J. Agric. Sci. Mansoura Univ., 33 (10): 7343 - 7354, 2008

POWER PREDICTION FOR OPERATING CHISEL AND MOLDBOARD PLOWS IN CLAY SOIL

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ABSTRACT

A non matched tractor power with the implement causes many disadvantages, which affect operation performance. To operate tractors more efficiently with agricultural implement; it is good to accomplish more work with less time and fuel. The drawbar power needed for operating chisel and moldboard plows was determined through the theoretical and experimental studies. The experimental study was carried out in Meet El Deeba Rice Mechanization Center, Kafr El-Sheikh Governorate, the soil is classified as a clay soil. The predicted power obtained for operating the moldboard plow which resulted from the theoretical analysis was very close to that obtained experimentally, and both agreed with that calculated from fuel consumption and equations published in *ASABE*, 2006 for chisel plow. Predicted drawbar power for operating the chisel plow was approximately 26% more than the drawbar power which is obtained from the experimental work at plowing speed of 3.2 km.h^{-1}. Increasing speed to 6.91 km.h^{-1} increased prediction power by only 3.63% compared with the experimentally results. Otherwise the prediction drawbar power for operating the moldboard plow was approximately 1.91% more than that obtained from the experimental at plowing speed of 3.2 km.h^{-1}. Increasing speed to 5.83 km.h^{-1} decreased prediction power by 11.38%. The theoretical specific power (W.cm^{-2}) increased by 115.77% as the theoretical plowing speed increased from 3.2 to 6.91 km.h^{-1} in case of using chisel plow. And increased by 81.54% as the plowing speed increased from 3.2 to 5.83 km.h^{-1} in case of using the moldboard plow.

INTRODUCTION

Operating performance depends heavily on how well the tractor and implement are matched, when they are ideally matched, one could expect reduced power loss, improved operating efficiency, reduced operating costs, and optimum utilization of capital on fixed costs. To achieve this goal, we must first understand how a tractor transfers power to the ground and then how to ensure the tractor is transferring power efficiently. Draft is an important parameter for evaluating implement performance and determining the required power. *Gee-Clough et al.* (1978) modeled the tractor-plow performance using empirical relationships based on experimental data obtained from 14 different fields with sandy clay loam, clay loam, and sandy loam soils. Predicted values were within ±20% of measured values for 86% of the cases. The dynamic component of plow draft is found to be the linear function of soil specific weight, share cut width and operating machine speed influenced by share apex angle for chisel plow, however, it is found to be linear function of soil specific weight and square term of operating speed influenced by moldboard tail angle for moldboard plow (*Elbanna*, 1992). Draft per unit width or cross-sectional area of the tilled zone is a function of soil type and the operating speed at which the implement is pulled (*Harrigan and Rotz*, 1994).

The draft values for the moldboard plow, chisel plow, subsoiler and standard chisel were all found to depend primarily on operating depth, the effect of speeds below 7.2 km h^{-1} was found to be small when compared with the depth effect (*Glancey et al.,* 1996). (*Al-Janobi* and *Al-Suhaibani*, 1998) applied the proposed model by (*Harrigan and Rotz,* 1995), they found that the specific drafts measured were very close to the predicted values for the moldboard plow and the chisel plows. When a tillage tool operates in the field, bending is induced in the shank, which is dependent on the soil resistance, the magnitude of the transverse force is a function of the soil resistance, when the shank is subjected to this force, it stores energy and releases it as soon as the soil resistance decreases (*Zhang,* 1997). *Natsis et al.* (2002) used tillage force dynamometer to measure draught of moldboard plough in a clay soil. The draft requirement for pulling a tillage implement through soil is dependent on implement parameters, tillage depth, driving speed and soil mechanical strength (*Keller,* 2004). *ASABE* Standards (2006) provide empirical equations to approximate draft and power requirements for a variety of tillage tools in three general soil conditions. It describes tillage draft as a function of implement type, soil type, implement width, depth, and speed. A number of other properties are also necessary to consider when analyzing tillage draft. Knowing the draft per tool and the number of tools, the total draft requirement for the implement is computed (*Grisso and Perumpral,* 2006). High tractor power than the implement-needed causes a soil compaction and lower operation efficiency due to the increase of the tractor weight and the 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. For these reasons, this study was carried out to help for selecting the suitable tractor with the implement or vise versa. A theoretical study attempts to predict the force and the draw power required for plowing cross sectional area from the soil. Also, to find out the relationship between the predicted power which resulted from the theoretical study and that obtained from the experimental work, and that calculated from fuel consumption and equations published in *ASABE*, 2006.

