used below or above the test range and the soil conditions.

1- Drawbar pull

Table (3) shows the effect of the forward speed, tire inflation pressure and equipment types and their overlaps on the drawbar pull is illustrate in table (3). As seen from the table, the increase of the forward speed (3.86, 4.18, 4.76, 5.82 and 7.21 km/h), increased drawbar pull (14.05, 14.86, 15.63, 16.22 and 17.12 kN) respectively. The reason may be due to when you increase the speed, reduced power necessary for the field operation. These results are consistent with the results obtained by Macmillan (2002). The same table shows that increasing inflation pressure from 80 to 140 and then to 160 kPa the drawbar pull has decreased from 16.10 to 15.54 and then to 15.10 kN, respectively. The reason may be due to when you///. Also the results in the same table show that the use of Moldboard plough superposed the Disk plough and disk harrow, in recording higher drawbar pull (20.78 kN). The reason may be due to the deepening of weapons Moldboard plough into the soil more than the rest of soil preparation equipment. These results are consistent with the results obtained by Younis & EL.Said (2009). Also in the table (3) show that The interaction between equipment type, forward speed and inflation pressure was significant on the drawbar pull, whereas the triple overlap between the forward speed 7.21 km/h, Moldboard plough and inflation pressure 80 kPa led to obtain the highest drawbar pull was 23.23 kN, while the lowest drawbar pull was 10.12 kN resulting from the overlap of the disk harrow, inflation pressure 160 kPa and traveling speed 3.86 km/h as illustrate in figure (3). To relate the changes in the drawbar pull (D_p) with inflation pressure (I.P) and Forward speed (Fs), a regression analysis was employed, and the prediction regression equation was obtained as in the following table:

	prediction regression equation	SE	R^2
moldboard plough	η_{TE} = 0.013913 I.P - 0.7371 Fs + 77.4186	0.32	0.72
disk plough	η_{TE} = 0.026158 I.P - 0.7324 Fs + 73.8789	0.42	0.92
disk harrow	η_{TE} = 0.07003 I.P - 1.1403 Fs + 65.4521	1.35	0.83

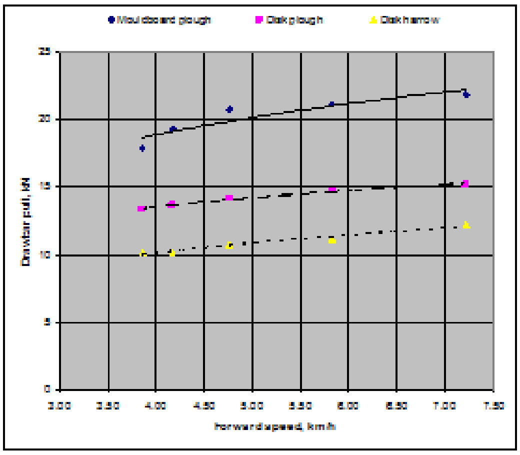


Fig (3). effect of the forward speed, tire inflation pressure 160 kPa and equipment on drawbar pull

2- Travel redaction (slip), %

Results illustrated in table (4) shows the effect of forward speed, tire inflation pressure and equipment and their overlaps on the wheel slip is illustrate in table (3). As seen from the table, the increase of the forward speed (3.86, 4.18, 4.76, 5.82 and 7.21 km/h), increased wheel slip (4.9, 5.71, 6.72, 7.72 and 9.31 %) respectively. The reason may be due to the increased forward speed leading to increase traction force and failure cohesion of the wheels of the soil surface. These results are consistent with the ones obtained by Jebur et. al (2016). The same table shows that increasing inflation pressure from 80 to 140 and then to 160 kPa the wheel slip has decreased from 6.31 to 6.95 and then to 7.37 %, respectively. This may be due to increased cohesion of the wheels of the soil surface. These results are consistent with the obtained by Serrano et. al (2009). Also the results in the table (4) illustrate that the use of Moldboard plough superposed the Disk plough and disk harrow, in recording higher wheel slip (8.57 %). The reason may be due to the Moldboard plough lead to increase in traction resistance force. These results are consistent with the results obtained by Guruswamy and Verma (1995). Also in the table (4) show that The interaction between equipment, forward speed and inflation pressure was significant on the wheel slip, whereas the triple overlap between the forward speed 7.21 km/h, Moldboard plough and inflation pressure 160 kPa led to obtain the highest wheel slip was 12.22 %, while the lowest wheel slip was 2.82 % resulting from the overlap of the disk harrow, inflation pressure 80 kPa and traveling speed 3.86 km/h as illustrate in figure (4). To relate the changes in the wheel slip (W.S) with inflation pressure (I.P) and Forward speed (Fs), a regression analysis was employed, and the prediction regression equation was obtained as in the following table:

