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Effect of plowing depths and type of transmission system on the performance of agricultural tractors under clay soil condition

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ABSTRACT

The study was conducted at the Experimental Farm of the University of Gedarif during summer season of 2016 at a soil moisture content of 7.24% and bulk density of 1.4 g/cm^3. Three types of tractors with different transmission systems were used in this study, the transmission systems were conventional, powershift and combination of conventional and powershift. The tested parameters were drawbar power, fuel consumption, wheel slip and field capacity. To evaluate the tested parameters, three different depths were used, namely, 15, 20 and 25 cm. A completely randomized block design with four replications was used to execute the experiment. The statistical analysis indicated that there was no significant difference ($p \geq 0.05$) between the tractors in drawbar power for the plowing depths of 15 and 20 cm, while there was a significant difference ($p \geq 0.05$) between conventional and the other two tractors for the depth of 25cm; it produced the least power. There was no significant difference between the treatments for the depths of 15 and 20 cm, no significant difference between conventional and powershift for the depth 25 cm, while there was a significant difference ($p \geq 0.05$) between the combination and the other two systems under the depth of 25 cm. The combination transmission system showed the highest fuel consumption for all depths. Comparing the values of fuel consumption with the drawbar power revealed that powershift had resulted in more drawbar power with less fuel consumption. Powershift system was less affected by changing the depth during the field operation. There was no significant difference ($p \geq 0.05$) between the treatments for the depths of 15, and 20cm, no significant difference between powershift and combination system for the depth of 25cm, while there was significant difference ($p \geq 0.05$) between conventional and the other two systems for the depth of 25cm since it was highly affected by the increased in plowing depth. The wheel percentage of slip for conventional and combination systems did not affected by plowing depth. Percentage of slip for the powershift was less than the recommended range 5-10% and it was unacceptable for the drawbar power that obtained from this tractor. There was no significant difference between the systems for the depths of 20 and 25 cm. No significant difference between conventional and poweshift for the depth of 15 cm while there was a significant difference between poweshift and the other two systems for the depth of 15cm. it could be concluded that powershift had resulted in more drawbar power with less fuel consumption and less affected by changing the depth during the field operation.

INTRODUCTION

The conventional tractors which was equipped with conventional engines and transmission system were going to be replaced by the modern tractors (engine with electronic fuel injection, power shift transmission, exhaust gas recirculation and air conditioning systems). The use of power shift transmission system to transmit the power from the engine to the drawbar is more comfortable for the operator, more tractor stability, less noise, equipped with multiple hydraulic and electric accessories. On the other hand, it contains a lot of parts that are theoretically exposed to the risk of breakdown with less skill of operator and service stations. Generally, the performance of the tractors depends on many factors such as design, working depth and speed; therefore it must be studied to achieve the optimum environmental and field operations.

Interest in hydro mechanical power-split (PS) drives for construction machines has grown in recent years. Numerous academic publications have shown their potential for reducing energy losses and increasing control flexibility, e.g. Carl and Ivantysynova (2006), Liscouet et al., (2006), Kumar et al., (2007) and Fleczoreck et al. (2010).

The primary purpose of agricultural tractors is to provide drawbar work since drawbar is the most commonly used power outlet of a tractor. According to Kathirvel et al. (2001), the ability to provide draft to pull various types of implements is a primary measure of the effectiveness of a tractor. Drawbar work is achieved through the drive wheel to move the tractor and or implements through the soil. Drawbar work can be expressed as the product of pull and travel speed. Therefore, the ideal tractor converts all the energy from the fuel into useful work at the drawbar. In practice, most of the potential energy is lost in the conversion of chemical energy to mechanical energy, along with losses from the engine through the drive train and finally through the tractive device (Zoz and Grisso, 2003). Reports from literature indicate about 20% to 55% of the available tractor energy is wasted wears at the tractive device-soil interface.