EXPERIMENTAL PROCEDURE AND METHODS

Theoretical and experimental studies were carried out to predict and determine the power needed for operating the chisel and the moldboard plows, the theoretical study based on the plowing cross sectional area and soil specific resistance. The experimental study was carried out in Rice Mechanization Center, Meet El-Deeba, Kafr El-Sheikh Governorate. The soil has been classified as a clay soil (64% clay, 20.4% silt and 15.6% sand). The average soil bulk density before tillage ranged from 1.15 to 1.30 $gm.cm^{-3}$, and the average soil moisture content (d.b.) was 19.8%. The tractors, implement and instrumentation used in this study were (Dutz tractor model DX 6.30 (4x4), 115 hp (85.8 kW) with an engine rated speed of 2400 rpm, (Ford tractor model 6610) of 75 hp (55.95 kW), 7 shares Behira Rau chisel plow (the shares are arranged in three rows such that the shares are in staggered position resulting in a spacing of 25 cm between each consecutive shares in the three rows), and 2 bottom moldboard plow.

Data collection

Speed of operation: The plowing speed was calculated from the time required to cover the distance of five revolutions for the tractor rear tire through tillage operation, at which the tractor and the machine usually state speed.

Width and depth of plowing measurements: The actual width and depth of plowing were measured and determined by using the soil profile meter. The same instrumentation and the same method were used by *Khadr* (1990). The difference between the unplowed soil surface and bottom of the plowed cross sectional area was measured to determine the plowing depth for moldboard.

Fuel consumption measurements: A local manufactured fuel meter Fig. (1) was connected with the fuel pipeline instead of the tractor fuel tank. A stopwatch was used to determine the time for a certain fuel volume consumed by the tractor with the nearest cubic centimeter.

A. Draft measurements: Strain gauge dynamometer, 10 ton, Fig. (2.a) was attached with a horizontal chain between two tractors to measure the draft force. Two wheel drive tractor (Ford model 6610), was used as a rear (towed) on which the implement was mounted; whereas the front tractor (Dutz 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 from the soil and the rear tractor was pulled to record and save the idle draft force. The difference gave the draft of the implement required to cut and disturb the soil, *Khadr* (2004) used the same instrumentation and the same method.

B. Draft prediction

1. Draft prediction from the proposed theoretical study: Draft required to pull tillage tools operated at shallow depths is primarily a function of width of the implement and the speed at which it is pulled. For tillage tools operated at deeper depth, draft also depends upon soil texture, plowing depth and geometry of the tool. The draft could be predicted for both of the chisel plow and the moldboard plow as follow:

a. draft prediction for chisel plow:

Plowed area determination: The plowed cross sectional area for any chisel plow could be predicted according to Fig. (3) and Equation (1).

$$A= (n-1)\ (2\ d-\frac{S-t}{2})(\frac{S-t}{2}) + (n \times t \times d) + d^2 \qquad (1)$$

Where: A : predicted plowing soil cross sectional area, cm^2.
n : number of chisel plow tines.
S : space between each two adjacent tines, cm.
t : tine width, cm. and d: adjustable plowing depth, cm.

For 7 shares chisel plow tines:

$$\therefore A = 6(2\ d-\frac{S-t}{2})(\frac{S-t}{2}) + (7 \times t \times d) + d^2 \qquad (2)$$

Draft prediction: The approximated draft for a 7 share chisel plow could be predicted from Equation (2) and the following equation:

Draft = plowed cross sectional area × the soil specific resistance

Soil specific resistance: The soil specific resistance is the resistance per unit area; it naturally varies with the texture, quality and condition of the soil, shape and operating speed of the plows. The soil specific resistance for clay soil ranges from 0.80 ~ 0.90 kg/cm^2 for large soil moisture content and from 0.90 ~ 1.00 kg/cm^2 for small soil moisture content (*Yanmar diesel engine instruction book*).

