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DETERMINING TRACTOR PERFORMANCE USING TRACTOR MOBILITY NUMBER AND ENGINE POWER

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ABSTRACT

Drawbar power used to describe the power requirement of an implement being towed or pushed. It is extremely useful in matching the rated horsepower of the tractor with the size of existing or purchased implements. In this paper, the tractors are classified according to their mobility number into three groups. The first group (I) has a range of mobility number of (4-5) at light soil and (17-23) at heavy soil. While the second (II) and the third (III) groups have ranges of (2-3) and (1-2) at light soil and (10-14) and (7-8) at heavy soil. Two methods are represented in this paper to describe drawbar power as a function of a tractor engine power. The first one predicts the drawbar power as a ratio of engine power at different soil types (clay soil, sandy clay loam and concrete road). The average drawbar ratios were 0.61, 0.55 and 0.75 for clay, sandy clay loam soils and concrete road for group I, 0.63, 0.52 and 0.78 for group II and 0.67, 0.55 and 0.84 for group III. The second method is a model that predicts the drawbar pull using a mobility number and engine power for the clay and sandy clay loam soil. The model doesn't include predicting drawbar power at concrete because it is impossible to measure soil penetration resistance at concrete road. The PTO power ratio is calculated as a ratio of engine power. It is found to be as an average of 0.90 for all tractors type. The axle power ratios are 0.87, 0.83 and 0.83 for tractors of group I, group II and group III respectively. The average tractive efficiency on clay and sandy clay loam soil are: 0.66 and 0.62 for tractors of group I, 0.78 and 0.67 for tractors of group II and 0.81 and 0.66 for tractors of group III.

INTRODUCTION

This paper presents quick methods to predict the tractor performance at different soil conditions for three categories of tractors. There is an attempt to better utilize the energy consumption in agricultural production. Utilizing the energy consumption in agricultural production is much needed practically for high energy requiring operations. Optimizing the performance of agricultural tractors leads to minimize the waste energy. The energy of tractors is wasted because of incompatibility of machine size to tractors energy. Jun et al. (1998) studied traction features of a tractor depend on dynamic rates of the engine and transmission parameters. Traction features of a tractor depend greatly on driving wheel explanation characteristics, on the physical-mechanical properties of soil and on the interaction of driving wheel and soil. Kazimieras and Janulevicius (2005). Stated that the increased fuel consumption for carrying ballast mass can be compensated by the lower fuel consumption because of the diminished wheel slippage. Three factors influences on this energy losses due to hydraulic pumps, alternator, cooling etc,(net engine power model). Drive line losses, depend on number of gear boxes or efficiency of converters. Energy losses due to engine wear and inadequate maintenance.

The power of the engine is often given with Din norm or SAE norm. But this given engine power is not totally available for the mobility of the tractor, because of numerous accessories (e.g. the alternator and hydraulic transmission). Normally a diver of the forest-tractor can not use the whole engine power capacity. Therefore The following coefficients to mobility can be used as the given engine power to a usable form: DIN-norm 0.55 and SAE-norm 0.5.

Sefa and Kazin (2004) derived two mathematical equations to predict torque and power requirements of the traction tires of horticultural tractors by applying dimensional analysis and regression over the variably describing the operational and geometric features of tires.

Hunt (1986) determined the average weight transfer coefficient for three types of hitches (Towed, mounted and siememounted). The coefficients define the amount of effective weight shift from the front tires to the rear tires due to the implement pull.

	Towed	Mounted	Siememounted
The coefficient of weight transferred to rear axle	0.22	0.45	0.65
The coefficient weight transfer from front tiers	0.82	0.29	0.39

Dwyre (1978) showed that the optimum ratio between the mass carried on the driving wheels and the power available at the driving axle is at least as important as choosing the correct tire size in obtaining the maximum drawbar pull for a ginen power input. This optimum mass/power ratio is very important on speed. at 6 km/h it is 100 kg/kW, but at 8 km/h it drops to 80 kg/kw. Although reducing the optimum ratio by about 20 kg/kW is not detrimental to performance in most field conditions, further reduction causes a very rapid drop in drawbar power. Mass/power ratio can be seen that 70% is a reasonable maximum tractive efficiency at which to aim. Thus; if one assume that 70% of the available power can be converted into drawbar power and the drawbar pull is 40% of the weight on the driving wheels. The relationship between weight on driving tires, available power and forward speed can be expressed as follows:-

The objectives of this study are:-

1- Developed a mathematical model for predicting the drawbar power
2- Found out the ratio between engine power ,drawbar power and P.T.O power.
3- Determined tractive efficiency for the three tractor groups at different soil types.

