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Determination of Draft Power Requirements for Tillage Implements Under Central Gezira Clay Soil Conditions

Anas DAbdAllahMohammed A. Ali and Osama A. Muhieldeen*

Faculty of Agricultural Sciences, University of Gezira, Wad Madani, Sudan
Corresponding Author: osamaabbas11@yahoo.com.
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Abstract

This study was conducted to determine the draft power required for different tillage implements under central Gezira clay soil conditions. The experimental work involved five implements (chisel plow, moldboard plow, disk plow, disk harrow and ridger) which were tested at three speeds (3.5, 4.0 and 4.5 km/h) under two levels of soil moisture content (14.8% - pre-watered soil, and 4.2% - dry soil). A split-split plot experimental design with three replications was used. The draft power required, and the fuel consumed, by operating individual implement for primary tillage were measured. Moreover, the draft power, and the fuel consumed, for the operation of a secondary tillage implement (disk harrow) after primary tillage were measured. Statistical analysis of the results showed that the required draft power and fuel consumption for primary and secondary tillage operations significantly increased with increased speed and decreased with increased soil moisture content. For primary tillage, the draft power required to operate the chisel plow was significantly higher than for the other tested implements, regardless of the operating speed and the soil moisture content (the highest value of chisel plow draft power was 31.07 HP, which was found in speed 4.5 km/hr and moisture content 4.2 %); while the disk harrow draft power requirements were significantly the lowest (the lowest value of disk harrow draft power was 14.82 HP, was found in speed 3.5 km/hr and moisture content 14.8 %). The fuel consumed by the operation of the chisel plow was significantly higher compared to the other tested implements, while the fuel requirements for the disk harrow were significantly the lowest. The results clearly indicated that pre-watering of soil moisture of 14.3 % before primary tillage, and operating the implement at a medium speed of 4.0 km/h, will significantly decrease the draft power and fuel required for both primary and secondary tillage operations

Keywords: Draft power, Fuel consumption, Tillage implement, Moisture conten

Introduction

To assure normal plant growth, the soil must be prepared in such conditions that roots can have enough air, water, and nutrients. Structure of the A-horizon is largely influenced by soil tillage systems and the implements used for tillage (Lal, 1997; Husnjak et al., 2002).

Crop establishment and growth, requires mechanical manipulation of the soil by equipment that either cuts, shatter, inverts or mixes the soil (Cannell, 1985; Gajri et al., 2002). It is performed for optimizing productivity by alleviating physical, chemical and biological constraints of the soil (Gajri et al., 2002). The optimum seedbed depends on soil texture (Kritz, 1983), and scientists disagree as to which aggregate size provides the ideal seedbed, but most of them suggest small amounts of dust (<0.5mm) and clods (>20mm) are necessary (Adem et al., 1984).

Farmers mostly depend on past experience for selecting tractors and implements for various farming operations rather than using quantitative methods. Therefore, prediction of implement draft requirement is important for tractor selection and implements matching (Al-Janobi and Al-Suhaibani, 1998).

Draft measurements are required for many studies including energy input for field equipment and tractive performance of a tractor. Vertical force affects weight transfer from implement to the tractor, and consequently, affects the tractive performance and dynamic stability of the tractor (Chen et al., 2007).

The draft of a plow is affected by many factors, such as the type and shape of bottom, the sharpness of the share, the overall adjustment of the plow, the depth and width of furrow, soil type, operating speed and soil characteristics.

The operating cost for any given implement could be minimized either by optimizing the travel speed or the operating width. The choice of an approperate implement can reduce tillage energy requirement by 40% (Michel et al., 1985). A correct matching of tractor-implement system would result in decreased power losses, improved efficiency of operation, reduced operating costs and optimum utilization of capital or fixed costs (Taylor et al., 1991).

This research endeavor is carried out to determine specific data about draft power requirements of different soil tillage implements under central Gezira clay soil conditions.

Materials and Methods

The experimental work to determine the draft requirement of different tillage implements under central Gezira clay soil conditions was conducted in the Demonstration Farm of the Faculty of Agriculture and Natural Resources, University of Gezira. The experimental site is located at latitude 14 °25′N and longitude 33°31′E within Greater Wad Medani Municipality. The soil of the site is classified as vertisol; and is characterized by its deep dark color, low organic matter content, low permeability, and deep cracks when dry. Its clay content is around 58%; bulk density 1.7 g/cm^3 , infiltration rate is 1.8 cm/hr, wetting front is 21.0 cm and its reaction is moderately alkaline (pH=8.1), non- saline (EC< 0.3ds/m) and slightly sodic (ESP =18%), (Fawzi and Abd El Ghani, 2005).