	prediction regression equation	**SE**	**R^2**
moldboard plough	W.S = 0.010026 I.P + 1.507002 Fs - 0.4856	0.32	0.98
disk plough	W.S = 0.0109 I.P + 1.202129 Fs - 0.43448	0.41	0.93
disk harrow	W.S = 0.017075 I.P + 1.03133 Fs - 2.5929	0.51	0.90

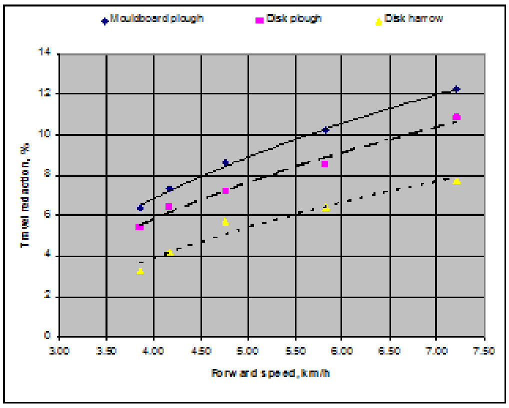


Fig (4). Effect of the forward speed, tire inflation pressure 160 kPa and equipment on drawbar pull

3- Drawbar specific fuel consumption (D.s.fc), l/kW.h

Results illustrated in table (5) shows the effect of forward speed, tire inflation pressure and equipment and their overlaps on the (D.s.fc) is illustrate in table (5). As seen from the table, the increase of the forward speed (3.86, 4.18, 4.76, 5.82 and 7.21 km/h), decreased (D.s.fc) (0.98, 0.90, 0.85, 0.68 and 0.54 l/kW.h) respectively with average of 44.89 %. The reason may be due to the increased forward speed leading to increase pull and fuel consumption. The same table shows that increasing inflation pressure from 80 to 140 and then to 160 kPa the (D.s.fc) has increased from 0.76 to 0.80 and then to 0.84 l/kW.h, respectively with ratio of 9.52 %. Also the results in the table (5) illustrate that the use of disk harrow superposed the moldboard plough and disk plough, in recording lowest (D.s.fc) (0.67 l/kW.h). The reason may be because of consuming less amount of power. So the table (5) indicate that the interaction between equipment, forward speed and inflation pressure was significant on the (D.s.fc), whereas the triple overlap between the forward speed 7.21 km/h, Moldboard plough and inflation pressure 80 kPa led to obtain the lowest (D.s.fc) was 0.46 l/kW.h, while the highest (D.s.fc) was 1.29 % resulting from the overlap of the disk harrow, inflation pressure 160 kPa and traveling speed 3.86 km/h as illustrate in figure (5). To relate the changes in the Drawbar specific fuel consumption (D.s.fc) with inflation pressure (I.P) and Forward speed (Fs), a regression analysis was employed, and the prediction regression equation was obtained as in the following table:

	prediction regression equation	SE	R^2
moldboard plough	D.s.fc = 0.00045 I.P - 0.09875 Fs + 1.12376	0.03	0.97
disk plough	D.s.fc = 0.00076 I.P - 0.0918 Fs + 1.1206	0.03	0.93
disk harrow	D.s.fc = 0.0016 I.P - 0.1624 Fs + 1.63741	0.06	0.93