MATERIALS AND METHODS

The tractors tested at the Testing and Research Station for Tractors and Agricultural Machinery, Alexandria. The drawbar pull, rolling resistance and PTO are identified. To achieve the goal of this paper the Mobility number, Tractive efficiency and Axle power are calculated. The tractors are divided into three groups according to their mobility number. All of these tractors are tested at concrete road and at the field at two different soil types (sandy clay loam soil and clay soil). The soils mechanical analysis of each soil type are shown at table 1 The specification of each groups are shown at table (2).

Table (1): Soil mechanical analysis and moisture content of soils.

Site of soil	Soil type	Sand, %	Silt, %	Clay, %	Moisture, %
Nubaria	Sandy clay loam	55.71	15.6	28.69	20
Kafer El Shiek	Clay	22.1	22.6	55.3	22

Mobility number

The mobility number is calculated from the following formula:

$$M_N = \frac{CIbd}{W}\left[\frac{1}{1+b/2d}\right]\sqrt{\frac{\delta}{h}}$$

Where:

M_N = wheel mobility number;
CI = Soil cone index, kPa
δ = tire deflection, m ;
b = wheel width, m;
d = wheel diameter, m;
h = section height; m;
W = vertical dynamic load on wheel, kN

Gee - Clough (1980) tested this equation and reported that a typical value of δ/h is equal to 0.2. While the average weight transfer coefficient from front wheel to rear wheel is 0.22 for towed (Hunt 1986).

Tractive efficiency:

The Tractive efficiency can be calculated from the following equation:

$$TE = \left(\frac{NT}{GT}\right)\left(\frac{V_a}{V_t}\right) = \left(\frac{NT}{GT}\right) * (1 - S)$$

Where:-

TE = Tractive efficiency;
NT = Net traction, kN;
GT = Gross traction, kN;
V_a = Tractor actual travel speed, km/h;
V_t = Tractor theoretical travel speed, km/h;
S = Wheel slip.

Tractive efficiency is affected by soil type. The tractors of high engine power have high tractive efficiency. As the tractive conditions become softer and looser, the tractive efficient decreases

Table (2): Tractors specification.

Group I						
	Tractor eng power, kW	**W_F, kN**	**W_R, kN**	**W_T, kN**	**WB, m**	**Tire size, in**
2WD	17.9	63.20	161.06	224.26	1.16	(10-28)
	18.64	63.61	155.96	219.59	1.84	(11-28)
	23.49	97.86	196.74	294.60	1.80	(11.2-24)
	23.49	73.39	123.34	196.73	1.83	(12.4-24)
	29.83	83.08	140.16	223.24	1.87	(11-28)
	35.05	108.05	153.92	261.97	1.97	(14.9-28)
Group II						
2WD	35.79	112.13	275.23	387.36	2.65	(14-38)
	37.30	79.51	179.41	258.92	2.06	(28-14)
	41.76	100.92	181.45	282.37	2.03	(14.9-28)
	48.47	132.52	234.45	366.97	2.13	(16.9-30)
	48.47	112.13	224.26	336.39	2.13	(14-30)
	48.47	106.01	202.34	308.35	2.30	(14-30)
	52.20	101.94	214.07	316.01	2.25	(13-28)
Group III						
4WD	82.02	281.35	391.44	672.79	2.75	Fw(16.9-24) Rw(18.4-34)
	65.62	156.98	248.73	405.71	2.35	Fw(12.4-24) Rw(18.4-30)
	123.04	387.36	407.75	794.11	2.75	Fw(16.9-28) Rw(20.8-38)

W_F = Static weight on the front wheel; kN
WT = Total tractor Static weight; kN
2WD = Tow wheel drive:
W_R = Static weight on the rear wheel; kN
WB = Tractor wheel base, m
4WD = Four wheel drive

Axle power

The axle power is calculated from the following equation:-

$$\text{Axle power} = \left(\frac{\text{drawbar power}}{\text{Tractive efficiency}} \right)$$

Drawbar pull

The usual procedure to measure the tractor pull, is by inserting a hydraulic or strain gauge dynamometers between the implement and the tractor hits points. Hydraulic dynamometer which, consist of a cylinder-piston system connected to a Bourdon tube gauge may be damped considerably by placing a restriction valve in the line to the gauge.

