The Effect Of Some Operating Parameters On Field Performance Of A 2WD Tractor

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ABSTRACT:

The research study was carried out for two consecutive seasons (1997/1998 and 1998/1999) at the farm of Tamboul testing and training center (Gezira State, Sudan) where the soil is heavy cracking clay (5.6% moisture content). The effect of three rear wheel track width settings (140 cm, 160 cm and 180 cm) and four levels of water ballast (zero%, 25%, 50% and 75%) on a two- wheel drive agricultural tractor field performance were evaluated. Engine fuel consumption, rear wheel slippage and effective field capacity were measured when the tractor was linked with either mounted disc plough or trailed offset disc harrow. It was found that generally wider track widths and higher levels of water ballasting and their interactions improved tractor field performance. Significant decrease (at 1% level) in fuel consumption was observed when using disc plough. Combining track width 180 cm with 25% and 50% water ballast levels gave a reduction of 28% fuel consumption when tractor was mounted with the disc plough. The trailed disc harrow showed no significant differences (at 5% level) between such combinations. The wheel slippage decreased from 21% at zero% water ballast to 9.04% at 75% ballast level when using disc plough. The disc harrow decreased the slippage by 26.7% when the water ballast level was increased from zero% to 75%. Combining the two factors significantly decreased the slippage (at 1% level) when wider track width and higher levels of water ballast were used with the mounted implement only. The field capacity of the tractor with mounted disc plough was increased from 0.64 ha/hr to 0.71 ha/hr when the track width was increased from 140 cm to 180 cm. Combining the track width 180 cm with 25% and 50% water ballast levels gave the highest effective field capacity of 0.74 ha /hr (15% average increase) for the mounted disc plough whereas when the trailed disc harrow was used, the highest field capacity was 2.17 ha/hr (21.7% increase) which was obtained from the combined effect of 180 cm track width and 50% water ballast level.

INTRODUCTION:

Land preparation is one of the most energy consuming operations in the field. The energy utilized by a tillage practice depends on many factors such as soil type and condition, operating depth and speed and hitch geometry. As energy is becoming more expensive, its efficient utilization in agricultural production has become a major concern of agricultural engineers and tractor owners. Optimizing the tractor performance in the field depends on the proper matching of the tractor and the implements, which could help in minimizing the fuel consumption and energy loss. Agricultural tractor efficiency relays on better tractive effort which can result from increasing the area of contact between the tractor wheels and the soil surface, and reducing the upnormal slippage. This will reduce tractor power losses and the amounts of fuel used and consequently allow covering more lands in a certain time.

Wheel slip at a given operating load is an important parameter when optimizing the tractor performance for a particular field operation. Tires and tracks operate at their maximum effectiveness within a certain range of slip, so operator could use the slip as an indicator of the tractor performance on site for a particular condition. Several attempts have been made to measure and control wheel slip of agricultural tractors so that power loss will be minimized (Reghavan et al.,1976; Thansantote et al., 1977; Gloker, 1984; Baloch et al., 1988). Turner, 1993 also reviewed a wide variety of methods and devices developed to obtain the measurements for slip calculation.

The tractive efficiency of a tractor could be improved by ballasting. Ballasting will increases the overall weight of the tractor and the area of contact between the soil and the tires and thereby reducing slippage. Ballasting a tractor is usually accomplished by one or more of the following methods; adding wheel weights, adding front weights and filling the tires with water. Increasing the load on a tractor drive wheel will increase the shear strength of the soil and therefore increases gross traction. The maximum thrust, which can be obtained from a wheel or track, will depend on the maximum shearing stress, which the soil can provide, and the area over which this stress is generated (Crossely and Kilgour,1983). Hofman (1977) and Domier and willans (1978) examined several combinations of ballast and speed for agricultural wheeled tractors and they concluded that when tires are ballasted, the extra weight transfer from the wheels should not be large enough to cause large losses in maximum power transmitted. Dwyer (1975 and 1978) indicated that, two wheel drive tractors do not achieve maximum tractive efficiency because of insufficient ballast and/or low field speed. He also stated that ballasting in most field conditions should be 1.0-0.8 kN/kW load on the drive axle but reducing below this figure will cause rapid drop in tractor output. In this concern, Dwyer (1975) suggested operating at wheel slip of 10% with a coefficient of traction of 0.4 to ensure operation at maximum efficiency. Several rules and methods have been offered in past and recent years to predict tractor field performance based on the amount of ballast added. Most of those methods provided certain recommendations of optimum weight/power ratios at different speeds for the tractor working in field conditions (Reece, 1968; Brixius and Zoz, 1976; Gee Clough et al. 1982; Brown, 1982; Rutherford and McAllister, 1983; Bloome et al. 1983). Zang and Chancellor (1988) developed an automatic control system of ballasting position which used with a 67 kW two wheel drive tractor and sensed the soil vertical reaction at the front axle. They found that, the system resulted in improvements in tractive performance and fuel efficiency of the two wheel drive tractors during tillage of about 5% compared of such tractors when operated without this system. Qaisrani et al. (1992) reported that proper ballasting reduced wheel slip, fuel consumption, tire wear and cost of tractor operation. They observed wheel slip reduction and fuel saving up to 33% and 26% respectively with proper ballasting in some cases.