4- Gross power losses (L_{power}), kW

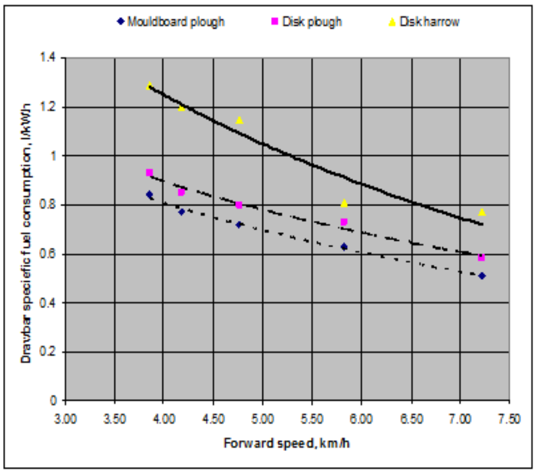
Table (6) showed the effect of forward speed, tire inflation pressure and equipment and their overlaps on the Power losses. As seen from the table, the increase of the forward speed (3.86, 4.18, 4.76, 5.82 and 7.21 km/h), increased Power losses (5.29, 6.42, 7.79, 9.89 and 12.03 kW) respectively with ratio of 56.03 %. The reason may be due to the increased forward speed leading to increase energy consumption.

Table (3). Effect of the forward speed, tire inflation pressure and equipment on drawbar pull (kN)

Drawbar pull, kN						Character studied	
Average equipment	interaction between equipment, inflation pressure and speed					Transactions	
	forward speed, km/h					inflation pressure, kPa	equipment
	7.21	5.82	4.76	4.18	3.86		
20.694	23.230	22.130	21.620	20.520	18.560	80	Moldboard plough
	22.860	21.730	21.000	19.620	18.140	140	
	21.820	21.200	20.760	19.340	17.860	160	
14.582	16.520	15.430	14.820	14.330	13.620	80	Disk plough
	15.820	15.000	14.720	13.860	13.420	140	
	15.223	14.720	14.220	13.620	13.350	160	
11.469	13.820	12.660	11.540	11.630	11.023	80	disk harrow
	12.550	11.920	11.620	10.820	10.360	140	
	12.230	11.120	10.720	10.220	10.120	160	
0.0016	0.0223					L.S.D = 0.05	
	17.118	16.221	15.629	14.858	14.050	Average speed	
	0.0021					L.S.D = 0.05	
	Average tire inflation pressure						
	160	140		80			
	15.104	15.543		16.097			
	0.0016					L.S.D = 0.05	

Table (4). Effect of the forward speed, tire inflation pressure and equipment on travel redaction (%)

travel redaction (Slip), %						Character studied	
Average equipment	interaction between equipment, inflation pressure and speed					Transactions	
	forward speed, km/h					inflation pressure, kPa	equipment
	7.21	5.82	4.76	4.18	3.86		
8.569	10.863	8.840	7.750	6.830	6.300	80	Moldboard plough
	11.527	9.820	8.330	7.220	6.320	140	
	12.220	10.220	8.620	7.323	6.360	160	
7.156	8.823	7.230	6.420	5.820	5.216	80	Disk plough
	9.153	7.823	7.00	6.120	5.330	140	
	10.817	8.517	7.217	6.436	5.423	160	
4.898	5.320	4.816	4.220	3.333	2.820	80	disk harrow
	7.320	5.816	5.220	4.123	3.133	140	
	7.720	6.433	5.717	4.227	3.250	160	
0.0018	0.0261					L.S.D = 0.05	
	9.307	7.724	6.721	5.714	4.905	Average speed	
	0.0023					L.S.D = 0.05	
	Average tire inflation pressure						
	160	140		80			
	7.366	6.950		6.306			
	0.0018					L.S.D = 0.05	



Fig(5). Effect of the forward speed, tire inflation pressure 160 kPa and equipment on Drawbar specific fuel consumption

The same table shows that increasing inflation pressure from 80 to 140 and then to 160 kPa the Power losses has decreased from 8.39 to 8.24 and then to 8.23 kW, respectively with ratio of 1.91 %. Also the results in the table (6) illustrate that the use of disk harrow superposed the moldboard plough and disk plough, in recording lowest (L_{power}) 7.40 l/kW.h. The reason may be because of recording lowest average of slip. These results are consistent with the obtained by Bashford L.L, (1984). Also table (6) showed that the interaction between equipment and forward speed was significant on the power losses, whereas the dual overlap between the forward speed 3.86 km/h and the using disk harrow led to obtain the lowest Power losses was 4.98 kW. So the table (6) indicate that the interaction between equipment, forward speed and inflation pressure was significant on the power losses, whereas the triple overlap between the forward speed 7.21 km/h, Moldboard plough and inflation pressure 160 kPa led to obtain the highest power losses was 13.94 kW, while the lowest power losses was 4.87 % resulting from the overlap of the disk