Rolling resistance

Rolling resistance was measured by a hydraulic dynamometer and two tractors. One of the two tractors was towed by the other. The rear (towed) tractor, which its rolling resistance is measured. A horizontal chain with the hydraulic dynamometer linked the two tractors. The rear tractor is being in neutral condition. The pull (rolling resistance) was recorded in the measure distance of 40 m as well as the time taken to traverse it. The rolling resistance for the tractor was measured for each soil type. This process was achieved on different soils and repeated three times. The measurements were conducted at 4.5 km/h forward speed and repeated three times. Average soil cone indicates for the two soil types were 1715 and 390 kPa for clay and sandy clay loam soils respectively

Engine power

Tractor engine power was tested in the laboratory according to Nebraska tests. A PTO dynamometer was used to load the tractor engine during the laboratory tests. The PTO dynamometer was made in U.S.A Nebraska with torquerating of 1355 N.m and rpm of pto ranged from zero to 3600 rpm

RESULTS ANS DISCUSION

Mobility number:

Table (3) shows the calculated mobility number for sixteen tractors under study. the tractors are classified according to their mobility number into three groups. The first group (I) has a range of mobility number of (4-5)at light soil and (17-23) at heavy soil. While second (II) and third (III) groups have range of (2-3) and (1-2) at light soil and (10-14) and (7-8) at heavy soil respectively. The values of mobility number varied according to engine power and tractor dimensions. Figure (1) shows the tractors mobility number under two soil texture. The mobility number for group III, which have the higher engine power, is the smaller than other two groups. The mobility number at concrete road wasn't recorded because of the measuring of cone index is not available.

Table (3) the mobility number of each tractors group

Tractors of Group I								**average**	**S.D**	**C.V**
M_{Ns}	4.36	4.18	5.02	4.59	4.12	4.00		4.38	0.38	8.58
M_{Nc}	19.16	18.39	22.07	20.17	22.50	17.60		19.98	1.98	9.91
Tractors of Group II										
M_{Ns}	2.46	3.170	2.97	2.86	2.84	3.12	2.47	2.90	0.30	10.26
M_{Nc}	10.78	13.94	13.02	12.56	11.00	13.70	10.85	12.50	1.45	11.57
Tractors of Group III										
M_{Ns}	1.71	1.73	1.74					1.73	0.02	0.88
M_{Nc}	7.54	7.52	7.67					7.58	0.08	1.07