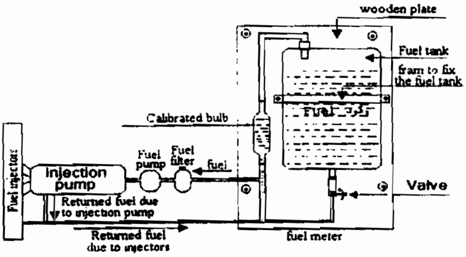
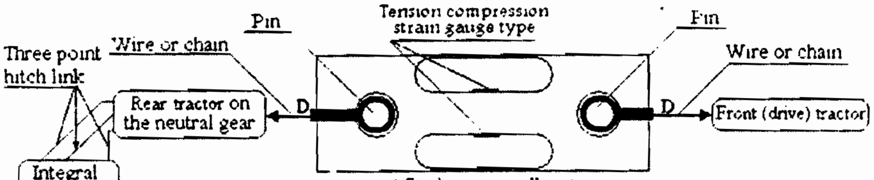
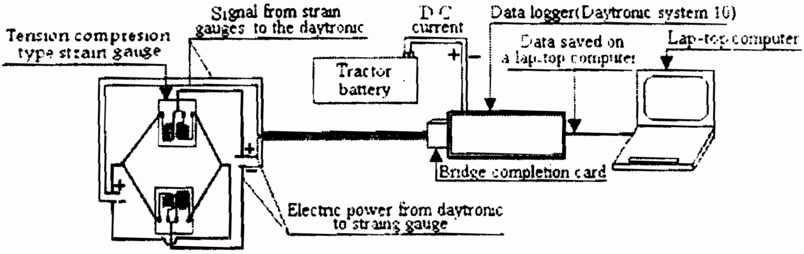


Fig. (1): Sketch drawing of the fuel meter connected with the tractor fuel system.



a) Strain gauge pull meter



b) Strain gauge wiring and connecting with data logger (daytronic system 10) and lap-top computer.

Fig. (2): Sketch drawing shows how to connect the strain gauge dynamometer between two tractors to measure the draft (a). And strain gauge wiring, connecting with daytronic system 10 and lap-top computer (b).

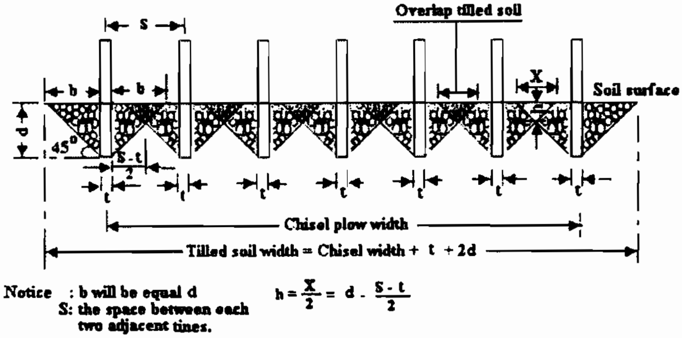


Fig.(3): Sketch drawing to show and estimate the tines plowing area.

b. draft prediction for moldboard plow through the proposed theoretical study:

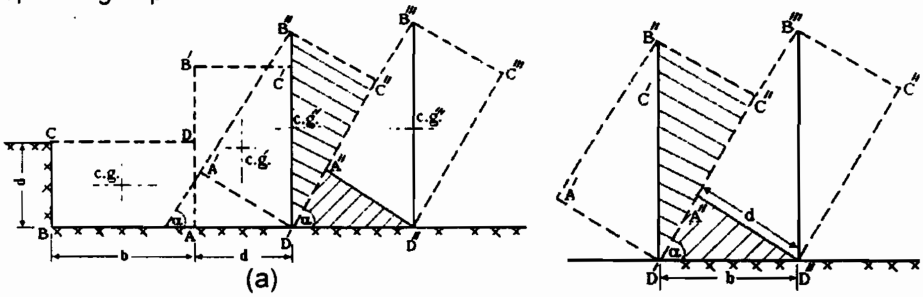
When the moldboard plow is thrust into the soil and plowing at a constant depth and width, theoretically the furrow slice section is turned from position ABCD to A′B′C′D′ and finally to A″B″C″D″ and its center of gravity c.g. changes its position from c.g. to c.g.′ then to c.g.″ and finally c.g.‴. If the furrow width is given as (b) and the depth is (d). Referring to Figs. (4.a and 4.b), at critical position of furrow slice the inclined angle of furrow slice (α) could be predicted as follow:

$$\frac{D\,D}{A\,D}=\frac{D\,B''}{D\,C''}, \qquad \therefore\ \frac{b}{d}=\frac{\sqrt{b^2+d^2}}{b}. \qquad \text{take } \frac{b}{d}=k$$

$$k=\sqrt{1+\frac{1}{k^2}}, \qquad \therefore\ k^4-k^2-1=0\ . \qquad \therefore\ k\approx 1.27, \qquad \therefore\ d=0.787\ b$$

$$\because\ \sin\alpha=\frac{d}{b}=\frac{1}{k}, \qquad \therefore\ \alpha=\arcsin\frac{1}{1.27}\approx 52^0$$

Easy may say that the furrow slice, (b) should be larger than (1.27 d), i.e. (d < 0.787 b). In this study the plowing depth (d) in case of using moldboard plow, was assumed less than (0.787b) with the same experimentally operating depth.



(a)

(b)

Fig. (4): Sketch drawing shows the turning of the furrow slice.