The experimental work involved five implements, chisel plow, moldboard plow, disk plow, disk harrow, and ridger. These were tested at three operational speeds; S1 = 3.5 km/h, S2 = 4.0 km/h, and S3 = 4.5 km/h under two levels of soil moisture content, which were M_1= 14.8% and M_2 = 4.2%.

The experimental design was split- split plot design, with three replications. The main plots were the soil moisture contents, the sub-plots were the operational speeds, while the implements types were assigned to the sub-sub plots.

The draft of implement or implements combination was measured using the pull-type dynamo meter through the procedure of Hassanin (2003):

The method used for determination of the fuel consumption for each tillage implement, and implements combination, was as follows:

(1) The auxiliary tractor fuel tank was filled to a specified level.

(2) At the end of completion of the test run on the experimental plot (3×40m) the

measuring cylinder was used to refill the fuel tank to the pre-specified level.

The amount of fuel required to refill the tank to the starting level

was the amount of fuel consumed in the experimental plot.

Results and Discussion

Table 1 presents the results of draft power for the primary tillage implements tested. The analysis of variance showed that there were significant differences ($P< 0.05$) between the treatments. At the first and second moisture levels (M_1 and M_2) the results indicated that the chisel plow had the highest draft power, while the disk harrow had the lowest draft power at all speed levels. However, there was no significant difference in draft power between the disk plow and the moldboard plow at the first speed (S_1) under the first moisture content level (M_1) and at the first and second speeds (S_1 and S_2) under the second moisture level (M_2). Morever, the results indicated that there was no significance difference in draft power beween the disk harrow and the ridger at the first and second speeds (S_1 and S_2) under the first moisture level (M_1) and at all speeds under the second moisture level (M_2). It is clear that the chisel plow requires more draft power than both the moldboard and the disk plows. This agrees with the findings of Bauder et al.(1981) who reported that penetration resistance was lower under the moldboard plow than under the chisl plow. Similarly, according to the studies of Mielke et al. (1984) and Erbach et al.(1992), the lowest penetration resistance was obbtined from the moldboard plow, and that the chisel plow requires more force than the moldboard plow and other tillage implements. On the other hand, both the disk harrow and the ridger, although wider in operating width, required the least draft power, because they have better penetration and are lighter in weight. The specific draft (force per cross sectional area of worked soil), energy use for moldboard plow, chisel plow and disc harrow at different soil conditions were investigated by Arvidsson et al. (2004). They found that the specific draft was generally the highest for the chisel plow and the lowest for the moldboard plow and the disc harrow and referred that to the differences in implement geometry and mode of soil break-up.

Table 2 display the results of fuel consumption for the primary tillage implements tested. The analysis of variance showed that there were significant differences ($P< 0.05$) between the treatments. The results indicated that the chisel plow had the highest fuel consumption, while the disk harrow had the lowest fuel consumption at almost all speed levels. However, there was no significant difference in fuel consumption between the disk plow and the moldboard plow at the first speed (S_1) under the first moisture content (M_1), and at the first and third speeds (S_1 and S_3) under the second moisture level (M_2). Moreover, the results indicated that there was no significant difference in fuel consumption between the disk harrow and the ridger at the first and third speeds (S_1 and S_3) under the second moisture level (M_2). It is noticed that fuel consumption followed closely the trend of draft power, in such a way that it was increased with increased speed and decreased with the increase in soil moisture content.

Table 3 presents the results for draft power for the secondary tillage implement (disk harrow) that used after primary tillage operations. The analysis of variance showed that there were significant differences ($P< 0.05$) between treatments.

At the first and second moisture levels (M_1 and M_2) the results indicated that applying the disk harrow after the chisel plow had the highest draft power, exceeded only by applying the disk harrow after the moldboard plow at the second speed (S_2) and under the second moisture level (M_2). On the other hand the disk harrow after the disk harrow had the lowest draft at all speeds and under both moisture content levels.

The results indicated that there was no significant difference in draft power between the disk harrow after the disk plow and after the moldboard plow at all speeds. There were no significant difference between disk harrow at first speed under the first moisture level (M_1), and at the third speed (S_3) under the second moisture level for all primary tillage operations. Results shows that, there was no significant difference in draft power between the disk harrow after the disk plow, after the moldboard plow and after the disk harrow at the second and third speeds (S2 and S3) under the first moisture level (M1), and between the disk harrow after disk plow and after disk harrow at the first speed (S1) under the second moisture level (M2) for all primary tillage operation.

