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Research Article

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Effect of Tillage Implement Type and Depth of Ploughing on Field Performance Parameters in Vertisol Clay Soil of Gezira Scheme (Sudan)

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Abstract This study was conducted during 2017 in Gezira scheme which is characterized by heavy vertisol clay soil. The objective of the study was to evaluate the field performance (effective field capacity "EFC", field efficiency "FE", draft, fuel consumption and drawbar power) of three tillage implements (Chisel Plough "CP", Moldboard Plough "MP" and Disc Plough "DP"), at three soil depths (10, 20 and 30 cm). A split plot design with three replications was used in the experiment. The results showed that CP recorded the highest EFC and FE at all depths. The highest EFC (1.11 ha/h) for the CP was recorded at 10 cm depth while the lowest one (0.42 ha/h) was recorded by the DP at 30 cm depth. The CP also recorded the highest FE at all depths (70%, 67% and 65% at 10, 20 and 30 cm; respectively) as compared to the other tillage implements. The highest draft values (15.0, 17.5 and 20.0 kN) were recorded by the MP at 10, 20 and 30 cm depth respectively; as compared to that of CP, 9.0, 11.0 and 13.3 and for the DP as7.0, 10.6, and 12.4 kN, for the same depth in sequence. Due to its high draft, the MP required the highest drawbar power, 28.6 kW at 30 cm depth. Low values of fuel consumption rate were recorded for the CP as 2.4, 3.4.0 and 4.5 l/ha as compared to 3.8, 4.9 and 5.9 l/ha; and 4.6, 5.8 and 6.8 l/ha for the DP and MP respectively at the three depth in sequence.

Keywords Tractor Performance, Field capacity, Efficiency, Draft, Fuel Consumption

1. Introduction

Farm machinery selection is fundamental in achieving the concept of sustainable agriculture, which becomes a global issue in the development of agriculture. Proper management and selection of implements contribute greatly in reducing cost and difficulties in field operations and maximize production. Machinery is used to manipulate soil to initiate a good environment for seed germination and plant growth, enhance adequate irrigation, incorporate fertilizer in furrows, provide traffic lanes, and for harvesting. The main item in the farming budget among all the agricultural operations is tillage operations which consume most of the power requirement [1]. Conventional practices in irrigated agricultural operations are rather intensive; they are almost four to five operations (uprooting, primary and secondary tilling, leveling and furrowing). Heavy equipped machines are used in these operations; many problems in soil physical properties are expected due to the use of tillage implements such as compaction [2]. Tillage practices have often been considered as a limiting factor to crop production in heavy clay soils due to the continuous use of tillage implements [3]. Tillage methods significantly affected the soil physical properties as increase in soil moisture contents and decrease in bulk density of soil were noted [4]. Draft information is frequently used in machinery management to calculate power requirements of tillage and seeding operation [5]. Gezira Scheme represents 47% of the total irrigated area and 10% of the total area under crop production in Sudan. [6] reported that the factors responsible for low yields in Gezira scheme include inadequate land preparation and shortage in water supply due to poor and lack of maintenance of the water distribution system. The major problems facing Gezira farmers include poor land preparation operations and machinery management, shortage of equipment and shortage of skilled laborers (manpower). Vertisols of the Gezira scheme represent difficult physical environment to crop production. Therefore, tillage is necessary to modify this environment to create optimum conditions for increasing crop production. [7] mentioned that the norms of behavior of Gezira clay soil (Vertisol) under irrigation is described as the eccentric 'odd man-out', when compared with the norms of behavior of Vertisols under irrigation else were in Africa, Asia and Australia. He stated that the main feature of soil, following moisture distribution, that the soil moisture increases to its greatest level in the top 20 cm and falls thereafter in the 60-80 cm zone. The Vertisols have cracks, which are the most important phenomena of the clay soil behavior. Cracks appear in the dry season in Gezira heavy clay soils and cause difficulties to the implements use in land preparation. There are many primary tillage implements used in this heavy clay soil and their performance varies with depth, therefore, the objective of this study was to evaluate the performance of chisel plough, disc plough and moldboard plough by measuring the field capacity, draft and fuel consumption at three depths 10, 20 and 30 cm.