The soil resistance acts upon the plow which is called the tractive resistance, the needed tractive force (draft) of the plow could be obtained by the following equation:

$D = s.\ b.\ d \cdot 10^{-3}$, kN

Where: D: draft (kN)., s : Soil specific resistance, $N.cm^{-2}$.
b: tilling width, cm., d : tilling depth, cm.

The soil specific resistance (s) is varies with the quality and conditions of the soil, tines and shares shapes and operating speeds of the plow, previous crop residue type and conditions, etc.

2- Draft prediction through the ASABE data management, 2006:

Implement draft prediction is based on Equation (3), introduced by *ASABE* standards (2006) for both of chisel and moldboard plows was employed to predict the drawbar power, beside the drawbar power determined experimentally and power estimated from fuel consumption have been compared with the power which resulted from the proposed theoretical study.

$$D = F_i [A + B (S) + C (S)^2]\ n\ d \qquad (3)$$

Where D is the implement draft (kN); F_i is the dimensionless soil texture adjustment; A, B, and C are machine specific parameters. For a chisel plow with a straight point (F_i =1.0 for fine, F_i = 0.85 for medium, F_i = 0.65 for coarse textured soils); (A = 91, B = 5.4, C = 0.0). For moldboard plow (F_i=1.0 for fine, F_i= 0.7 for medium and F_i=0.45 for coarse textured soils); (A = 652, B = 0.0 and C = 5.1); S is operating speed ($km.h^{-1}$); n is the number of tools for chisel plow, but it is equal the plowing width in case of plowing with moldboard plow, m., and (d) is operating depth for major tools (cm). The constant parameter, A, is a function of soil strength while the coefficient of speed parameters, B or C, is related to soil bulk density. Soil is categorized as fine, medium, or coarse. Fine-textured soil is described as high in clay content, medium textured are loamy soils, and coarse textured are sandy soils.

Drawbar power prediction and estimation:

The drawbar power could be predicted theoretically from the soil plowing cross sectional area, the soil specific resistance and the plowing speed. The flow chart Fig. (5) shows how to predict power requirements for moldboard and chisel plows. The following equation could be used to estimate the drawbar power:

Drawbar power = draft (kN) × operating speed ($m.s^{-1}$), kW.

Power prediction from the fuel consumption:

As mentioned by (Hunt, 1983), the power required for plowing the soil could be predicted from the fuel consumption by the following equation:

$$\text{Thermal efficiency}(\zeta_{th}),\% = \frac{P \times C}{FC \times \text{Fuel heating value (HV)}}$$

$$(\zeta_{th}),\% = \frac{P\ (kW) \times 3600\ s.h^{-1}}{FC\ (kg.h^{-1}) \times 10^4\ k\ Cal.\ kg^{-1} \times 4.187\ kJ.\ k\ Cal^{-1})}$$

P: brake power, kW., C: constant

(ζth) : Thermal efficiency, it is assumed to be equal 30%.

FC : Fuel consumption, $kg.h^{-1}$.

Assuming that the lower colorific value for the fuel = 10^4 $kCal.kg^{-1}$.

Specific power determination:

The specific power is the power needed for plowing and pulverizing a unit area. The flow chart shows how to predict the specific power as indicated in Fig. (5). It could be obtained as follow:

$$\text{Sp. power} = \frac{\text{Needed drawbar power, W}}{\text{Plowed soil cross sectional area, cm}^2} \quad , W.cm^{-2}.$$

(Yanmar diesel engine instruction book). Where: Sp. power is the specific power.

Tractor power determination

To determine the PTO power we must use a factor to account for the traction capability of different soil conditions. These factors for different soil surface conditions are: 0.64 (firm soil); 0.55 (tilled soil); and 0.47 (soft/sandy soil). The PTO power is equal to the drawbar power divided by the factor to account the traction capability, (*Khalilian and Hallman*, 1996). The brake power could be estimated by dividing the PTO power by 0.9 (*ASABE*, 2006).

