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Performance of Some Tillage Implements and Their Influence on Yield of Rain-Fed Sorghum under Sandy Loam Soil Conditions

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Abstract: In Sudan, sorghum productivity in the traditional rain-fed sector is very low. One of the major reasons contributing to low yield is unreliable rainfall. So, selecting an appropriate tillage implements that conserves soil moisture and achieves better performance is highly needed. A field experiment was conducted at the demonstration farm of the faculty of Natural Resources and Environmental studies, Alsalam University, to evaluate the performance of some tillage implements and their effects on the yield of rain-fed sorghum. The treatments consisted of three types of tillage implements namely chisel plow, cultivator and offset disc harrow. The experiment was laid out in a randomized complete block design (RCBD) with three replicates. The performance variables measured were effective field capacity (ha/h), field efficiency (%) and wheel slippage (%).The results of analysis showed the cultivator increased significantly the effective field capacity and field efficiency in comparison with the offset disc harrow and the chisel plow. The chisel plow and the cultivator were showed a significant increase in slippage percentage compared to the offset disc harrow. However, the tested tillage implements did not have a significant effect on the yield of sorghum.

Keywords: Tillage implements, Performance variables, Rain-fed sorghum, Field efficiency, cultivator.

INTRODUCTION

The economy of the Sudan is highly dependent on agriculture, which occupies an estimated 43% of its labor force and accounts for about 30% of its GDP. Its crop portfolio is quite diversified, including cereals (sorghum, millet, wheat, rice and maize), oilseeds (sesame, groundnuts and sunflowers), industrial crops (cotton and sugarcane), fodder crops (alfalfa, fodder sorghum and Rhodes grass), pulses (broad beans and pigeon peas) and horticultural crops (okra, onions, tomatoes, citruses, mangos, date palms) (FAO, 2021).

Sorghum is the staple food crop of the vast majority of the population in Sudan, especially in rural areas. It serves as a primary source of food, beverage and total livelihood for millions of people in the country. It is produced mainly in the central clay plain of Sudan under rain. Its cultivated areas represent more than 40% of the total cultivated areas. Soil tillage plays a vital role in the production of cereal crops. The aim of tillage is to create a favorable environment for seed germination and growth, to break physical soil barriers like a hardpan, to incorporate fertilizer and to control weeds.

Agriculture is very sensitive to timely operations and weather conditions and huge amount of money is spent on investment, therefore there is the need to evaluate the capacitive performance of agricultural machines for proper machinery selection, optimization and farm scheduling (Sale, *et al.*, 2013). The ability to anticipate the performance of tractors during field operations has been of great interest to scientists, manufacturers and users in order to optimize the total operation (Grisso, *et al.*, 2008). The performance of agricultural machines is assessable by the rate at which an operation is accomplished and by the quality of the output. An important criterion of farm tractor performance is the amount of travel reduction or slip of the drive wheels for a given drawbar load. Wheel slip is a good measure of how well tractor is setup for tillage conditions. Optimal wheel slip range from 10 to 15% depending on soil conditions (Goering & Hansen, 2004). Efficient machinery management requires accurate performance data on the capabilities of individual machines in order to meet a given work schedule and to form balanced mechanization systems by matching the performance of separate items of equipment (Whitney, 1988). The performance of a machine often depends on the skill of the operator or on weather and soil conditions (Edwards, 2015). In Sudan, sorghum is one of the major crops grown in the traditional rain-fed sub-sector. Traditional rain-fed farming is the most widely practiced and most vulnerable to crop failure due to insufficient or unequal rainfall distribution. The productivity of the main crops in the traditional rain-fed sub-sector is very low compared to their productivity in other parts. The

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major constraints contributing to low yield of sorghum in rain-fed sub-sector are low soil fertility due to mono cropping practices and unreliable rainfall. Low productivity in the traditional rain-fed sub sector is the main source of low income, and has resulted in substantial migration to urban areas. Most farmers depend on traditional agriculture as the main economic activity and source of income and food. To improve the productivity in the traditional rain-fed agriculture several improved technologies have been developed and released by Agricultural Research Corporation (ARC). A key challenge is how to manage limited rainfall so that surface runoff does not occur, and hence more water is stored in the root zone and becomes available for plant growth. El Naim, *et al*., (2012) found that chisel plough at depth of 25 cm had the highest grain yield and yields components on sandy clay soil in rain-fed conditions in North Kordofan, Sudan. Inappropriate tillage practices in sorghum can inhibit crop growth and decrease the grain yield. On the other hand, the availability of performance data would have been a good guide for a better understanding and selection of the capabilities of machines. Studies on effect of different tillage implements on sorghum yield and the availability of performance data particularly on sandy loam soil are scanty. Thus, this study was conducted with the objective of evaluating the performance of selected tillage implements and their effect on rain-fed sorghum yield under sandy loam soil condition of West Sudan.