Generally, the draft power for secondary tillage using disk harrow was much higher after the chisel plow compared to the other primary tillage implements tested.

Table 4 shows the consumption of fuel (gal/fed) for the secondary tillage implement (disk harrow) used after primary tillage operations. The analysis of variance showed that there were significant differences ($P< 0.05$) between treatments.

The results indicated that the disk harrow after the chisel plow had the highest fuel consumption at all speeds and under both moisture levels except disk harrow after moldboard there were no significant differences between them at speed three under (M1) and also at speed three under (M2). On the other hand, no appreciable differences in fuel consumption were observed for the disk harrow after the disk plow, after the moldboard plow and after the disk harrow at all speeds and under both moisture levels.

Generally, form all the above results, it is obvious that draft power and fuel consumption increase with the increase in operating speed, regardless of the tillage implement used, which agree with the studies carried out by Al Janobi and El-Suhaibani (1998), and Saunders et al (2000). Moreover, draft power and fuel consumption decrease with increase in soil moisture content, up to a certain limit, regardless of the tillage implement used, which agrees with the findings of Dexter and Bird (2001) and Mueller et al (2003).

Conclusions:

For primary tillage operations, the draft power and fuel consumption of each tested implement significantly increased with increased operating speed and decreased with increased soil moisture content level.

For secondary tillage operations using a disk harrow over previously tilled soil, the draft power and fuel consumption significantly increased with increased operating speed and decreased with increased soil moisture content level, regardless of the primary tillage operation performed.

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Table.1: Comparisons of draft power for primary tillage implements.

Implement	Draft power (HP)					
	Moisture level (M_1)			Moisture level (M_2)		
	S_1	S_2	S_3	S_1	S_2	S_3
Disk Plow	17.33^b	19.87^b	22.85^c	17.91^b	21.18^b	24.25^c
Moldboard Plow	19.95^b	22.25^a	24.42^b	19.29^b	22.39^b	26.15^b
Chisel Plow	20.24^a	24.64^a	27.07^a	22.32^a	27.07^a	31.07^a
Disk Harrow	14.82^c	15.94^c	18.16^e	14.86^c	16.61^c	19.38^d
Ridger	14.86^c	17.73^c	20.29^d	15.19^c	$18.23b^c$	20.51^d
Cv%	2.05	2.11	1.41	1.55	1.84	1.53
SE±	0.92	0.94	0.63	0.69	0.82	0.68

Means followed by the same letter (s) in the same column are not significantly different at P = 0.05 according to Duncan's Multiple Range Test.

Table.2: Comparisons of Fuel consumption for primary tillage implements.

Implement	Fuel consumption (gal/fed)					
	Moisture level(M_1)			Moisture level(M_2)		
	S1	S2	S3	S1	S2	S3
Disk Plow	1.12^b	1.12^b	1.30^c	1.30^b	1.50^a	1.52^b
Moldboard Plow	1.14^b	1.32^a	1.35^b	1.32^b	1.32^b	1.50^b
Chisel Plow	1.32^a	1.32^a	1.50^a	1.50^a	1.50^a	1.69^a
Disk Harrow	0.56^d	0.57^d	0.76^e	0.77^c	0.76^d	0.93^c
Ridger	0.75^c	0.76^c	0.92^d	0.76^c	0.81^c	0.95^c
Cv%	0.03	0.03	0.04	0.03	0.03	0.03
SE±	0.01	0.02	0.02	0.01	0.02	0.01

Means followed by the same letter (s) in the same column are not significantly different at P = 0.05 according to Duncan's Multiple Range Test.

Table 3: Comparisons of draft power for secondary tillage implement after primary tillage.

Implements	Horse power (HP)					
	Moisture level (M_1)			Moisture level (M_2)		
	S1	S2	S3	S1	S2	S3
Disk harrow after Disk Plow	13.34^{ab}	14.80^b	16.65^b	12.65^b	15.49^b	17.43^a
Disk harrow after Moldboard Plow	12.65^{bc}	14.40^b	16.40^b	13.38^a	16.24^a	18.16^a
Disk harrow after Chisel Plow	13.47^a	15.54^a	17.65^a	13.55^a	15.25^b	18.10^a
Disk Harrow after Disk Harrow	12.47^c	14.65^b	16.32^b	12.65^b	14.35^c	17.16^a
Cv%	0.75	0.42	0.59	0.36	0.53	1.50
SE±	0.33	0.18	0.26	0.16	0.23	0.65

Means followed by the same letter (s) in the same column are not significantly different at P = 0.05 according to Duncan's Multiple Range Test.