M_{NS} = Tractor mobility number at sandy clay loam soil

M_{NC} = Tractor mobility number at clay soil

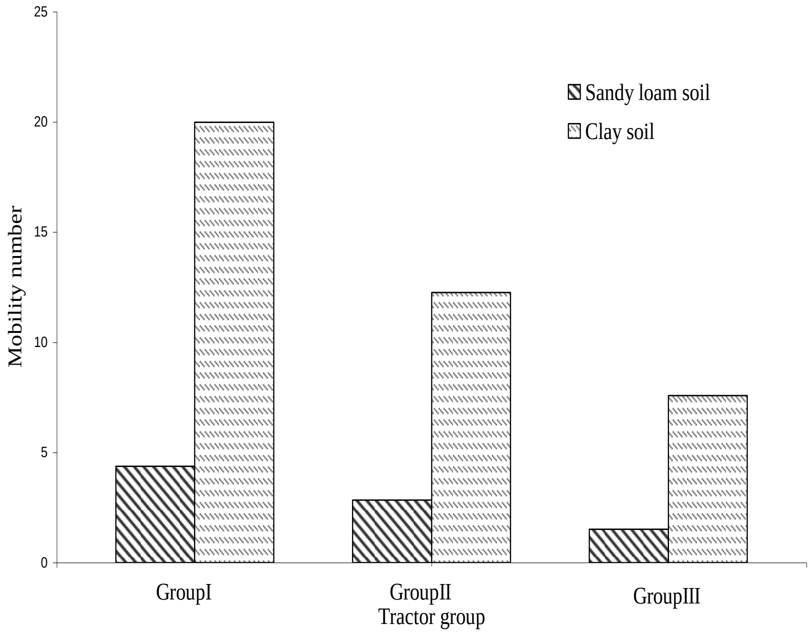

Fig.(1): The average of mobility number for the three tractor groups.

Predicting tractor drawbar power

Method1:

The method doesn't include predicting drawbar power at concrete surface because of it is impossible measure soil penetration resistance. Soil penetration resistance is the important term to determine tractor mobility number. By using the dimension analysts, the relation between drawbar power, tractor mobility number and engine power for clay and sandy clay loam soil can be expressed as follow:

$$DBP = K\left(\frac{Pe}{M_N}\right) \qquad (1)$$

Where:-

DBP = Drawbar power, kW;
Pe = Engine power, kW;
M_N = Mobility number;
K = Experimental constant.

The value of constant k depends on soil types and tractor specification, but for each tractor group the value of constant k was found to be close inside the group and is differed between groups. Table (4) shows the value of K_S and K_C for each tractor The average values of constant were 2.27 and 12.48 for tractors group I, 1.45 and 7.59 for tractors group II and 0.92 and 4.92 for tractors group III at sandy clay loam and clay soil respectively.

Table (4): The value of constant (K) for the two soil types.

Tractors of group I								average
Ks	2.34	2.34	2.54	2.25	2.11	2.04		2.27
Kc	12.37	11.77	13.52	12.22	11.78	11.23		12.48
Tractors of group II								
Ks	1.40	1.43	1.46	1.45	1.48	1.49	1.44	1.45
Kc	7.30	7.75	7.77	7.73	7.62	7.84	7.09	7.59
Tractors of group III								
Ks	0.92	0.89	0.94					0.92
Kc c	5.14	4.74	4.88					4.92

K_C is the constant for clay soil. **K_S is the constant of sand loam soil.**

Method2:

The drawbar power ratio is expressed as a ratio between drawbar powers to engine power. The method is predicted the drawbar power for the three different soil type.

$$\text{Drawbar ratio} = \frac{\text{Drawbar power}}{\text{Engine power}} \qquad (2)$$

Figure (2) shows the relation between measured and predicted drawbar power predicted for all tractors under the two prediction methods. Also the predicted values of drawbar power from the two methods are very close to measuring values which presented by 45˚ line. The root square means error (RMSE) used to compare both the method1 and method2 with measuring drawbar power at three different soil type, it could be calculated as follows:-

$$\text{RMSE} = \sqrt{\frac{\Sigma\left(Y - \hat{Y}\right)^2}{n}}$$

Where:-

RMSE = Root square of means error;
Y = Measured drawbar, kW;
$\hat{Y}$ = Predicted drawbar, kW;
n = Number of tractor in each group.

Table (5) shows that the RMSE of the two methods, the high values of RMSE means the predicted drawbar power is far from the measured values than the lower values. So it is clear that the predicted drawbar values using method1 is very close to measured values for tractors of group I and group II, and they almost are the same for tractors of group III.