Implement hitch system is influenced by the size of implement and tractor, and the type of implement. With regard to hitching, the implement may be trailed, fully mounted or semimounted . The trailed implements always have means for supporting their weights and a small vertical forces can be transferred from the implement to the tractor. However, the fully mounted implements depend entirely on the tractor for balancing vertical forces. This type of hitching has the best effect of the dynamic load distribution of the tractor i.e. more weight transfer and weight addition is provided to the tractor rear wheels (Alock, 1986).

The objective of this research work is to evaluate the effect of rear wheel track width and water ballasting on a two-wheel tractor field performance by measuring fuel consumption, rear wheel slippage and field capacity when the tractor was linked with a mounted disc plough or trailed offset disc harrow under a heavy clay soil.

MATERIALS AND METHODS:

The experiment was conducted for two consecutive seasons (1997/1998 and 1998/1999) at the farm of Tamboul testing and training center (Gezira State, Sudan) where the soil is heavy cracking clay soil (5.6% moisture content), which is considered as predominant agricultural soil in the Sudan. The total area is 30.24 hectare. A two-wheel drive tractor (72 HP) and two tillage implements namely 3-bottom fully mounted disc plough and 24-plate trailed offset disc harrow were used for the study. The treatments included three rear wheel track width setting, 140 cm, 160 cm and 180 cm and four levels of water ballasting, zero%, 25%, 50% and 75%. Each treatment was replicated three times giving a total of thirty six plots.

The total area was divided into two main blocks, one for disc plough in an area of 11.34 hectare and the other for disc harrow in an area of 18.9 hectare. Each block subdivided into three sub-blocks for 3 replicates and twelve treatments were randomly distributed within each subblock. The experiment was a randomized complete block design.

The rear wheel track widths and water ballast levels were adjusted by jacking up the rear wheels and removing the rim from disc or the complete wheel then reassembled again in their new position after tape measurement of the required track width. Ballasting each rear wheel with water to selected level was done by connecting a hose between the water source and the valve of the inner tube.

Fuel Consumption :

Fuel consumption of the tested tractor at different levels of the variable was carried out by filing up the fuel tank before starting each operation then after finishing every treatment. The fuel tank was refilled again using a 1000-milliliter graduated cylinder. The total quantity of fuel needed to refill the tank was recorded and calculated as fuel consumption in liter/ha.

Wheel Slip :

The tractor wheel slippage at different levels of the two factors (track width and water ballast) and their combinations was calculated as a persantage loss of forward speed of the tractor as follows :

Slippage = [(theoretical speed - actual speed) / theoretical speed] ×100

The theoretical and actual field speed at deferent levels of track width and water ballast were measured using stop watch to record the time taken by the tractor to travel a specific distance (100m) with the specific implement raised up or working in the field respectively.

Effective Field Capacity :

The total time taken by the tractor to finish the operation in each experimental plot was recorded by keeping the working speed as constant as possible throughout the work. The effective field capacity was calculated by the following formula (Hunt, 1983):

$$Ef = A/T$$

Where :

Ef = effective field capacity, ha/hr

A = the area ploughed in each plot, hectare.

T = total time taken in each working plot, hr.