2. Materials and Methods

2.1. Experimental area description:

This study was conducted in Gezira scheme during the period from 2016 to 2017. The study area (0.42 ha) is characterized by semi-arid climate. Annual mean air temperature is 30 ºC, total precipitation is 280 mm (20 years average) and almost all of which falls between July and October. Soil of Gezira scheme is classified as vertisol, these soils are deep, dark colored, low in organic matter, very slowly permeable when wet and deeply cracked when dry. The clay content of the soil ranges between 50 and 60%. Calcium carbonate and gypsum accumulation occur in the sub soil [7]. Newholland tractor (80-66s) and Foton tractor (1254) were used in the experimental measurements. The specifications of tractors are given in the Table 1.

Table 1: Specifications of tractors used in the experiment

Description	Newholland (80-66s)	Foton (TF1254)
Model	Iveco (80-66s)	Perkins (TF1254)
Country of origin	Italy	China
Engine type	Diesel	Diesel
No. of cylinders	4	6
HP	80(58.8KW)	125(91.9KW)
Rev/m	2200	2200
Max. engine torque (NM)	300	470
Cooling system	Water	Water
Size of rear tires	13.6-38	14.9-42
Weight (kg)	3370	5545
Width (mm)	1750	2345
Height (mm)	2437	2995

Three tillage implements (chisel plough, disc plough and moldboard plough) were used in the experiment and they were operated at three depths (10, 20 and 30 cm). The specifications of the implements are shown in Table 2. Chain, bolts, stop watch, paper sheets, tape meter (50m), steel rods, steel container (4 gallons), measuring cylinder (1 litre) and dynamometer were used in the experiment for different measurements. The experiment was arranged in a split plot design and the treatments were replicated three times. Tillage treatments were assigned to the main plots whereas depth treatments were assigned to the sub plots. The total area of experiment was 4200 m^2 (0.42 ha), divided into nine plots 30 x12 m each. A space of 5m was used to separate the plots while replicates were separated by a distance of 3m.

Table 2: Specifications of Implements used in the experiment

Items	Specifications		
	Chisel plough	**Disc plough**	**Moldboard plough**
Type	Tractor mounted	Tractor mounted	Tractor mounted
Width (m)	2.00	0.90	1.25
Weight (kg)	450	350	400
No. of units	5	3	3

2.2. Parameters measurements:

- Effective, theoretical field capacities (EFC, TFC), efficiency (FE) and fuel consumption of different machines were calculated as follows:

$$\text{EFC}\ (ha/h) = \frac{Areaofplot\ \ (360\,m^2)\text{x(ha)}}{\text{Time needed to cover the plot (hr) x10000}\,m^2} \qquad (1)$$

$$\text{FE}\ (\%) = \frac{\text{EFC}\ (ha/h)\ \text{x100}}{\text{TFC}\ (ha/h)} \qquad (2)$$

$$\text{Fuel consumption (l/ha)} = \frac{Reading\ \ of\ cylinder\ \ (ml\,/1000)}{Total\ \ plot\ area\ (ha)} \qquad (3)$$

Draft measurement of each implement was done as follows:

- The auxiliary tractor (Foton) and the tested tractor (Newholland) were linked together through the dynamometer using steel chain.
- The auxiliary tractor was used to pull the tested tractor alone.
- The reading of the dynamometer was recorded.
- The tested tractor was then loaded with the implement operated at constant depth controlled with manual hydraulic lever of the tractor.

The reading was repeated and taken the average implement draft was calculated as follows:

Implement draft (KN) =

Pull of tested tractor with implement (KN) -Pull of the same tractor only (KN) (4)

The power exerted by the tractor on the implement was calculated using the following equation:

Dbp = D * S / 3.6 (5)

Where:

Dbp = Draw bar power (KW), D = Implement draft (KN)

S = Forward speed (Km/h)

3. Results and Discussion

Table 3 shows results of all measured parameters for the three implements at the three depths 10, 20 and 30cm. The chisel plough recorded the highest effective field capacity (2.64 ha/h) at 10 cm depth, which was higher by 26.5% than the moldboard plough and by 43.2 % than that of disc plough at the same depth (Fig1).