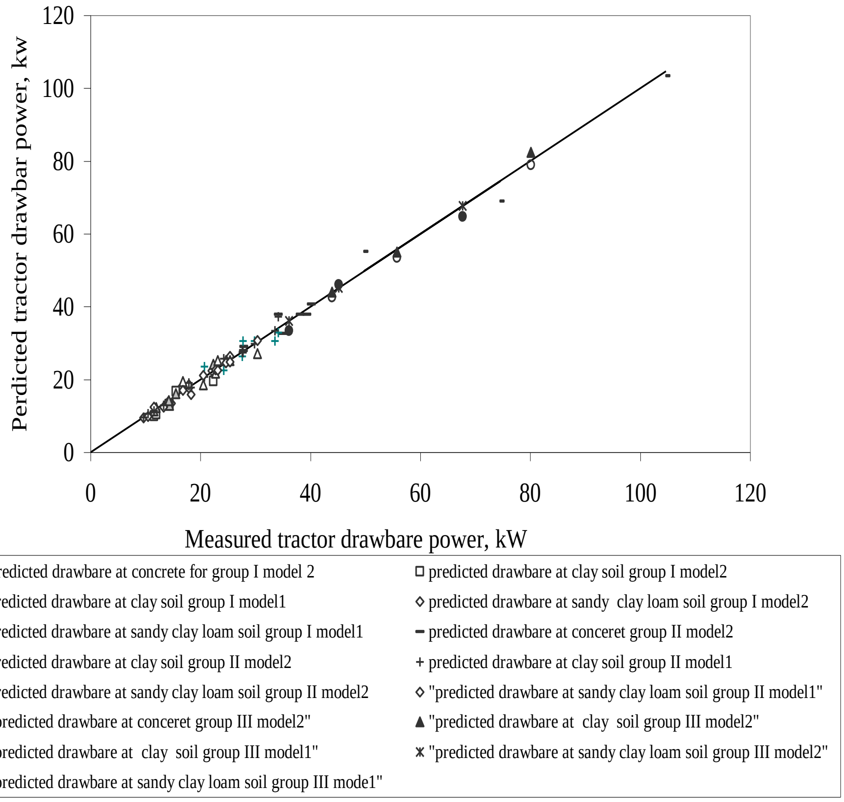

Fig. (2): Relation between measured and predicted drawbare power for different tractor groups

The drawbar power ratios for the different tractor groups at three different soil types (concrete, sandy clay loam soil and clay soil) are shown in Tables (6). The average drawbar ratios are 0.75, 0.55 and 0.53 for tractors of group I at concrete road, clay and sandy clay loam soil respectively. While they are 0.78, 0.63 and 0.52 for tractors of group II at concrete road, clay and sandy clay loam soil respectively. For group III these values are 0.84, 0.67 and 0.55 for tractors of group III at concrete track, clay and sandy clay loam soil respectively. Table (7) shows the measured drawbar power at three different soil types (clay, sandy clay loam soil and concrete road) and predicted drawbar power output from equations (1 and 2).

Table (5): The RMSE values of the different predicted methods at the different soil types.

	Concrete	Clay soil		Sandy clay loam soil	
	Method2	Method1	Method2	Method1	Method2
GroupI	0.85	1.00	1.65	1.30	2.88
GroupII	1.84	1.16	2.00	0.34	1.80
GroupII	4.5	1.66	1.44	2.30	2.50

Table (6): Drawbar power ratio of three off road types of tractors.

Pe, kW	MDBPc	DBPRC	MDBPcl	DBPRcl	MDBPs	DBPRs
	Tractors of Group I					
17.9	14.73	0.82	10.02	0. 56	9.62	0.52
18.64	14.17	0.76	10.44	0.58	10.44	0.56
23.49	16.41	0.70	13.15	0.51	13.27	0.57
23.49	17.90	0.76	13.15	0.57	11.56	0.49
29.83	22.07	0.74	16.70	0.55	15.66	0.53
35.05	25.35	0.72	19.63	0.55	17.90	0.51
	Tractors of group II					
35.79	27.78	0.78	24.24	0.68	20.51	0.57
37.3	27.89	0.75	20.73	0.56	16.78	0.45
41.76	35.05	0.84	27.59	0.66	22.74	0.54
48.47	38.11	0.79	29.83	0.62	24.61	0.51
48.47	39.34	0.81	33.56	0.69	25.35	0.52
48.47	34.15	0.70	27.74	0.57	23.12	0.48
52.2	40.19	0.77	34.12	0.65	30.39	0.58
Tractors of group III						
82.02	74.5	0.91	55.78	0.68	45.12	0.55
65.62	49.74	0.76	43.97	0.67	36.1	0.55
123.04	104.66	0.85	80.1	0.65	67.67	0.55

