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Effect of Some Conservation Tillage Practices on Growth and Yield Attributes of Rainfed Sorghum (Sorghum bicolor (L.)Moench) At Alfula, West Kordofan State, Sudan

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Abstract— The judicious use of water in agriculture is very much possible through adoption of various engineering interventions and other best management practices in the crop production system. A field experiment was conducted for two consecutive seasons (2016/2017 and 2017/2018) at the Demonstration Farm of the Faculty of Natural Resources and Environmental Studies, University of Alsalam, West Kordofan State. The objective was to study the effect of some conservation tillage practices on growth and yield attributes of rainfed sorghum. The treatments consisted of five tillage practices, namely, chisel plow, cultivator practice, offset disc harrow, chisel plow + offset disc harrow and no-tillage practice (control), and two sorghum cultivars. An experiment was laid out in strip-plot design arranged in a randomized complete block design with three replications. Data were collected on plant height (cm), stem diameter (mm), number of leaves per plant, plant population (plant/m2) and sorghum grain yield (kg/ha). The tillage implements were tested for the effective field capacity (ha/h), field efficiency (%) and slippage percentage (%). Results showed that plant height, stem diameter, number of leaves per plant, plant population, and grain yield (kg/ha) were not significantly affected by the tillage practices during the first season. However, both chisel plow and cultivator were significantly increased sorghum grain yield by 29.5% and 22.3%, respectively, during the second season. The difference among the tillage implements namely chisel plow, cultivator and offset disc harrow with regard to their performance parameters was found significant for both seasons. The cultivator recorded the highest values in the effective field capacity and field efficiency were 2.6 ha/h, 84% and 2.1 ha/h, 86%, respectively, for both seasons. The chisel plow recorded the highest value of 12.33% and 14% in slippage during the first and second season, respectively.

Keywords— Conservation Tillage; Rainfed Sorghum; Performance parameters; Sandy loam soil; Tillage implements; Effective field capacity

I. INTRODUCTION

Sorghum {Sorghum bicolor (L.)Moench}is the world's fifth major cereal crop after wheat, maize, rice, and barley in feeding human population (Onwueme and Sinha, 1999).In Sudan grain sorghum ranks first in term of both area and quantity of crop production under both irrigated and rain-fed sectors. At least one third of the total cropped area in Sudan is annually placed under sorghum. About 93% of total sorghum area is in the rain-fed sector, whereas the total production varies from year to year due to the quantity and distribution of rains.

One of the basic and important components of agricultural production technology is soil tillage. Inappropriate tillage practices can inhibit crop growth and decrease yield. Tillage is defined as any physical loosening of the soil carried out in a range of cultivation operations, either by manually or mechanically (Ahn and Hintze, 1990). Soil manipulation involves soil disturbance and this can have great deteriorative consequences if not carefully or adequately incorporated. Conservation tillage is a generic term for the use of tillage techniques to promote in-situ moisture conservation. It has been defined as any tillage sequence that reduces the loss of soil or water relative to plow-till; often it is a form of non-inversion tillage that retains a protective layer of mulch (Lal, 1995).Conservation tillage reduces the number of tillage operations, avoiding mixing of the soil and maintaining plant residues on the soil surface as mulch (Moreno et al., 1997).There are many systems and practices, which are often referred to as conservation tillage. The most important and widely applied systems are no tillage or zero-tillage, minimum tillage and strip tillage (FAO, 1987). Moreover, chisel tillage is also considered as conservation tillage practice (Jackson and Piper, 1989). The choice of the best conservation tillage method for fields should be based on the severity of the erosion problem, soil type, crop rotation, available equipment, and management skills. Samarajeewa et al. (2006) pointed out that conservation tillage systems could be more productive than conventional tillage systems as a result of improved soil quality and water use efficiency of plants. In Sudan, Mohammed et al. (2012) stated that conservation tillage techniques improved soil moisture stored within the root zone as compared to the conventional harrowing using the wide level disc, resulting in higher dry matter and grain yield of sorghum in clay soil (Vertisol).

Proper soil management is a key to sustainable agricultural production. Proper type of tillage is one of essential practices for soil management. Degradation of land under rain-fed farming situation due to continuous erosion by water and wind, intensive mono cropping systems and bare soil surface has impoverished the soil resulted in declined soil fertility and crop productivity. In Sudan the productivity of sorghum under the rain-fed sector is generally low and stagnant as compared to the irrigated sector. The productivity of sorghum under irrigation is almost 4 fold that under rain-fed (MOAF, 2008).The climate of Kordofan is generally arid and semi-arid. In addition, the pattern of rainfall is characterized by uneven distribution during the season and is fluctuating from year to year in terms of intensity, quantity and timing. Most farmers practice no-till planting, this is affected by soil moisture conditions, because planting when the soil is too wet or too dry may result in a poor crop stand and yield. The potential benefit of conservation tillage is that more soil moisture is conserved for crop use. There is limited information available about the effect of conservation tillage techniques on the yield of sorghum, particularly in the sandy loam such as that of South West Kordofan. Hence, research study in this area is highly needed to determine the appropriate conservation tillage practice together with the optimum tractor size and implements. Therefore, this research work was carried out to achieve the following objectives:

1- To study the effect of different conservation tillage techniques viz: (chisel plowing, offset disc harrowing, chiseling + harrowing and cultivation) as compared to the traditional method (manual) on growth and yield attributes of two sorghum cultivars under Alfula, South West Kordofan condition.