Table 3: Field performance of tillage implements

Plough	Chisel plough			Disc plough			Moldboard plough		
Parameter	**Soil Depths (cm)**								
	10	**20**	**30**	**10**	**20**	**30**	**10**	**20**	**30**
EFC (ha/h)	1.11	0.77	0.59	0.63	0.50	0.42	0.82	0.63	0.53
FE (%)	70	67	65	68	65	63	66	66	64
Draft (kN)	18.00	19.30	20.77	14.50	17.70	15.50	27.8	28.6	24.80
Dbp (kW)	9.0	11.0	13.3	7.0	10.6	12.4	15.0	17.5	20.0
Fuel cons (l/ha)	6.94	6.89	6.92	6.32	6.64	6.55	9.99	9.56	9.53

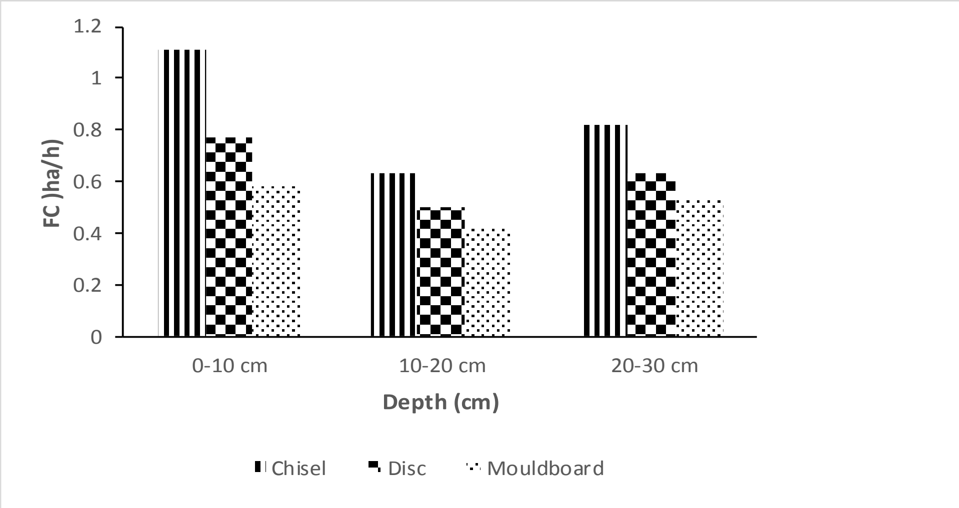

Figure 1: Effect of different tillage implements on effective field capacity

The superiority of the chisel plough in the values of field capacity over the moldboard and disc plough was observed at all depths. Compared to a moldboard plow, the chisel plow has a greater field capacity, requires less power, creates no back or dead furrows and it can be managed to leave significant amounts of crop residue on the soil surface [5]. The results indicated that the effective field capacity increases with decrease of depth for the same implement. [8] studied the performance of two tillage implements: (disc and chisel plough) and their effect on some soil physical properties. He found that the higher values of both theoretical and effective field capacities were recorded by chisel plough (1.23 ha/h and 0.90 ha/h) as compared to disc plough (0.63 ha/h and 0.50 ha/h). The results of the high field capacity of the chisel plough also agree with the results obtained by [2]. The statistical analysis (Table 4) showed that field capacity was highly affected by the implement and the interaction of the implement and ploughing depth ($P \leq 0.01$). The statistical analysis (Table 4) showed no significant differences at $P \geq 0.01$ between the effects of different treatments on the field efficiency. The average values for chisel, disc and moldboard plough were 67%, 66% and 65%, respectively, (Figure 2).