MATERIALS AND METHODS

Study Area

A field experiment was carried out in July (rainy season) of the season (2020/2021) in the demonstration farm of the Faculty of Natural Resources and Environmental Studies, University of Alsalam, Alfula, West Kordofan State, Sudan (latitude100:50′ -120:30′ N and longitudes 270: 40′-29˚ E) (Fig. 1). The climate is semi-arid relatively cool in winter and hot in summer .The soil of the experimental site is sandy loam consisting of more than 60 % sand with an average pH value of 6.

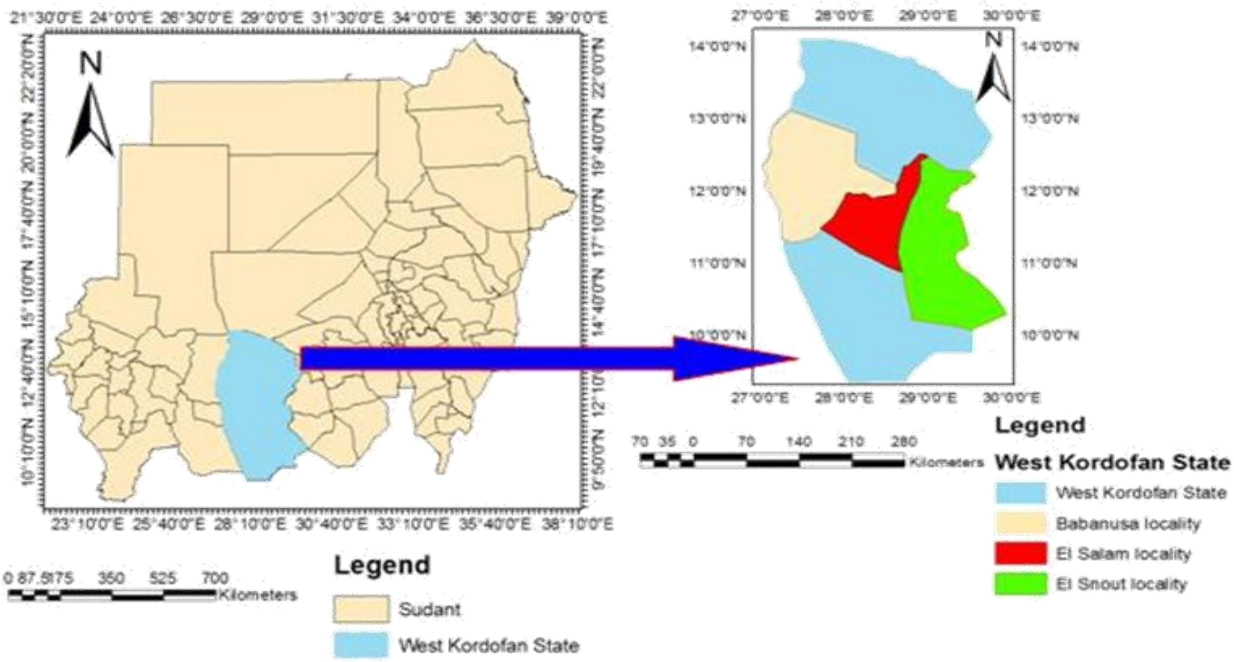

Figure 1: Location of the experimental site (Alsalam Locality)

Experimental Design and Procedures:

The experimental site was cleared manually prior to performing the tillage operation. The experiment laid out in a randomized complete block design with three replications for each in 3mx50m blocks. The treatments were the chisel plow, offset disc harrow and the cultivator. Each plot was 25 m long and 3 m wide. Different Tractors were used to pull the tillage implements, the chisel plow was pulled by a 61 kW (82 hp) Foton, the cultivator pulled by a 56 kW (75 hp) New Holland while the offset disc harrow was pulled by a 93 kW (125 hp) Foton. Tillage implements were made only one pass during the tillage operation. Tillage implements width, the average working depths and the tractor operating

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speeds were shown in Table 1.A local cultivar of sorghum (Sorghum bicolor) used as a test indicator crop. It was grown according to the recommended standard cultural practices for rain-fed sorghum.