2- To determine the performance (field capacity, field efficiency and slippage) of the tillage implements used.

II. Materials and Methods

Study area:

A field experiment was carried out for two consecutive seasons (2015/2016 and 2016/2017) in the Demonstration Farm of the Faculty of Natural Resources and Environmental Studies, University of Alsalam, Alfula, Elsalam Locality, West Kordofan State (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.

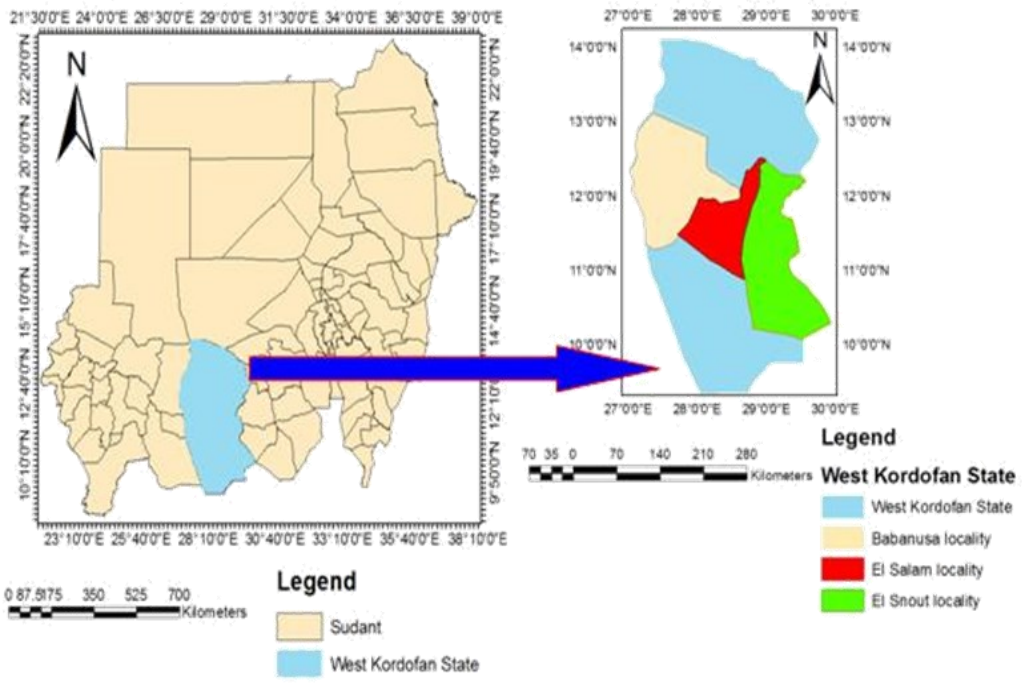

Fig 1 Location of the experimental site (Elsalam Locality)

Experimental design and procedures:

The treatments consisted of five tillage practices namely, chisel plow, cultivator, offset disc harrow, chisel plow + offset disc harrow and no-tillage practice (control), as the main-plots, and two sorghum cultivars (Wad Ahmed and Zinnary) as the sub-plots. Tillage operation in this study performed by making one pass with straw incorporated as well. Tillage depth was adjusted to be 30 cm for chisel plow, 25 cm for offset disc harrow and 15 cm for cultivator practice. The two sorghum cultivars (Wad Ahmed and Zinnary) were planted manually by using traditional hoes. Standard cultural practices for rain-fed sorghum as suggested by the Sudanese research centers were used during this study. The experimental design was factorial laid out in strip-plot arranged in a randomized complete block design with three replications. An experimental block of 30 m long and 3 m wide was used for each treatment. The total area used for the study was 1800 m2. Moisture content of the soil was

measured once for both seasons, after a month of germination, in each experimental unit at depth 0 - 30 cm (Table 1).

A simple rainfall gauge was installed to record the amount of rainfall in the experimental site for both seasons. An amount of monthly rainfall is shown in (Fig 2).

Plant height (cm), number of leaves per plant, stem diameter (mm), plant population (plant/m^2 and grain yield (kg/ha) were measured.

The performance parameters of the different tillage implements were determined as follows:

The forward speed of tractor was calculated using the following equation:

$$S = \frac{D_T}{t} \times 3.6 \quad (1)$$

Where,

S = speed (km/h).
D_T = travelled distance (m).
t = time (sec).

The Theoretical field capacity was calculated using the following equation (ASABE, 2006).

$$TFC = \frac{W \times S}{C} \quad (2)$$

Where:

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

The effective field capacity was calculated using the following equation (ASABE, 2006).

$$EFC = \frac{A \times 3600}{T \times 10000} \quad (3)$$

Where:

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

Field efficiency was calculated using the following equation suggested by Kepner *et al*. (1982):

$$FE = \frac{EFC}{TFC} \times 100 \quad (4)$$

Where:

FE = field efficiency, %.
EFC = effective field capacity, ha /h.
TFC = theoretical field capacity, ha /h.