Draft force and power requirement for tillage implements were considerably affected by implement design and conditions of soil. In terms of effects on draft force and soil disturbance, Rahman and Chen (2001) reported that the working depth of tillage implement was more critical than the working speed. Kheiralla et al. (2004) formulated a draft force models for ploughs based on traveling speed and tillage depth. Travel speed and tillage depth were used to study the draught of the tillage implements. They found the draft of the tillage implements was significantly affected by both travel speed and tillage depth. The draught for the tandem disk varied quadratically with depth when used as a primary tillage implement. The tillage depth mostly influenced the draft of the chisel plough. Although the linear effect of travel speed was found to be significant, speed showed little effect on chisel plough draught. The field cultivator draught was linearly dependent on speed and speed by depth interaction, and quadratic dependent on depth.

The objective of this study was to investigate the effect of plowing depths and type of transmission system on the performance of tractor under clay soil condition.

MATERIALS AND METHODS

Experimental site:

The study was conducted at the Experimental Farm of the University of Gedarif during summer season of 2016. The soils of the area are heavy dark cracking clays (Hamdoun et. al, 1999). The experiment was conducted at a soil moisture content (dry base) of 7.24% and bulk density of 1.4 g/cm^3. The climate of the area is semi-arid to high rainfall savanna with hot summer and worm winter. The average temperature in the hottest April or May is 40 – 42ºC. The average rainfall is

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400–1000 mm which falls mainly during May to October, (July and August receive the highest quantities).

Experimental materials:

1. Three types of tractors with different transmission systems were used in this study. The transmission systems were conventional, powershift and combination of conventional and powershift. Some of the specifications are shown in Table (1).

Table (1) tractors specification

Item	Tractor Transmission type		
	Conventional	Powershift	Combination
Number of cylinders	6	6	6
Power (kW)	134	134	134
Fuel system	Inline	Rotary type	Inline
Front tire dimensions	16.9R28	540/65R28	16.9R28
Rear tire dimensions	20.8R38	650S/65R38	20.8R38

2. A spring pull-type Dynamometer (SN2650) was used for measuring the draft force available for the tractors used in this study.
3. A plastic, 50-meters long measuring tape was used for distance measurements.
4. A cylindrical glass gauge was used for the measurement of fuel consumption.
5. Cell-phone stop watch was used to record the time required to determine the speed.
6. An auger for soil sampling for measuring moisture content and bulk density.
7. Mounted chisel plow with (11) shanks and 3m width was used to conduct the experiment of tractor performance parameters.

Experimental procedure:

The tested parameters were drawbar power, fuel consumption, wheel slip and field capacity.

Two tractors were used to determine the draft. The dynamometer was attached between the two tractors when the tested tractor was loaded by the implement. To evaluate the tested parameters, three different speeds were used, namely, 5, 6 and 7 km/hour.

After determining the speed and the draft at which the tractors were capable to pull the implement, the drawbar power is calculated using the following equation (Hunt, 2001):

$$DBP = \frac{S \times D}{C} \quad (1)$$

Where:

DBP	=	Drawbar power (kW)
S	=	Travel speed, (km/hr)
D	=	Draft, (kN)
C	=	Constant (3.6)

The fuel consumption was estimated as follows (tractor in plowing position):

a) The tractor fuel tank was filled at the starting point of the experimental block.
b) The tractor was moved from the started point to the end (100 m).
c) The time (t) required to cover the distance was recorded and the quantity of fuel (Q) required to fill the tank was measured.
d) Then the fuel consumption was calculated as follows.

$$F.C = \frac{Q}{t} \quad \ldots\ldots (2)$$

Where:

F.C	=	Fuel consumption (L/h)
Q	=	Quantity of consumed fuel required to fill the tank (L)
T	=	Time (hr)

Tractor wheel slip was found by determining the number of tire rotations when the tractor travels over a set distance, at the working speed without load then determining the number pf rotations while the tractor is under load. Then the slip was determined by the use of the following equation:

$$slip(\%) = \frac{(no\ of\ rotation\ with\ load - no\ of\ rotation\ without\ load)}{\text{no of rotation with load}} \times 100 \ldots\ldots (3)$$

The field capacity was measured by determining the time required to travel (100, 60m) to obtain the speed. Then the field capacity was determined using the formula (Kepner et al, 1978):

Where: $$TFC = \frac{S\ x\ W}{C} \quad \ldots\ldots (4)$$

TFC	=	Theoretical field capacity (ha/hour)
S	=	Operating speed (km/hour)
W	=	Implement width (m)
C	=	Constant (10)

Experimental design:

The randomized complete block design (RCBD) with four replications (blocks) was used to execute the experiment. The block was (100m x 3m) with 1.5m spacing between blocks. Three treatments were tried each with three replications. Analysis of variance was done using (MSTAT) program at 0.05 of probability level and Duncan's Multiple Range Test (DMRT) to evaluate the different tested parameters.