Table (5). Effect of the forward speed, tire inflation pressure and equipment on Drawbar specific fuel consumption, (l/kW.h)

Drawbar specific fuel consumption, l/kW.h						**Character studied**	
Average equipment	**interaction between equipment, inflation pressure and speed**					**Transactions**	
	forward speed, km/h					**inflation pressure, kPa**	**equipment**
	7.21	5.82	4.76	4.18	3.86		
0.988	0.460	0.580	0.687	0.727	0.807	80	Moldboard plough
	0.480	0.550	0.710	0.760	0.830	140	
	0.507	0.630	0.720	0.770	0.840	160	
0.742	0.530	0.633	0.703	0.806	0.880	80	Disk plough
	0.603	0.650	0.727	0.820	0.890	140	
	0.580	0.730	0.800	0.850	0.930	160	
0.670	0.650	0.770	1.020	1.030	1.110	80	disk harrow
	0.677	0.800	1.100	1.170	1.280	140	
	0.773	0.810	1.150	1.200	1.290	160	
0.002	0.0134					L.S.D = 0.05	
	0.584	0.683	0.846	0.903	0.984	**Average speed**	
	0.0026					L.S.D = 0.05	
	Average tire inflation pressure						
	160	140		80			
	0.84	0.80		0.76			
	0.002					L.S.D = 0.05	

Table (6). Effect of the forward speed, tire inflation pressure and equipment on Power losses, (kW)

Power losses, kW						**Character studied**	
Average equipment	**interaction between equipment, inflation pressure and speed**					**Transactions**	
	forward speed, km/h					**inflation pressure, kPa**	**equipment**
	7.21	5.82	4.76	4.18	3.86		
8.99	13.93	10.64	7.98	7.00	5.71	80	Moldboard plough
	13.72	10.51	7.74	6.78	5.38	140	
	13.94	11.26	8.06	6.80	5.40	160	
8.46	12.19	10.05	8.73	6.58	5.42	80	Disk plough
	11.84	10.15	7.87	6.65	5.45	140	
	12.42	10.01	7.55	6.67	5.29	160	
7.40	9.94	8.90	7.86	5.87	5.04	80	disk harrow
	10.41	8.91	7.28	5.77	5.02	140	
	9.85	8.58	7.07	5.68	4.87	160	
0.001511	0.005826					L.S.D = 0.05	
	12.03	9.89	7.79	6.42	5.29	**Average speed**	
	0.001981					L.S.D = 0.05	
	Average tire inflation pressure						
	160	140		80			
	8.23	8.24		8.39			
	0.001677					L.S.D = 0.05	

harrow, inflation pressure 160 kPa and traveling speed 3.86 km/ has illustrate. To relate the changes in the power losses (L_{power}) with inflation pressure (I.P) and forward speed (Fs), a regression analysis was employed, and the prediction regression equation was obtained as in the following table:

	prediction regression equation	SE	R^2
moldboard plough	L_{power} = 0.010031 I.P + 1.50713 Fs - 0.4871	0.32	0.98
disk plough	L_{power} = 0.010931 I.P + 1.20139 Fs - 0.4336	0.41	0.94
disk harrow	L_{power} = 0.017077 I.P + 1.03173 Fs - 1.63741	0.51	0.90

5- Tractive efficiency (η_{TE}), %

Table (7) showed the effect of forward speed, tire inflation pressure and equipment and their overlaps on the tractive efficiency. As seen from the table, the increase of the forward speed (3.86, 4.18, 4.76, 5.82 and 7.21 km/h), decreased tractive efficiency (74.02, 73.19, 72.29, 71.86 and 70.74 %) respectively. This may be due to the losses in output power that come from both travel reduction and rolling resistance. These results are consistent with the results obtained by **Jebur (2015)**. The same table shows that increasing inflation pressure from 80 to 140 and then to 160 kPa the tractive efficiency has increased from 70.70 to 72.84 and then to 73.67 %. This may be due to the increased slippage percentage. Also the results in the table (7) illustrate that the use of moldboard plough superposed the disk harrow and disk plough, in recording highest tractive efficiency 75.37 %. The reason may be because of recording highest average of drawbar power. The table (7) showed that the interaction between equipment and forward speed was significant on the

Table (7). Effect of the forward speed, tire inflation pressure and equipment on Tractive efficiency, (%)