$MDBP_C$ = Measured drawbar ratio at concrete road, kW
$MDBP_{cl}$ = Measured drawbar ratio at clay; kW
$MDBP_s$ = Measured drawbar ratio at sandy clay loam soil: kW
$DBPR_C$ = Drawbar ratio at concrete road;
$DBPR_{cl}$ = Drawbar ratio at clay;
$DBPR_s$ = Drawbar ratio at sandy clay loam soil

Table (7): Predict drawbar power tractors at three soils types

Concrete	Clay soil		Sandy clay loam soil	
Drawbar power, kW				
Method2	**Method1**	**Method2**	**Method1**	**Method2**
Group I				
13.42	11.66	10.02	9.32	9.49
13.98	12.65	10.44	10.12	9.88
17.62	13.28	13.15	10.62	12.45
17.62	14.53	13.15	11.62	12.45
22.37	16.55	16.7	16.44	15.81
26.29	24.85	19.63	19.39	18.58
Group II				
27.92	25.68	22.55	21.16	18.61
29.08	20.68	23.49	17.05	19.39
32.57	27.45	26.31	22.62	21.72
37.81	29.84	30.54	24.59	25.21
37.81	33.42	30.54	24.77	25.21
37.81	27.35	30.54	22.54	25.21
40.72	37.18	32.89	30.65	27.14
Group III				
68.9	53.53	54.96	46	45.12
55.12	42.56	43.97	33.33	36.09
103.36	78.97	82.44	64.7	67.67

The regression equation between measured and predicted drawbar power of the two methods from Eq.(1) and Eq. (2) can be expressed as following:-

$$\mathbf{DBP_m = B \times DBP_p + A} \qquad (3)$$

Where:-

DBP_m = Measured drawbar power, kW;

DBP_p = Predicted drawbar power, kW

A and B = Regression coefficient

Summary output for regression analysis of Eq.(3)-for clay and sandy clay loam soil and concrete are shown in Table (8). The high value of R^2 means the predicted drawbar for the regression close to the measured drawbar.

Effect of net traction ratio on tractive efficiency

Tractive efficiency (TE) is shown at Table (9) for real data in sandy clay loam and clay soil as a function of NTR in Fig. (3) at zero net traction (pull) the ratio of net traction ratio (NTR) to gross, traction ratio (GTR) approaches zero. The difference between GTR and NTR is the motion resistance ratio MRR. The NTR ranged between 0.47 to 0.79 and the maximum tractive efficient was 0.83 at NTR 0.66 at clay soil,(group III) the minimum tractive efficient was 0.56 at NTR of 0.48 at sandy clay loam soil (group I). the average tractive efficiency were 0.66, 0.62 and 0.75 for clay soil, sandy clay loam soil and concrete road respectively for group I, 0.8, 0.67 and 0.78 for clay soil, sandy clay loam soil and concrete road respectively for group II and 0.81, 0.66 and 0.84 for clay soil, sandy clay loam soil and concrete road respectively for group III.

Table (8): Summary output for regression analysis of Eq.(3)

Group I					
	Concrete	**Clay soil**		**Sandy clay loam soil**	
	Method2	**Method1**	**Method2**	**Method1**	**Method2**
A	2.16	2.58	1.18	2.8	0.25
B	0.88	0.82	0.997	0.8	1.01
R^2	0.98	0.97	0.89	0.85	0.90
Group II					
A	1.33	3.08	-1.54	-0.33	-2.47
B	0.95	0.87	1.05	1.01	1.11
R^2	0.85	0.95	0.78	0.99	0.75
Group III					
A	-6.15	2.42	3.81	0.57	0
B	1.087	0.98	0.93	1.021	1
R^2	0.96	1	0.99	0.98	1