Table 4: Statistical analysis of performance of tillage implements

Source of Variation	**df**	**Field capacity**		**Efficiency**		**Draft (kN)**		**Drawbar power(Kw)**		**Fuel Consumption (l/ha)**	
Block	2	0.00	ns	40.15	**	0.76	ns	5.78	ns	0.06	ns
D	2	1.52	**	36.04	**	54.94	**	29.55	ns	10.20	**
Error (a)	4	0.00		0.15		0.26		14.05		0.02	
Implement	2	1.19	**	12.70	**	146.60	**	329.54	**	12.29	**
Interaction	4	0.12	**	3.20	ns	0.57	ns	25.24	ns	0.00	ns
Error (b)	12	0.00		1.31		1.51		14.31		0.01	
Total	26										
CV (%)		4.29	3.12	0.58	1.74	3.95	9.54	18.60	18.77	3.00	1.92
0.67		0.09		0.50				4.91		0.18	
1.26		0.05		1.18				3.89		0.09	
D×EM 5%		0.09		2.04		2.19		6.73		0.16	

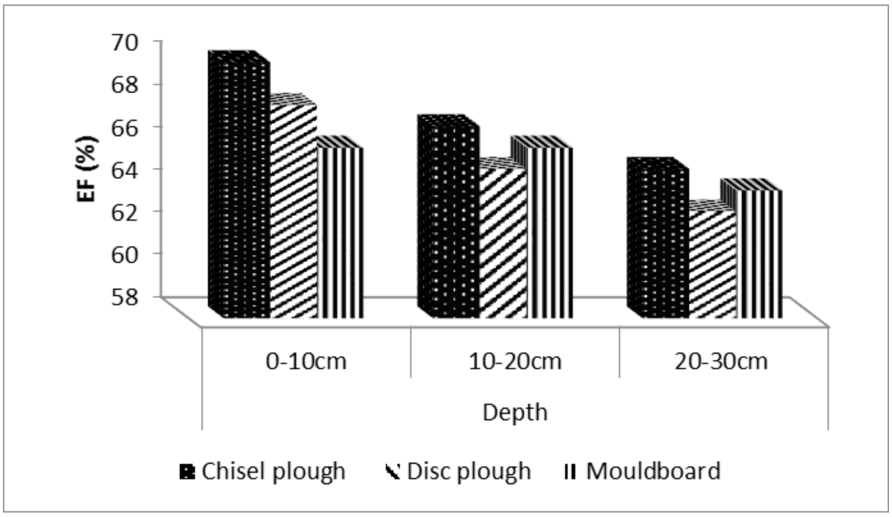

Figure 2: Effect of different tillage implements on efficiency (%)

The mean draft values for chisel plough, moldboard plough and disc plough at different depths are shown in figure 3a. The moldboard plough recorded higher draft values than the other two implements by 25%, 35%, 21% for the chisel plough, and by 36%, 24%, 23% for the disc plough at the three depths 10, 20 and 30 cm, respectively. The highest draft of the moldboard plough may be attributed to the large surface area of the implement and the great pressure exerted by soil on it in addition to the relatively more time taken before the furrow slice is inverted and dropped out of the moldboard part of the plough. The vertical portions (shanks) of the chisel plough have small surface area and thus subject to low soil pressure. As for the disc plough; the soil exerts moderate pressure on the discs because of the relatively fast inversion of the soil out of the discs. The results revealed that draft increases with increases in depth; this was in agreement with the results obtained by [9]. They reported that a linear relationship existed between draft and depth of operation. A significant increase in draft and power requirements was observed for all the implements with an increase in depth and speed. The Statistical analysis (Table 4) showed highly significant differences ($P \leq 0.01$) between the values of draft of the studied implements. The highest drawbar power was reported by the moldboard plough (28.6 kW) at the depth of 20 cm which was greater by 38.1% and 32.5% than the power required by the disc plough and chisel plough at the same depth respectively. [10] found that the maximum drawbar power occurred in chisel plowing by forward velocity of 4 km/h and minimum occurred in disk plowing by forward velocity of 1.5 km/h. The general trend is the increase of the drawbar power with depth for the three implements (Fig 3b).