RESULTS AND DISCUSSION

Drawbar power:

The effect of plowing depth and type of transmission systems at constant speed on the tractors performance was investigated. The statistical analysis indicated that there was no significant difference (p ≥0.05) between the tractors in drawbar power for the plowing depths of 15 and 20 cm, while there was a significant difference (p ≥0.05) between conventional and the other two tractors for the depth of 25cm; it produced the least power (Table2).

Table (2): Effect of plowing depth on drawbar power (kW/hr)

Transmission type	Depth (cm)		
	15	20	25
Conventional	30.24a	69.36a	79.8b
Powershift	32.90a	73.24a	89.08a
Combination	30.24a	73.44a	85.68a
Mean	31.13	72.01	84.85
C.V	8.61	4.31	2.86
S.E±	1.55	1.79	1.40
L.S	6.07	7.04	5.51

Where: C.V= Coefficient of Variance, S.E= Stander Error, L.S= least Significant Difference

Fuel consumption:

The statistical analysis showed that there was no significant difference(p ≥0.05) between the treatments for the depths of 15 and 20 cm, no significant difference between conventional and powershift for the depth 25 cm, while there was a significant difference between the combination and the other two systems under the depth of 25 cm, (Table 3). The combination transmission system showed the highest fuel consumption for all depths. Comparing the values of fuel consumption with the drawbar power revealed that powershift had resulted in more drawbar power with less fuel consumption **Table (3): Effect of depth on fuel consumption (l/hr)**

Transmission type	Depth (cm)		
	15	20	25
Conventional	21.43a	23.33a	25.00b
Powershift	20.77a	21.43a	25.03b
Combination	25.00a	28.57a	33.24a
Mean	22.40	24.44	27.75
C.V	12.04	19.14	12.85
S.E±	1.52	2.67	2.06
L.S	6.12	10.61	8.09

Field capacity:

Table (4) showed that as the depth is increased, field capacity is decreased but the powershift system was less affected by changing the depth during the field operation. The analysis of variance indicated that there was no significant difference (p ≥0.05) between the treatments for the depths of 15, and 20cm, no significant difference between powershift and combination system for the depth of 25cm, while there was significant difference (p ≥0.05) between conventional and the other two systems for the depth of 25cm since it was highly affected by the increased in plowing depth.

Table (4): Effect of depth on theoretical field capacity (ha/hour)

Transmission type	Depth (cm)		
	15	20	25
Conventional	1.33a	1.16a	1.14b
Powershift	1.43a	1.30a	1.27a
Combination	1.32a	1.30a	1.22a
Mean	1.36	1.25	1.21
C.V	7.36	4.32	2.85
S.E±	0.058	0.032	0.017
L.S	0.227	0.003	0.078

Wheel slip:

Table (5) showed that the wheel percentage of slip for conventional and combination systems did not affected by plowing depth. Percentage of slip for the powershift was less than the recommended range 5-10% and it was unacceptable for the drawbar power that obtained from this tractor. This was because of zero wheel slip at the depth of 15cm. The analysis of variance showed that there was no significant difference (p ≥0.05) between the treatment for the depths of 20 and 25 cm. No significant difference (p ≥0.05) between conventional and poweshift for the depth of 15 cm while there was a significant difference (p ≥0.05) between poweshift and the other two systems for the depth of 15cm.