Table 4: Comparisons of fuel consumption for secondary tillage implement after primary tillage:

Implements	Fuel consumption (gal/fed)					
	Moisture level (M_1)			Moisture level (M_2)		
	S1	S2	S3	S1	S2	S3
Disk harrow after Disk Plow	0.56^b	0.56^b	0.67^b	0.57^b	0.67^b	0.68^{bc}
Disk harrow after Moldboard Plow	0.57^b	0.57^b	0.68^{ab}	0.57^b	0.70^a	0.71^{ab}
Disk harrow after Chisel Plow	0.61^a	0.62^a	0.70^a	0.65^a	0.72^a	0.73^a
Disk Harrow after Disk Harrow	0.55^b	0.58^b	0.57^b	0.57^b	0.57^b	0.66^c
CV%	0.02	0.02	0.02	0.02	0.02	0.03
SE±	0.01	0.01	0.03	0.03	0.01	0.02

Means followed by the same letter (s) in the same column are not significantly different at P = 0.05 according to Duncan's Multiple Range Test.

تحديد متطلبات قدرة الجر لآلات الحراثة تحت ظروف التربة الطينية لوسط الجزيرة

أنس دفع الله عبد الله محمد، محمد أحمد علي عمر، أسامة عباس محي الدين النويري
كلية العلوم الزراعية ، جامعة الجزيرة، ودمدني– السودان

المستخلص

أجريت هذه الدراسة لتحديد قوة الجر المطلوبة لآلات حراثة مختلفة تحت ظروف تربة وسط الجزيرة. التجربة شملت خمسة آلات (المحراث الحفار، المحراث المطرحي، المحراث القرصي، المشط القرصي والطراد) والتي تم اختبارهاعلى ثلاث سرعات (3.5، 4.0 و 4.5 كلم/ساعة) تحت مستويين من رطوبة التربة (14.8% للتربة المروية مسبقا و 4.2% للتربة الجافة) نفذت هذه التجربة بتصميم نظام القطع المنشقة بثلاث تكرارات. تم قياس قوة الجر المطلوبة والوقود المستهلك لتشغيل آلات الحراثة الأولية المفردة. بالإضافة لذلك تم قياس قوة الجر والوقود المستهلك لتشغيل آلة حراثة ثانوية (المشط القرصي) بعد الحراثة الأولية. أظهر التحليل الإحصائي أناحتياجات قوة الجر واستهلاك الوقود للحراثة الأولية، والثانوية ازدادت معنويا بزيادة السرعة وانخفضت مع زيادة محتوى رطوبة التربة. للحراثة الأولية، كانت قوة الجر المطلوبة لتشغيل المحراث الحفار هي الأعلى معنويا من بينالآلات المختبرة الأخرى، بغض النظر عن سرعة التشغيل ومحتوى رطوبة التربة(أعلا قيمة لقوة جر المحراث الحفار هي 31.07 حصان وجدت عند السرعة 4.5 كم/ساعة ومحتوي رطوبة تربة 4.2%) : في حين كانت احتياجات المشط القرصي هيالأقل معنويأعلا قيمة لقوة جر المشط القرصي هي 14.82 حصان وجدت عند السرعة 3.5 كم/ساعة ومحتوي رطوبة تربة(14.8%) ً. بالإضافة لذلك كان الوقود المستهلك أثناء تشغيل المحراث الحفار أعلي معنوياً من الآلات المختبرة الأخرى، في حين كانت احتياجات المشط القرصيالأقل معنوياً. وللحراثة الثانوية كانت احتياجات قوة الجر والوقود المستهلك لتشغيل المشط القرصي بعد المحراث الحفار الأعلى معنوياً، ولكن لم تكن هناك فروقات معنوية واضحة عند استخدام المشط القرصي بعد الآلات المختبرة الأخرى. تشير النتائج بوضوح إليأنالري المسبق عند رطوبة 14.3% قبل الحراثة الآولية وتشغيل الآلة على سرعة متوسطة تعادل4 كلم /ساعة سوف تقلل معنويا من احتياجات قوة الجر والوقود للحراثة الأولية والثانوية معا.