The performance variables of the different tillage implements were then determined.

The Tractor Forward Speed:
It calculated using the following relation.

$$S = \frac{D_T}{t} \times 3.6 \quad \text{.................Equation 1}$$

Where,
S = Speed (km/h).
D_T = Travelled distance (m).
t = Time (sec).

The Theoretical Field Capacity:
The Theoretical calculated using (Equation. 2) as recommended by (ASABE, 2006).

$$TFC = \frac{W \times S}{C} \quad \text{...................Equation 2}$$

Where:
TFC = Theoretical field capacity, (ha/h).
S = Speed, (km/h).
W = Width of implement, (m).
C = Constant, (10).

The Effective Field Capacity:
An equation.3 is used to calculate effective field capacity as suggested by (ASABE).

$$EFC = \frac{A \times 3600}{T \times 10000} \quad \text{................Equation 3}$$

Where:
EFC = Effective field capacity, (ha/h).
A = Plot area, (m^2).
T = Total plot time, (sec).

Field Efficiency:
The field efficiency calculated using (Equation 4) as introduced by (Kepner, *et al.*, 1982).

$$FE = \frac{EFC}{TFC} \times 100 \quad \text{..................Equation 4}$$

Where:
FE = Field efficiency, %.
EFC = Effective field capacity, ha/h.
TFC = Theoretical field capacity, ha/h.

Wheel Slippage:
It calculated as a percentage loss of forward speed of the tractor using (Equation.5) as suggested by (Zoz & Grisso, 2003).

$$S\% = (1 - \frac{V_P}{V_t}) \times 100 \quad \text{............Equation 5}$$

Where:
S = Slippage, %.
V_p = Practical velocity, km/h.
V_t = Theoretical velocity, km/h.

Sorghum grain yield (kg/ha) was determined from randomly selected plots by cutting the plant heads then threshed and weighed to give grain yield in (kg/m^2.). Then it converted to kilogram per hectare using the following formula:

$$\text{Grain yield (kg/ha)} = \frac{yield\ per\ net\ plot\ (kg)}{net\ plot\ area\ (m^2)} \times 10000\ m^2 \quad \text{..............Equation 6}$$

Statistical Analysis:
The collected data were analyzed using Statistix 8 program for analysis of variance (ANOVA) and means separation using least significance differences (LSD) at the 0.05 level of significance.

Table 1: Implement width, average tillage depth and the tractor operating speed

Implement	Tillage Width (m)	Average tillage depth (cm)	Tractor operating speed (km/h)
Chisel plow (9 shanks)	1.9	25	5.65
Cultivator (11 tines)	1.89	13	9
Offset disc harrow (18 discs)	2	17	6.45

RESULTS AND DISCUSSION

Effective Field Capacity:

The field capacity of a machine is a function of its width, speed and efficiency of operation. The cultivator had the highest effective field capacity

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followed by the offset disc harrow and the chisel plow (Table 2). A significant increase in the effective field capacity which obtained by the cultivator could be attributed mainly to the increase in its tractor operating speed as compared to those of the chisel plow and the offset disc harrow. This in turn may have led to the increase in the effective field capacity due to the positive relation between them. Similar findings were observed by Muhsin (2017) and Singh (2018).

Field Efficiency:

The cultivator once again recorded the highest value of field efficiency followed by the chisel plow and the offset disc harrow (Table 2). An increase in the field efficiency under the cultivator could be attributed to the increase in the effective field capacity, as they are directly related to each other. This result is in agreement with the findings of Gasim & Madlol, (2011).

Wheel Slippage:

The results of analysis indicated that the chisel plow and cultivator significantly increased the slippage percentage as compared to the offset disc harrow (Table 2). The chisel plow had the highest wheel slippage percentage followed by the cultivator while the minimum value recorded under the offset disc harrow .The tractor wheel slippage is mainly associated with the depth and width of implement. The highest value of slippage percentage obtained by the chisel plow could be attributed to the increase in the depth of the tillage as compared to those of the offset disc harrow and the cultivator. Similar findings were reported by Leghari, *et al*., (2016) and Moitzi, *et al*., (2014).

Table 2: Performance variables of the tillage implements

Implements	Effective field capacity (ha/h)	Field efficiency (%)	Wheel slippage (%)
Chisel plow	1.2^{b}	78.7^{b}	12.3^{a}
Cultivator	2.6^{a}	84.0^{a}	11.9^{a}
Offset disc harrow	1.57^{b}	77.3^{b}	8.0^{b}
$LSD_{0.05}$	0.48	1.83	1.06

Means having the same superscript letter (s) are not significantly different at P<0.05.