RESULTS AND DISCUSSION:

Analysis of variance was run for the collected data and the results showed that engine fuel consumption of the tractor was decreased as far as wider track widths and higher water ballast levels were used with both mounted and trailed implements (Table 1 and 2). As shown in Table 1, a significant reduction (at 1% level) in fuel consumption was found when the mounted disc plough was used at 180 cm track width. Increasing of water ballast level from zero % to 25% decreased fuel consumption from 9.9 liter/ha to 8.86 liter/ha but again increased to 9.05 liter/ha and 9.24 liter/ha when ballast level was increased to 50% and 75% respectively. This is mainly due to the fluctuation in wheel slippage (Table 3). The lowest fuel consumption of 7.71 liter/ha was obtained from the combination of 180 cm track width with 25% and 50% water ballast levels. Such combinations showed no significant differences (at 5% level) with trailed disc harrow (Table 2). This could be attributed to the absence of the dynamic load transfer to the rear wheels during work by the freely floating disc harrow. This agreed with the observation of Baloch at al. (1988). In the case of disc plough, the existence of dynamic load transfer to the rear wheels improves traction, reduces slippage and therefore leads to lower fuel consumption. These observations are similar to those of Barger et al. (1979) and Qaisrani et al. (1992).

Table (1) : The effect of track width and water ballasting and their combination on tractor fuel consumption (liter/ha) with mounted disc plough

Water ballast level	Rear wheel track width			
	140 (cm)	160 (cm)	180 (cm)	Individual effect of water ballasting
Zero %	10.76	9.33	9.52	9.90
25 %	9.14	9.71	7.71	8.86
50 %	9.90	9.33	7.81	9.05
75 %	10.29	8.86	8.67	9.24
Individual effect of track width	10	9.33	8.48	

For individual effect of track width : SE = ± 0.01, LSD at (5%) = 0.04
For individual effect of water ballasting : SE = ± 0.02, LSD at (5%) = 0.05
For their combination : SE = ± 0.03, LSD at (5%) = 0.08

Table (2) : The effect of track width and water ballasting and their combination on tractor fuel consumption (liter/ha) with trailed disc harrow

Water ballast level	Rear wheel track width			
	140 (cm)	160 (cm)	180 (cm)	Individual effect of water ballasting
Zero %	3.43	3.33	3.05	3.24
25 %	3.71	3.90	3.62	3.71
50 %	3.43	3.52	3.33	3.43
75 %	3.33	3.43	3.43	3.43
Individual effect of track width	3.52	3.52	3.33	

For individual effect of track width: SE = ± 0.001, LSD at (5%) = 0.01
For individual effect of water ballasting : SE = ± 0.01, LSD at (5%) = 0.02
For their combination: SE = ± 0.01

The rear track width significantly reduced (at 1% level) wheel slip by 42% when the track width increased from 140 cm to 180 cm with mounted disc plough (Table 3). The track width had no significant effect (at 5% level) on wheel slippage with trailed disc harrow (Table 4). This effect of implement hitch system, as mentioned before, could be attributed to high dynamic load transfer from the mounted disc plough to the rear wheels, thus improving the tractive effort. This agreed with the conclusion of Barger et al. (1979). For the tailed disc harrow, there was a reverse effect which could be due to both the absence of dynamic load transferred from the implement and the tendency of the harrow to penetrate into the soil at wider track widths which may result in the sinkage of the tractor rear wheels. This is in line with the report of Baloch et al. (1988).

In general increasing water ballast level was observed to decrease wheel slip with both systems of implement hitch (Table 3 and 4). From Table 3 it is clear that the slippage was highly decreased with mounted disc plough.

The slip was decreased from 21% at zero% ballasting to 9% at 75%. The trailed disc harrow decreased slippage from 9% to 6.6% for the above ballasting levels respectively (Table 4). This decrease in wheel slippage is due to the weight addition on the rear wheels and the increased wheel soil area of contact and improvement in the adherence effort. The results agreed with those found by Qaisrani et al. (1992).

Table 3 also showed the combining effect of track width and water ballasting levels on rear wheel slippage when mounted disc plough was used. It was observed that wider track width with higher levels of ballasting decreased the slippage very much. It was decreased by 75% when the combination of 140 cm track width and zero% water ballast was increased to 180 cm track width with 75% water ballast level. From harrowing mean slippage values in Table 4, it can be stated that the general trend indicates that the slippage was decreasing as far as higher water ballast levels were used, but the track width had a reversed effect of increasing slip.