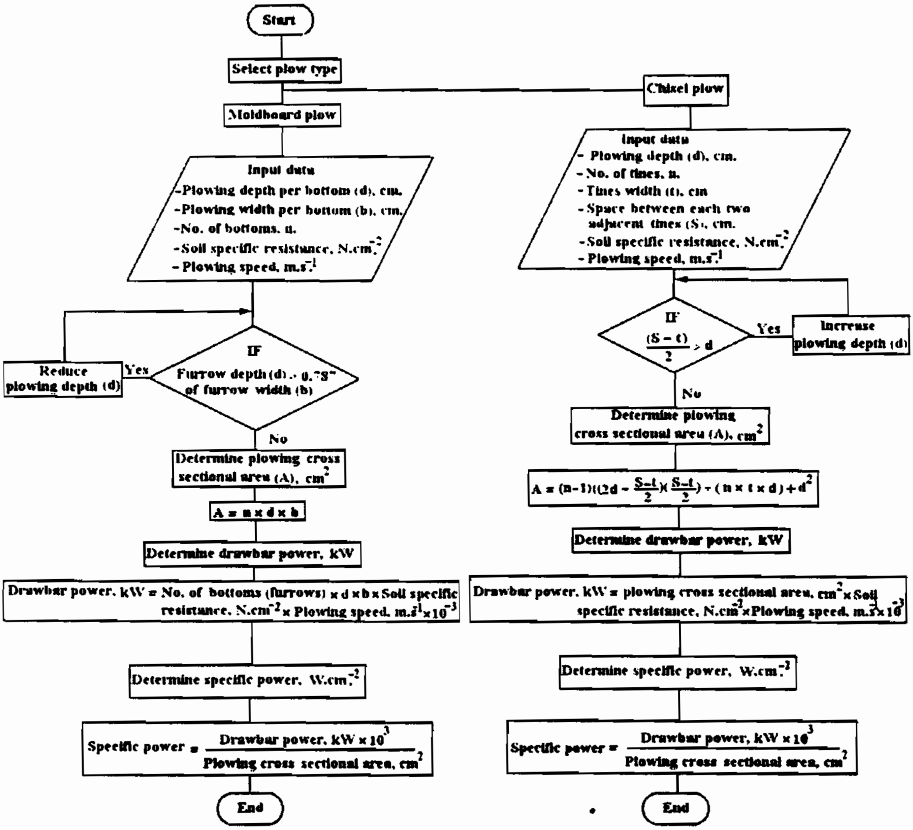


Fig. (5): Flow chart shows how to predict power requirements for moldboard and chisel plows.

Soil mean weight diameter and the soil pulverization ratio determination:

The Soil mean weight diameter and the soil pulverization ratio were determined with the same method and the same sieves used by *Khadr* (1997).

RESULTS AND DISCUSSION

Effect of plowing speed on power requirements

From Table (1), prediction of power for chisel plow was approximately 26% more than the experimental at plowing speed of 3.2 km.h^{-1}. Increasing speed to 6.91 km.h^{-1} increased prediction power by only 3.63%. Otherwise the prediction of power for moldboard plow was approximately 1.91% more than the experimental at plowing speed of 3.2 km.h^{-1}. Increasing speed to 5.83 km.h^{-1} decreased prediction power by 11.38%. The drawbar power increases with the increase of plowing speed, this may return to the increase of the soil pulverization which requires more power. Figs. (6 and 7), show that, the predicted drawbar power through the theoretical analysis in this study has the highest coefficient of determination, that may return to the constant cross sectional plowing area and a constant soil specific resistance, thus the predicted draft will be constant. Figs. (8 and 9) show the relationship among the determined drawbar power and both of the predicted drawbar power from the theoretical analysis, the fuel consumption and from the equations published by *ASABE* (2006). The estimated drawbar power from the theoretical analysis affected the plow type, operating speed, and the previous crop residue and its condition. The predicted drawbar power obtained from the theoretical analysis for moldboard plow was very close to that obtained from the experimental work, and both agreed with that calculated from fuel consumption and equations published in *ASABE*, 2006, as compared with chisel plow. That may return to homogenous plowing depth for moldboard plow. Theoretically, the drawbar power required for plowing a theoretical area of 2514 cm^{-2} increased by 11.25, 15.76, 47.21 and 115.76% as the plowing speed increased from 3.2 to 3.56, 3.71, 4.72 and 6.91 km.h^{-1} respectively in case of using the chisel plow. Also, at using the moldboard plow the drawbar power required for plowing a theoretical area of 2300 cm^{-2} increased theoretically by 35.97, 38.2, 77.56 and 81.49% as the plowing speed increased from 3.2 to 4.36, 4.43, 5.69 and 5.83 km.h^{-1}. The highest power as a result of increasing the plowing speed improved the soil mean weight diameter and the soil pulverization ratio.

Tractor power prediction:

When tractors and implements are matched depending on the situation, one may start with the tractor and select an implement to effectively utilize the drawbar power generated or start with the implement and select a tractor that can provide adequate pull to operate the implement. In the first case, the pull that the tractor can develop is predicted first and then the draft requirement per single soil engaging tool. Knowing the total pull available and the draft per single soil engaging tool, the number of soil engaging tools the tractor can handle with the available pull is calculated. Then knowing the spacing between the soil engaging units, the width of the implement is determined. Determining the draft per tool and the number of tools the total draft requirement for the implement is computed, then selecting the matched tractor-implement systems to get high operation efficiency.