Table (5): Effect of depth on wheel slippage (%)

Tractor type	Depth (cm)		
	15	20	25
Conventional	6a	6a	8a
Powershift	7b	2a	6a
Combination Mean	6a	8a	10a
Mean	6.33	5.33	8
C.V	39.74	29.65	28.87
S.E±	0.96	0.91	1.33
L.S	3.78	10.26	5.24

Estimating the brake power matching the size of chisel plow:

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Many studies revealed that the drawbar power could be 20-30% of the engine power. This result was used to estimate the drawbar power required to pull the chisel plow under different depths. According to Table (6) the brake power to match the size of the chisel plow can be predicted by the following equation:

$$BP = \frac{NS * \text{DRPS}}{0.73}$$

Where:

BP = brake power (kN)

NS = number of shanks of chisel plow

DRPS = drawbar power require per one shank

Table (6) Required drawbar power per one shank for specific depth

Depth(cm)	15	20	25	30
DRPS	2.83	6.55	7.71	9.74

CONCLUSION

From the results of the study, the fallowing conclusions can be drawn:

1. The combination transmission system showed the highest fuel consumption for all depths.
2. Powershift had resulted in more drawbar power with less fuel consumption.
3. Powershift system was less affected by changing the depth during the field operation.
4. Conventional system was highly affected by the increased in plowing depth.

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تأثيرعمق الحرث ونوع نظام نقل القدرة على أداء الجرارات الزراعية تحت ظروف التربة الطينية

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الخلاصة

تم اجراء التجربة بالمزرعة التجريبية بجامعة القضارف في موسم 2016 وكانت نسبة الرطوبة 7.24% والكثافة الظاهرية 1.40جرام/سم^3. استخدمت ثلاثة أنواع من الجرارات بنظم نقل حركة مختلفة وهي النظام التقليدي والنظام الناقل بالقدرة والنظام المزدوج. تم قياس قدرة الجر ومعدل استهلاك الوقود والسعة الحقلية ونسبة انزلاق العجل. لتقييم تلك العوامل تم استخدام ثلاثة أعماق حرث مختلفة هي 15 و20 و25 سم. استخدم نظام القطاعات العشوائية الكامل بأربعة تكرارات. من التجربة وجد أنه لا يوجد فرق معنوي ($p \geq 0.05$) في قدرة الجر بين النظم الثلاثة للأعماق 15 و 20 سم بينما وجد فرق معنوي بين النظام التقليدي والنظامين الآخرين عند العمق 25 سم حيث أعطى النظام التقليدي أقل قدرة. بالنسبة لاستهلاك الوقود فلا يوجد فرق معنوي ($p \geq 0.05$) بين النظم الثلاثة عند الأعماق 15 و 20 سم ولا يوجد فرق معنوي بين النظام التقليدي والنظام الناقل بالقدرة عند العمق 25 سم بينما يوجد فرق معنوي ($p \geq 0.05$) النظام المزدوج والنظامين الآخرين عند العمق 25 سم. أظهر النظام المزدوج أعلى معدل لاستهلاك الوقود لكل الأعماق. بمقارنة قيم معدلات استهلاك الوقود مع القدرة أظهر أن النظام الناقل بالقدرة أعطى أعلى قدرة جر بأقل معدل استهلاك وقود. السعة الحقلية كانت أقل تأثرا بعمق الحرث. لا يوجد فرق معنوي في السعة الحقلية بين النظم الثلاثة للأعماق 15 و 20 سم ، كذلك لا يوجد فرق معنوي بين النظام الناقل بالقدرة والنظام المزدوج عند العمق 25سم بينما يوجد فرق معنوي ($p \geq 0.05$) بين النظام التقليدي والنظامين الآخرين عند العمق 25 سم لأنه تأثر كثيرا بزيادة عمق الحرث. لم يتأثر انزلاق العجل للنظام التقليدي والمزدوج بعمق الحرث. نسبة انزلاق العجل للنظام الناقل بالقدرة أقل من الموصى به(5-10%) وغير مقبول لقدرة الجر المتحصل عليها من هذا الجرار. لا يوجد فرق معنوي بين النظم الثلاثة عند الأعماق 20 و25 سم، ولا يوجد فرق معنوي بين التقليدي والناقل بالحركة عند العمق 15 سم بينما يوجد فرق معنوي بين الناقل بالقدرة والنظامين الآخرين عند العمق 15 سم حيث أعطى أعلى نسبة انزلاق. من الدراسة وضح أن النظام الناقل بالقدرة أعطى أكبر قدرة بأقل معدل استهلاك للوقود وأقل تأثراً بتغيير أعماق الحرث.

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