Table (3) : The effect of track width and water ballasting and their combination on tractor slippage (%) with mounted disc plough

Water ballast level	Rear wheel track width			
	140 (cm)	160 (cm)	180 (cm)	Individual effect of water ballasting
Zero %	31.95	16.66	14.38	21.0
25 %	14.22	13.40	8.65	12.09
50 %	15.12	15.33	11.02	13.82
75 %	11.15	7.96	8.01	9.04
Individual effect of track width	18.11	13.34	10.52	

For individual effect of track width: SE = ± 0.33, LSD at (5%) = 0.96
For individual effect of water ballasting: SE = ± 0.39, LSD at (5%) = 1.1
For their combination: SE = ± 0.67, LSD at (5%) = 1.91

Table (4) : The effect of track width and water ballasting and their combination on tractor slippage (%) with trailed disc harrow

Water ballast level	Rear wheel track width			
	140 (cm)	160 (cm)	180 (cm)	Individual effect of water ballasting
Zero %	7.76	11.26	7.99	9.00
25 %	9.11	8.26	11.42	9.70
50 %	7.16	7.31	7.31	7.26
75 %	6.26	6.23	7.31	6.59
Individual effect of track width	7.57	8.34	8.51	

For individual effect of track width: SE = ± 0.29
For individual effect of water ballasting: SE = ± 0.34, LSD at (5%) = 0.97
For their combination: SE = ± 0.01, LSD at (5%) = 1.68

Wider track width was observed to increase the effective field capacity for both mounted and trailed implements. Table 5 and 6 showed that field capacity was increased from 0.64 ha/hr to 0.71 ha/hr and from 1.71 ha/hr to 2.02 ha/hr when the track width was increased from 140 cm to 180 cm for the mounted and trailed implements respectively. For the mounted disc plough, the effective field capacity increase could be due to reduced slippage by using wider tracks which in turn improved the tractive effort and efficiency. This agreed with the conclusion of Barger et al. (1979). For the trailed disc harrow, it was found that the effective field capacity was increased because the increase in wheel slippage is not significant with the track width (Table 4). Increasing of water ballast level from zero% to 75% was found to increase the effective field capacity from 0.64 ha/hr to 0.71 ha/hr for the mounted disc plough (Table 5) while for the trailed disc harrow, the highest field capacity obtained was 1.91 ha/hr at 50% water ballasting level (Table 6). Interaction of the two factors significantly increased (at 1% level) the actual field capacity when wider track width and the higher levels of water ballast was used with both mounted disc plough and trailed disc harrow (Table 5 and 6). Table 5 showed that the highest field capacity was 0.74 ha/hr (15% average increase) and was found when the track width of 180 cm was combined with 25% and 50% levels of water ballast for the mounted implement. When the trailed disc harrow was used, the highest field capacity was 2.17 ha/hr (21.7% increase) and was obtained from the combination of 180 cm track width and 50% water ballast level (Table 6). The field capacity obtained by the trailed disc harrow is greater than that of mounted disc plough because the wheel slippage for harrowing is less than for ploughing at the same combination (Table 3 and 4).

Table (5) : The effect of track width and water ballasting and their combination on tractor field capacity (ha/hr) with mounted disc plough

Water ballast level	Rear wheel track width			
	140 (cm)	**160 (cm)**	**180 (cm)**	**Individual effect of water ballasting**
Zero %	0.61	0.63	0.68	0.64
25 %	0.64	0.66	0.74	0.68
50 %	0.61	0.65	0.74	0.67
75 %	0.70	0.71	0.69	0.71
Individual effect of track width	0.64	0.66	0.71	

For individual effect of track width: SE = ± 0.02, LSD at (5%) = 0.06
For individual effect of water ballasting: SE = ± 0.02, LSD at (5%) = 0.07
For their combination: SE = ± 0.04, LSD at (5%) = 0.12

Table (6) : The effect of track width and water ballasting and their combination on tractor field capacity (ha/hr) with trailed disc harrow

Water ballast level	Rear wheel track width			
	140 (cm)	**160 (cm)**	**180 (cm)**	**Individual effect of water ballasting**
Zero %	1.68	1.74	1.94	1.79
25 %	1.77	1.73	2.02	1.84
50 %	1.70	1.86	2.17	1.91
75 %	1.70	1.87	1.93	1.83
Individual effect of track width	1.71	1.79	2.07	

For individual effect of track width: SE = ± 0.05, LSD at (5%) = 0.13
For individual effect of water ballasting: SE = ± 0.05, LSD at (5%) = 0.15
For their combination: SE = ± 0.09, LSD at (5%) = 0.26

CONCLUSION:

The advantage of using wider track width and higher level of ballast, to improve fuel consumption and wheel slippage, was observed only with the mounted disc plough in some cases of combination. There where a saving of 28% fuel consumption and a reduction in wheel slippage up to 75%. However, the advantage of using wider track width and higher level of ballast, to improve effective field capacity, was found better with the trailed disc harrow. At some cases of combination, it was found an increase in effective field capacity up to 21.7% with the trailed disc harrow compared to an average increase of 15% with the mounted disc plough.