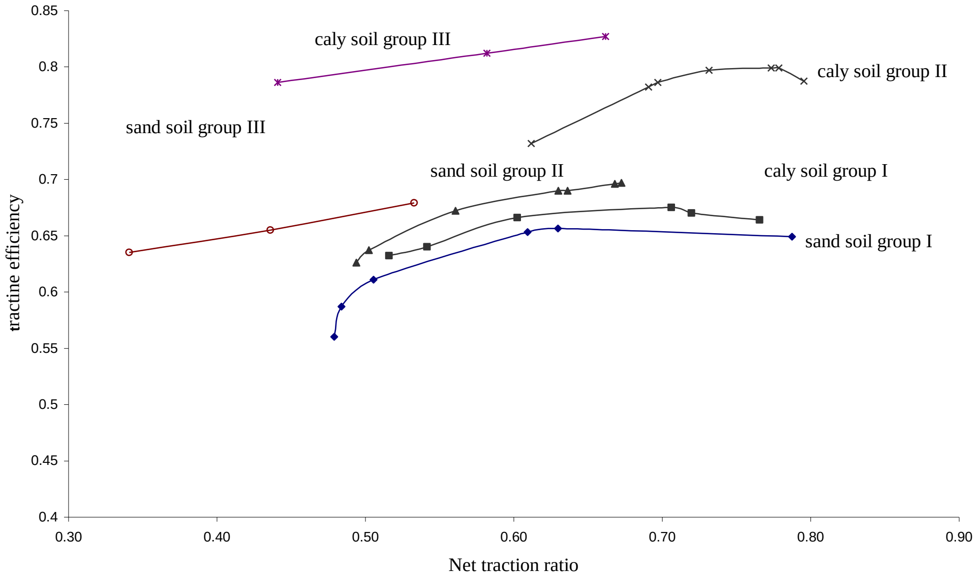

Fig. (3): Effect of net traction ratio on tractive efficiency.

Table (9): Effect of net traction ratio and gross traction ratio on tractive efficiency.

	Group I					
	Clay soil			Sandy clay loam soil		
	NTR	**GTR**	**TE**	**NTR**	**GTR**	**TE**
	0.52	0.62	0.632	0.48	0.66	0.56
	0.54	0.71	0.64	0.48	0.62	0.59
	0.60	0.72	0.67	0.51	0.73	0.61
	0.71	0.82	0.67	0.61	0.77	0.65
	0.72	0.82	0.67	0.63	0.78	0.66
	0.77	0.88	0.66	0.79	0.90	0.65
average	0.64	0.64	0.66	0.58	0.74	0.62
	Group II					
	NTR	**GTR**	**TE**	**NTR**	**GTR**	**TE**
	0.61	0.73	0.73	0.49	0.68	0.63
	0.69	0.79	0.78	0.50	0.73	0.64
	0.69	0.80	0.78	0.56	0.76	0.67
	0.73	0.84	0.79	0.63	0.80	0.69
	0.77	0.88	0.80	0.64	0.81	0.69
	0.78	0.89	0.799	0.67	0.83	0.69
	0.79	0.90	0.79	0.67	0.87	0.697
average	0.72	0.83	0.78	0.59	0.78	0.67
	Group III					
	NTR	GTR	TE	NTR	GTR	TE
	0.441	0.54	0.78	0.34	0.52	0.64
	0.582	0.7	0.81	0.44	0.64	0.66
	0.662	0.78	0.83	0.53	0.74	0.68
average	0.56	0.67	0.81	0.44	0.63	0.66

PTO power ratio

The PTO power ratio of all tractors group under studies are shown in tables (11). The value of these ratios found equals for three tractor groups with average of 0.9,

Table (11): PTO ration for the three tractor groups.

Group I			Group II			Group III		
Pe, kW	PTO power, kW	PTO ratio	Pe, kW	PTO power, kW	PTO ratio	Pe, kW	PTO power, kW	PTO ratio
8.95	7.37	0.82	41.76	33.93	0.81	82.03	74.57	0.91
17.90	16.51	0.92	52.20	48.47	0.93	67.11	60.40	0.9
22.37	20.51	0.92	52.20	50.71	0.97			

PTO ratio=The ratio between engine power and PTO power

Axle power

The axle tire power ratios are 0.87, 0.83 and 0.83 for tractors of group I, group II and group III respectively**.** the value of axle power for each tractor are plotted at Table (10).

Table (10) : the calculated axle tire power for thee tractors groups.