Effect of operating speed on specific power

As indicated in Table (1), the specific power increases with the increase of the plowing speed in case of using the theoretical analysis, the experimental measurements data, the fuel consumption and equations published in *ASABE*, 2006. That may return to the increases of the soil pulverization with the plowing speed, which causes an increase of the specific energy during using the chisel or the moldboard plows. The percentage of theoretical specific power increased by about 11.32, 15.77, 47.3 and 115.77% as the theoretical plowing speed increased from 3.2 to 3.56, 3.71, 4.72 and 6.91 km.h^{-1} respectively for chisel plow. In addition, they increased by about 35.98, 38.27, 77.63 and 81.54% as the plowing speed increased from 3.2 to 4.36, 4.43, 5.69 and 5.83 km.h^{-1} for the moldboard plow. From these studied results and use a factor to account for the traction capability of different soil conditions, we could predict and select the tractor power.

Table (1): Comparison between theoretical drawbar power and specific power prediction through theoretical studies and determination through field measurements for chisel and moldboard plows.

Implement	Cal. through meas				From proposed th. Study				From fuel cons.		From ASABE, 2006		From measurements		From measurements	
	Avg PS	Ad pl depth	M pl depth	Pl width	Pl Area	Pred draft	Pred Db P	Pred Sp P	Avg FC	Avg Db P	Avg Draft	Avg Db P	Avg Draft	Avg Db P	Avg SMWD	Avg Soil pulv
	km h^{-1}	cm	cm	cm	cm^2	kN	kW	W cm^{-2}	kg h^{-1}	kW	kN	kW	kN	kW	mm	%
Chisel plow	3.20	18.0	14.92	1.75	2514	20.97	18.66	7.42	11.33	19.57	13.55	12.15	16.64	14.81	48.12	33.50
	3.56	18.0	14.78	1.75	2514	20.97	20.76	8.26	11.61	20.05	13.69	13.76	16.72	16.56	46.72	34.94
	3.71	18.0	14.80	1.75	2514	20.97	21.60	8.59	12.78	22.08	13.39	14.41	17.21	17.73	45.43	36.23
	4.72	18.0	14.00	1.75	2514	20.97	27.47	10.93	12.79	22.10	14.67	19.24	17.30	22.67	42.93	38.50
	6.91	18.0	13.40	1.75	2514	20.97	40.26	16.01	16.63	28.73	16.17	31.05	20.23	38.85	39.23	43.10
Moldboard	3.20	23.0	23.00	1.00	2300	19.18	17.07	7.42	12.78	22.07	16.17	14.39	18.82	16.75	81.86	27.20
	4.36	23.0	22.85	1.00	2300	19.18	23.21	10.09	14.11	24.37	17.13	20.73	20.47	24.77	97.64	27.43
	4.43	23.0	22.57	1.00	2300	19.18	23.59	10.26	15.20	26.26	17.22	21.19	21.60	26.57	71.82	32.69
	5.69	23.0	22.00	1.00	2300	19.18	30.31	13.18	19.33	33.38	18.63	29.44	22.02	34.80	66.02	34.49
	5.83	23.0	20.00	1.00	2300	19.18	30.98	13.47	19.66	33.95	18.89	30.51	21.66	34.96	60.57	39.19

- (Sp. P) : Specific power
- (FC) : Fuel consumption
- (Cal. Through meas.): Calculation from measurements
- (PPF) : Power prediction from fuel consumption
- (PP ASAE, 2006): Power prediction from ASAE, 2006.
- Power determination from measured data
- (SMWD) : Soil mean weight diameter
- (Soil pulv.) : Soil pulverization ratio from measurements.
- (PS) : Plowing speed
- (Ad.pl. depth): Adjustable plowing depth
- (M pl. depth) : Measured plowing depth
- (Pl. width) : Plowing width
- (Pl. Area) : Plowing area
- (Pred. draft) : predicted draft from theoretical study
- (Db P) : Predicted drawbar power from theoretical study

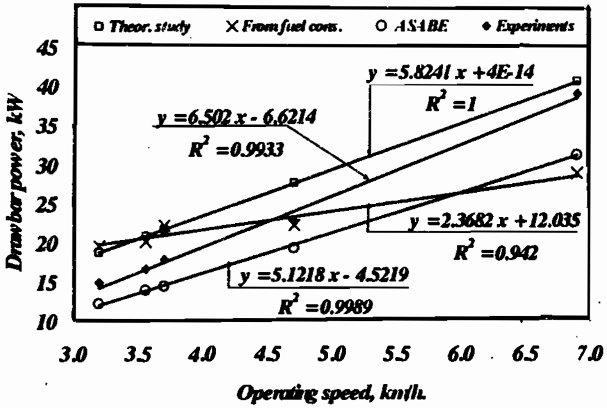


Fig. (6): Effect of operating speed on drawbar power for 7-tine integral chisel plow.