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تأثير بعض عوامل التشغيل على الأداء الحقلي لجرار زراعي ذو عجلات دفع ثنائية

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الملخص :

أجريت هذه الدراسة البحثية لموسمين متتاليين (١٩٩٨/١٩٩٧ و١٩٩٩/١٩٩٨) في مـــزرعة مركز تمبول للاختبار والتدريب بولاية الجزيرة بالسودان (على تربة طينية متشـــققة ذات نسبة رطوبة ٥,٦٪) بغرض تقييم تأثير ثلاث حالات من المسافة بين العجلين الخلفيتين (١٤٠ ، ١٦٠، ١٨٠ سم) للجرار وأربعة مستويات من وزن الماء في الإطـــارات الخلفية (صفر٪، ٢٥٪، ٥٠٪، ٧٥٪) على الأداء الحقلي لجرار زراعي ذي عجـــلات دفـــع ثنائية . وقد تم أخذ القياسات اللازمة لكل من استهلاك المحرك للوقـــود، نسبة انزلاق العجلات الخلفية والأداء الحقلي الفعلي للجرار أثناء التشغيل مع كل من المحراث القرصي المعلق والمشط القرصي المقطور.

بصـــفة عامة وجد أن المسافة العريضة بين العجلات الخلفية والمستويات العالية من وزن الماء في الإطارات الخلفية أو كليهما معاً أدت إلى تحسن كبير في استهلاك الوقود وخاصة عند استخدام المحراث القرصي المعلق. كما وجد أن استهلاك الوقود قل بنسبة (٢٨٪) نتيجة استخدام مسافة بين العجلات الخلفية بعرض ١٨٠ سم مع نسبة ٢٥٪، ٥٠٪ من الماء في الإطارات الخلفية وذلك في حالة المحراث القرصي المعلق، أما في حالة المشط المقطور فلم يلاحظ هناك فروقات معنوية عند الجمع بين المعاملات المختلفة.

كما وجد أن نسبة الانزلاق في العجلات الخلفية انخفضت من ٢١٪ عند استخدام إطارات خالية من الماء إلى ٩,٠٤٪ عند استخدام ٧٥٪ نسبة ماء في الإطارات الخلفية وذلــك في حالــة المحــراث القرصي المعلق، بينما في حالة استخدام المشط القرصي المقطــور انخفض الانزلاق بنسبة ٢٦,٧٪ عند زيادة نسبة الماء في الإطارات من صفر إلى ٧٥٪. أيضا وجد أن هناك انخفاض ملحوظ في نسبة الانزلاق (عند مستوى اختبار ١٪) وذلك عند الجمع بين مسافات أعرض للعجلات الخلفية ونسب أعلى من الماء في الإطارات الخلفية.

كذلــك بينــت الدراســة أن الســعة الحقلية الفعلية للجرار قد زاد من ٠,٦٤ هكتار/ساعة إلى ٠,٧١ هكتار/ساعة عند زيادة المسافة بين العجلات الخلفية من ١٤٠ ســم إلى ١٨٠ سم وذلك عند عمل الجرار مع المحراث القرصي المعلق. أما عند الجمع بين معاملات المسافة بين العجلات ونسب الماء في الإطارات، فقد اتضح أن استعمال مســافة ١٨٠ سم مع ٢٥٪ و٥٠٪ نسبة ماء في الإطارات قد أعطى أعلى سعة حقلية مقدارهــا ٠,٧٤ هكتار/ساعة (بمتوسط زيادة ١٥٪) للمحراث القرصي المعلق أما بالنسبة للمشط القرصي المقطور كانت أعلى سعة حقلية مقدارها ٢,١٧ هكتار/ساعة (بزيادة ٢١,٧٪) عند استخدام مسافة بين العجلات ١٨٠ سم مع نسبة ماء ٥٠٪ في الإطارات الخلفية للجرار.