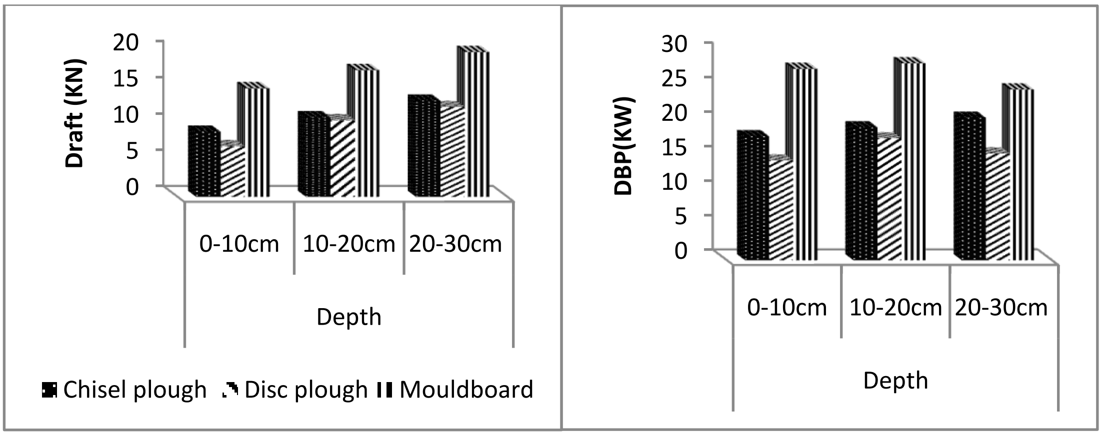

Figure 3: Effect of different tillage implements on (a) draft and (b) drawbar power (KW)

The statistical analysis (Table 4) showed highly significant difference ($P \leq 0.01$) between the values of the power requirement of the tillage implements. The moldboard plough recorded the highest fuel consumption rates (4.64, 5.76 and 6.8 l/ha) at 10, 20, and 30 cm depth, respectively; as compared to the other studied implements. Fuel consumption rate increased with increase of ploughing depth for all implements (Fig 4). These variations might be due to the different power requirement by the studied implements. The amounts of fuel consumed by the tractor under different implements were in the range as reported by [11] in Rahad scheme, Sudan. These results are also in line with the results reported by [12] in a heavy clay soil in Sudan. The statistical analysis (Table 4) showed highly significant difference of the fuel consumption for the different studied implements ($P \leq 0.01$). The general observation is that EFC and FE increased with depth while drawbar decreased with depth.

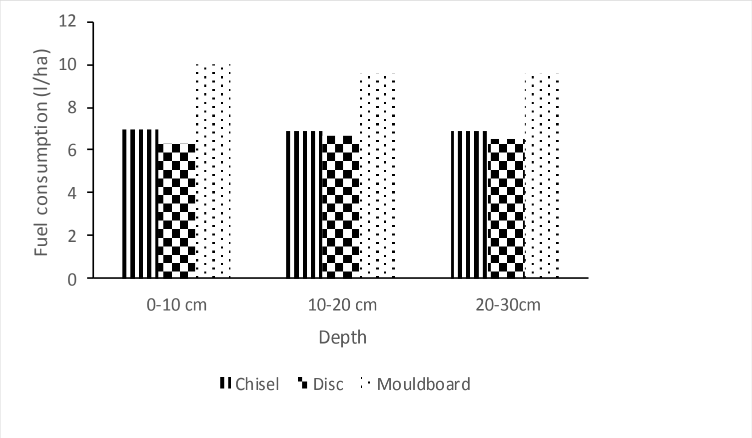

Figure 4: Effect of different tillage implements on fuel consumption (l/ha)

4. Conclusion

Effective field capacities, field efficiency, fuel consumption, draft and drawbar power was significantly affected by tillage implement and depth of operation. Generally, effective field capacity and efficiency decreased with the increase in soil depth, while the draft, drawbar power and fuel consumption rate increased with the increase of ploughing depth.

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