Sorghum Grain Yield

The result of analysis did not show any significant differences among the tillage implements (Figure 2). However, the cultivator tended to increase in the sorghum grain yield by 13% and 17% as compared to the offset disc harrow and chisel plow, respectively. The results indicated that sorghum grain yield is less sensitive to the tillage methods under sandy loam soil. Unger & Wiese, (1979) stated that the response of fibrous rooted grain crops (wheat and sorghum) in relation to the amount of water available for crop use is less affected by the tillage methods. Similar findings were reported by Bashir, *et al*., (2015) they found different tillage systems showed similar effects on yield and yield components of sorghum.

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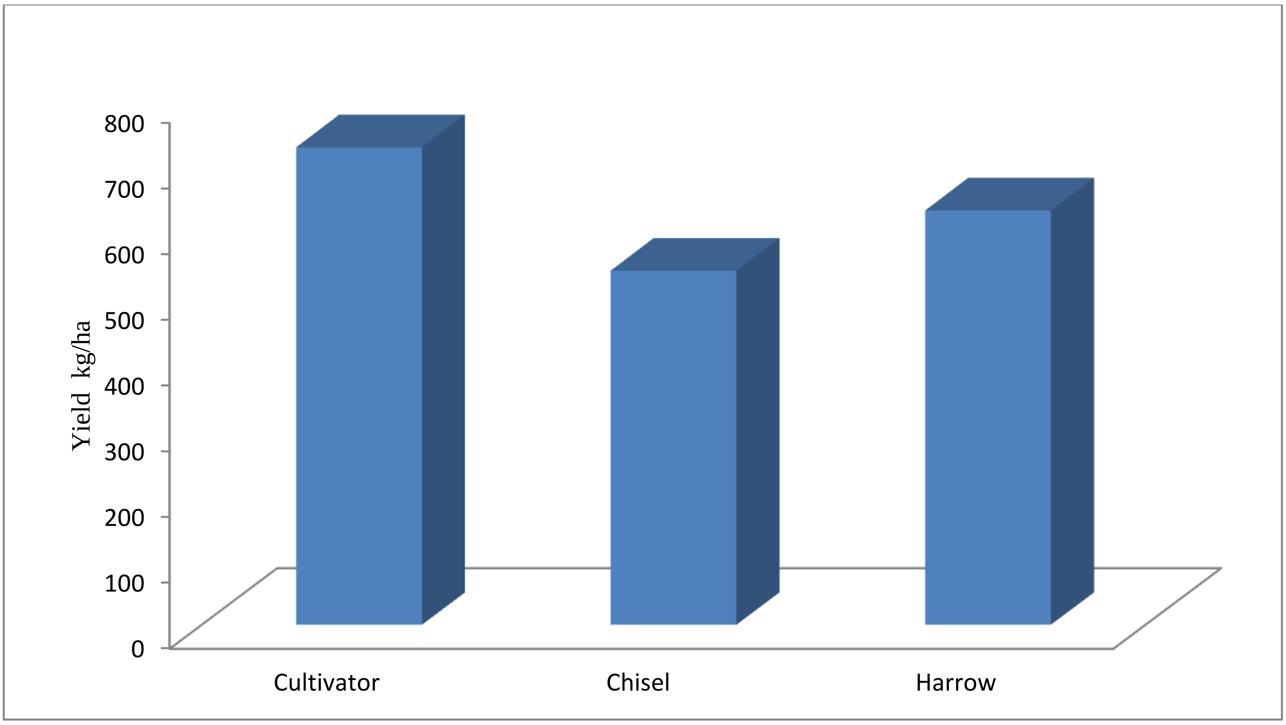

Figure 2: Sorghum grain yield as affected by tillage implements

CONCLUSION

It can be concluded from the results of this study that on sandy loam soil, the cultivator resulted in a significant increase in the effective field capacity and field efficiency as compared to the offset disc harrow and chisel plow. Both chisel plow and the cultivator increased significantly the percentage of wheel slippage. The sorghum grain yield was not influenced by the tillage methods. There was an increase trend in sorghum grain yield under the cultivator compared to the offset disc harrow and the chisel plow. Further studies should be carried out to determine the other performance parameters such as the drawbar power, draft and fuel consumption in this type of soil to select the optimum size of the tractor that could be used. As well as studies on a combination use of water conserving tillage practices and soil amendments is recommended to ensure higher sorghum grain yield in rain-fed areas.

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