Axle tire power ratio					
Group I		Group II		Group III	
Axle power	ratio	Axle power	ratio	Axle power	ratio
15.63	0.87	29.83	0.83	71.20	0.87
16.51	0.88	30.57	0.82	53.81	0.82
20.27	0.86	35.05	0.84	97.82	0.8
20.79	0.88	40.27	0.83		
24.71	0.83	39.52	0.82		
31.00	0.88	39.52	0.82		
		43.25	0.83		
Average ratio	0.87	Average ratio	0.83	Average ratio	0.83

En. power = Engine power, kW:
Ratio = the ratio between engine power and axle tire power

Conclusion

The drawbar power is affected by tractor engine and its mobility number. The higher tractor power has low mobility number. The drawbar power is increasing proportionally with tractor engine power and inversely with mobility number. The axle drawbar power affected by engine power and it is found to be with a constant ration for all tractor groups of approximately 0.83. The model describes the relation between tractor engine power and its mobility number gives a good perdition for drawbar power. Tractive efficient at concrete road was the maximum for all tractor groups.

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تحديد اداء الجرار باستخدام رقم حركة الجرار

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تعتبر القدرة على كلا من قضيب الشد وعمود الادارة الخلفى ومحور عجل الجرار من العوامل التى تحدد آداء الجرار الزراعى تحت الظروف المختلفة من العمل. وتختلف هذه القدرات باختلاف قدرة المحرك ورقم حركة الجرار. تحديد رقم الجرار يختلف من تربة الى اخرى وهو يعتمد على مقاومة اختراق التربة والوزن الديناميكى وابعاد الجرار الهندسية (قطر العجل-عرض وارتفاع الكاوتش-انبعاج العجل).
تم الاستعانة باختبارات الجرارات التى اختبرت بمحطة ابحاث واختبار الجرارات والألآت الزراعيه بالاسكندرية فى دراسة تاثير كل من رقم الجرار وقدرة المحرك على آدائه تحت ظروف التشغيل المختلفة (تربة رملية طينية لومية-تربة طينية). قسمت الجرارات الى ثلاث مجاميع طبقا لرقم الجرار (mobility number) تم تحديد العلاقة بين القدرة على عمود الجر ورقم الجرار وقدرالمحرك على النحو التالى:-

$$DBP = k\left(\frac{Pe}{M_N}\right)$$

Where:-

DBP	=	القدرة على قضيب الشد بالكيلو وات
Pe	=	قدرة المحرك بالكيلو وات
M_N	=	رقم حركة الجرار
k	=	ثابت تجريبى.

وكانت قيم الثابت k هى ٢,٧٩, ١١,٠٨ لجرارات المجموعة الاولى و ١,٤٥, ٧,٥٩ لجرارات المجموعة الثانية و ٠,٩٢, ٤,٩٢ لجرارات المجموعة الثالثة وذلك للاراضى الرملية الطينية اللومية والتربة الطينية على الترتيب ولم يتم حساب الثابت الطريق الخرسانى لتعذر معرفة مقاومة اختراق التربة له.

واهم النتائج التى تم الحصول عليها هى:-

١. متوسط النسبة بين القدرة على عمود الادارة الخلفى وقدرة المحرك هى ٠,٩ للمجموعات الثلاثة.
٢. متوسط النسبة بين قدرة المحرك و القدرة على محور الجرار هى ٠,٨٧و٠,٨٣و٠,٨٣ للمجموعات الثلاث على الترتيب.
٣. متوسط نسبة القدرة بين القدرة على قضيب الشد وقدرة المحرك فى الاراضى الطينية و الرملية الطينية اللومية والطريق الخرسانى هى ٠,٦١, ٠,٥٥, ٠,٧٥ للمجموعة الاولى و٠,٦٣, ٠,٥٢, ٠,٧٨ للمجموعة الثانية ٠,٦٧, ٠,٥٥, ٠,٨٤ للمجموعة الثالثة
٤. متوسط كفاءة الشد على التربة الطينية والتربة الرملية الطينية اللومية كمابلى:-
- ٠,٦٦, ٠,٦٢ لجرارات المجموعة الاولى.
- ٠,٧٨, ٠,٦٧ لجرارات المجموعة الثانية
- ٠,٨١, ٠,٦٦ لجرارات المجموعة الثالثة لكل نوع تربة على التوالى.