Tractive efficiency, %						Character studied	
Average equipment	interaction between equipment, inflation pressure and speed					Transactions	
	forward speed, km/h					inflation pressure, kPa	equipment
	7.21	5.82	4.76	4.18	3.86		
75.37	73.287	74.187	74.873	75.947	76.033	80	Moldboard plough
	72.793	74.417	74.937	76.017	76.800	140	
	75.767	76.083	76.210	76.380	76.867	160	
73.41	70.670	71.456	71.810	73.583	73.647	80	Disk plough
	71.970	73.370	73.893	74.273	74.370	140	
	73.303	74.047	74.157	75.280	75.297	160	
68.43	60.463	64.700	65.460	65.597	68.876	80	disk harrow
	69.197	69.233	69.457	70.243	71.587	140	
	69.220	69.377	69.830	70.553	72.683	160	
0.0026	0.0249					L.S.D = 0.05	
	70.741	71.864	72.291	73.097	74.017	**Average speed**	
	0.0034					L.S.D = 0.05	
	Average tire inflation pressure						
	160	140		80			
	73.67	72.84		70.7			
	0.0026					L.S.D = 0.05	

tractive efficiency between forward speed 7.21 and 5.82 km/h at the using of disk harrow. So the table (7) indicate that the interaction between equipment, forward speed and inflation pressure was significant on the tractive efficiency, whereas the triple overlap between the forward speed 3.86 km/h, Moldboard plough and inflation pressure 80 kPa led to obtain the highest tractive efficiency was 76.03 %, while the lowest tractive efficiency was 60.46 % resulting from the overlap of the disk harrow, inflation pressure 80 kPa and traveling speed 7.21 km/h. To relate the changes in the tractive efficiency (η_{TE}) with inflation pressure (I.P) and forward speed (Fs), a regression analysis was employed, and the prediction regression equation was obtained as in the following table:

	prediction regression equation	SE	R^2
moldboard plough	η_{TE} = 0.013913 I.P - 0.7371 Fs + 77.4186	0.32	0.72
disk plough	η_{TE} = 0.026158 I.P - 0.7324 Fs + 73.8789	0.42	0.92
disk harrow	η_{TE} = 0.07003 I.P - 1.1403 Fs + 65.4521	1.35	0.83

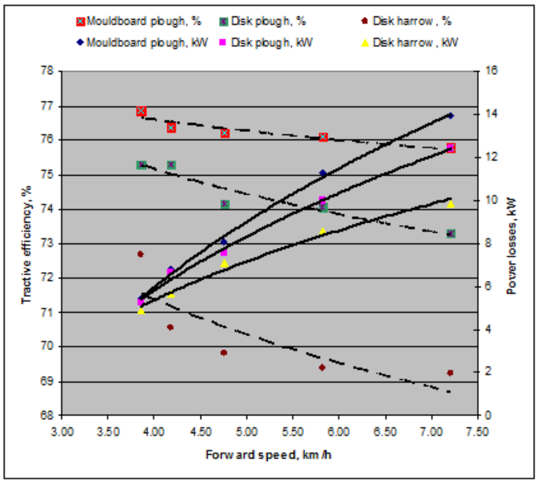


Fig (11). Relationship between tractive efficiency and power losses

6- The relationships between tractive efficiency and gross power losses

The relation between the forward speed and both the tractive efficiency and gross power losses of the moldboard plough , disk plough and disk harrow operations with the use of different inflation pressure are presented in fig. (5). In general, the results showed that the power losses increased by increasing the forward speed for both implements, but the tractive efficiency decreased with the increase of forward speed. With the use of 160 kPa inflation pressure and forward speed from 4.18 to 7.21 km/h, the power losses increased by 51.23, 46.30 and 42.33 %, while the tractive efficiency decreased by 0.80, 2.63 and 1.91 %, in case of the moldboard plough , disk plough and disk harrow, respectively.

Conclusion

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

1- The forward speed and the tire inflation pressure were the most important factors that affecting the drawbar pull, drawbar specific fuel consumption and tractive efficiency.

2- The wheel slip and drawbar pull increased with increasing of the forward speed, while decreased with inflation pressure.

4- The drawbar specific fuel consumption decreased with the increase in the forward speed, while increased with inflation pressure.

5- The use of tire inflation pressure 160 kPa produced the highest value (73.67 %) of tractive efficiency, drawbar while the lowest value of power losses was 8.23 kW.

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