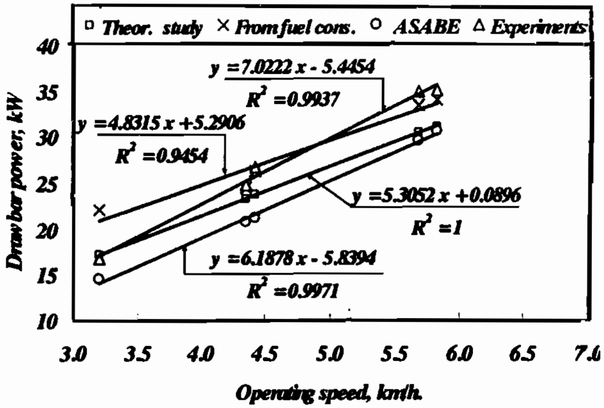


Fig. (7): Effect of operating speed on drawbar power for 2-bottom, 50 cm integral moldboard plow.

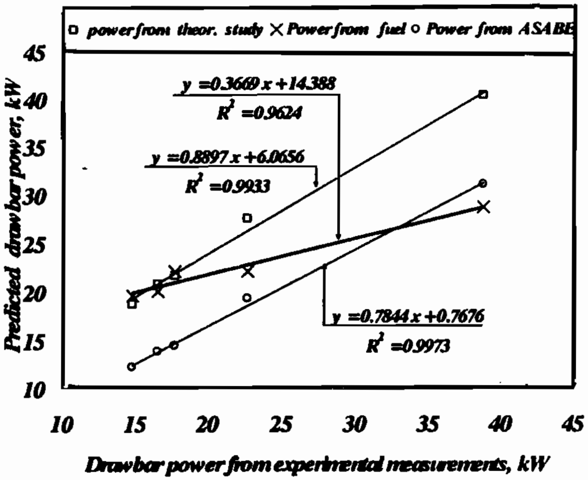


Fig. (8): The relationships between the predicted and the experimental drawbar power for 7-tine integral chisel plow.

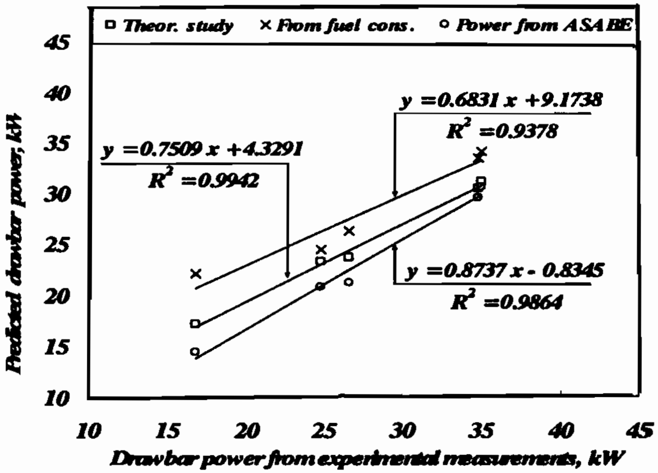


Fig. (9): The relationships between the predicted and the experimental drawbar power for 2-bottom, 50 cm integral moldboard plow.

Conclusions

In this study a flow chart has been used to show how to predict the drawbar power requirements for operating any chisel and moldboard plows (under certain experimental conditions). The theoretical and experimental studies showed that:

1- The predicted power obtained for the moldboard plow which resulted from the theoretical analysis in this study, was very close to that obtained from the experimental work, and both greed with that calculated from fuel consumption and equations published in *ASABE*, 2006.

2- Prediction of power for chisel plow was approximately 26% more than the experimental at plowing speed of 3.2 $km.h^{-1}$. Increasing speed to 6.91 $km.h^{-1}$ increased prediction power by only 3.63%.

3- Prediction of power for moldboard plow was approximately 1.91% more than the experimental at plowing speed of 3.2 $km.h^{-1}$. Increasing speed to 5.83 $km.h^{-1}$ decreased prediction power by 11.38%.

4- The specific power ($W.cm^{-2}$) increased by 115.77% as the theoretical plowing speed increased from 3.2 to 6.91 $km.h^{-1}$ in case of using chisel plow. And increased by 81.54% as the plowing speed assumed to be increased from 3.2 to 5.83 $km.h^{-1}$ in case of using the moldboard plow.

5- The matched tractor size could be selected according to the plow size or vise versa, at any soil condition.

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التنبؤ بالقدرة اللازمة لتشغيل المحراث الحفار والمحراث القلاب المطرحي في أرض طينية

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استخدام جرار ذات قدرة لا تتناسب مع متطلبات القدرة لتشغيل الآلة يسبب العديد من المشاكل. استخدام جرار ذات قدرة أعلي مما تتطلبه الآلة يسبب كبس التربة وكذلك كفاءة تشغيل أقل وذلك نتيجة زيادة كل من وزن الجرار ومعدل استهلاك الوقود وكذلك زيادة التكاليف الثابتة نتيجة ارتفاع ثمن الجرار بالمقارنة بالجرار ذات القدرة المناسبة لتشغيل الآلة. واستخدام جرار ذات قدرة أقل مما تتطلبه الآلة يحدث فقد في القدرة نتيجة الانزلاق في عجل الجرار وكذلك زيادة التآكل في عجل الجرار. ولهذه الأسباب أجريت هذه الدراسة للمساعدة في اختيار الجرار المناسب للمعدة.

أجريت دراسة نظرية وعملية للتنبؤ بقدرة الجرار المناسب لتشغيل المحراث الحفار والمحراث القلاب المطرحي، وتم تقدير القدرة علي قضيب الجر للجرار(كيلووات) والقدرة النوعية (القدرة اللازمة لحرث وإثارة وحدة مساحة مقطع التربة، وات.سم$^{-2}$) أثناء تشغيل كل من المحراث الحفار والمحراث القلاب المطرحي وذلك من خلال كل من الدراسة النظرية المقترحة، معدل استهلاك الوقود، المعادلات والبيانات المنشورة في ASABE (٢٠٠٦) ، ومن خلال قياسات حقلية. ووجد من الدراسة مايلي:

١- القدرة علي قضيب الجر لتشغيل المحراث الحفار والمتنبأ بها من خلال التحليلات النظرية (الدراسة النظرية) زادت عن المتحصل عليها من خلال تجارب حقلية بحوالي ٢٦% عند سرعة حرث ٣,٢كم.س$^{-1}$. وبزيادة السرعة الي ٦,٩١ كم.س$^{-1}$ زادت بنسبة ٣,٦٣% فقط. ولكن زادت بنسبة ١,٩١% عن المتحصل عليها من خلال التجارب العملية لتشغيل المحراث القلاب المطرحي علي سرعة ٣,٢ كم.س$^{-1}$، وبزيادة سرعة الحرث إالي ٥,٨٣ كم.س$^{-1}$ تناقصت القدرة المتنبأ بها بنسبة ١١,٣٨%.

٢- قيم القدرة المتنبأ بها من خلال الدراسة النظرية المقترحة للمحراث القلاب المطرحي قريبة من القيم المتحصل عليها من خلال كل من خلال معدل استهلاك الوقود، ASABE(٢٠٠٦)، القياسات الحقلية وذلك مقارنة بالمحراث الحفار.

٣- زادت القدرة النوعية (القدرة اللازمة لحرث وإثارة وحدة مساحة مقطع التربة، وات.سم$^{-2}$) بمعدل ١١,٣٢، ١٥,٧٧، ٤٧,٣، ١١٥,٧٧% بزيادة سرعة الحرث من ٣,٢ إلي ٣,٥٦، ٣,٧١، ٤,٧٢، ٦,٩١ كم.س$^{-1}$علي الترتيب لتشغيل المحراث الحفار، وبمعدل ٣٥,٩٨، ٣٨,٢٧، ٧٧,٦٣، ٨١,٥٤% بزيادة سرعة الحرث من ٣,٢ إلي ٤,٣٦، ٤,٤٣، ٥,٦٩، ٥,٨٣ كم. س$^{-1}$ علي الترتيب للمحراث القلاب المطرحي.

٤- تتناسب سرعة الأداء والقدرة اللازمة لتشغيل المحراث الحفار والمحراث القلاب المطرحي عكسيا مع متوسط قطر قلاقيل التربة وتتناسب طرديا مع نسبة تفتيت التربة.

٥- من خلال التنبؤ بمساحة مقطع الحرث، المقاومة النوعية للتربة وسرعة الأداء أمكن التنبؤ بالقدرة علي قضيب الجر وبالتالي يمكن اختيار الجرار المناسب لأداء عملية الحرث بالمحراث المتاح أو اختيار المحراث المناسب مع الجرار المتاح. ولتشغيل الجرار بأعلى كفاءة مع الآلة الزراعية يجب أداء العملية في أقل وقت وأقل استهلاكا للوقود.