Wheel slippage was calculated as a percentage loss of forward speed of the tractor as suggested by Zoz and Grisso (2003) as follows:

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

Where:

S = slippage, %.
V_p = practical velocity, km/h.
V_t = theoretical velocity, km/h.

Data analysis:

The collected data were analyzed using Statistix 8 software program for analysis of variance and means separation.

Table 1 Soil moisture content (%) of the different tillage practices

Treatments	Moisture content (%)
First season	
Cultivator	5.36
Chisel plow	4.71
Chisel plow + offset disc harrow	4.85
Offset disc harrow	5.25
No-tillage	5.32
Second season	
Cultivator	7.83
Chisel plow	8.03
Chisel plow + offset disc harrow	8.24
Off set disc harrow	7.74
No-tillage	7.91

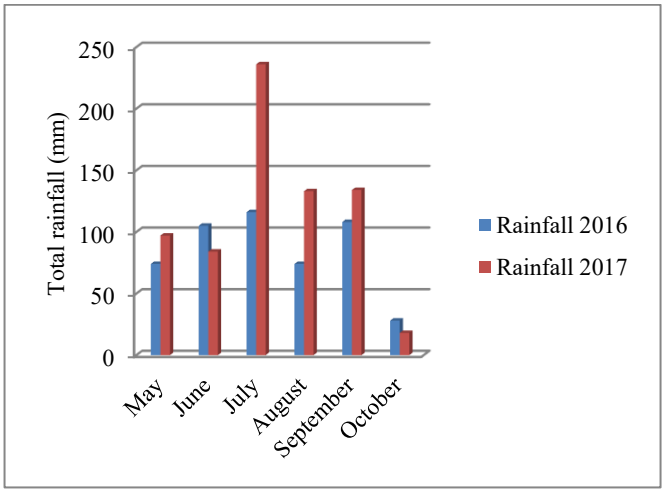

Fig. 2 Monthly rainfall of the experimental site for the two seasons

III. RESULTS

Growth and yield attributes:

Stem diameter

Different tillage practices had no significant effect on stem diameter for both seasons (Table 2). However, the chisel plow gave higher value of stem diameter during the first season. While during the second season the chisel plow + offset disc harrow gave higher value followed by cultivator, chisel plow and offset disc harrow. Zinnary cultivar when compared with Wad Ahmed cultivar showed a significant increase in stem diameter for both season (Table 2).

Number of leaves per plant

The effect of tillage practices on the number of leaves per plant for two sorghum cultivars is presented in Table 2. No significant difference was observed among tillage practices on the number of leaves per plant for both seasons. However the chisel plow scored higher number of leaves per plant followed by the cultivator during the first season. The chisel plow + offset

disc harrow recorded the higher value on the number of leaves per plant followed by chisel plow during the second season. Zinnary cultivar significantly increased the number of leaves per plant for both seasons (Table 2).

Plant height:

Table 2 illustrates the effect of tillage practices on plant height in both seasons. The different tillage practices had no significant effect on plant height. The chisel plow produced the tallest plants followed by the chisel plow + offset disc harrow during the first season. In the second season, the chisel plow + offset disc harrow gave the tallest plants followed by the cultivator. Zinnary cultivar when compared with Wad Ahmed cultivar significantly increased the plant height in the two seasons (Table 2).

Table 2 Effect of different tillage practices on growth and yield attributes of the sorghum cultivars for the two seasons

Treatments	Stem diameter	No. of leaves	Plant height (cm)	Plant popu. Pln/m^2	Grain yield Kg/ha
First season					
Cultivator	11.65[a]	11.55[a]	57.83[a]	18[a]	315.45[a]
Chisel	13.39[a]	12.67[a]	76.50[a]	22.50[a]	318.02[a]
Harrow	12.72[a]	11.61[a]	67.45[a]	21.50[a]	329[a]
Chisel+harrow	13.35[a]	11.50[a]	70.17[a]	23.49[a]	366.78[a]
No-tillage	13.06[a]	11.05[a]	62.61[a]	22[a]	337.08[a]
$LSD_{0.05}$	2.83	1.87	34.48	6.552	204.48
Wad Ahmed	10.74[b]	9.59[b]	40.65[b]	17.79[b]	315.63[b]
Zinnary	14.92[a]	13.76[a]	70.18[a]	31.2[a]	600[a]
$LSD_{0.05}$	1.48	1.22	22.68	3.73	283.02
Second season					
Cultivator	9.03[a]	7.53[a]	29.50[a]	22.2[a]	228.33[a]
Chisel	10.23[a]	8.88[a]	29.53[a]	16.31[b]	241.67[a]
Harrow	6.33[a]	6.42[a]	18.34[a]	9.31[c]	201.50[b]
Chisel+harrow	10.17[a]	8.54[a]	36.68[a]	15.19[b]	201.67[b]
No-tillage	7.32[a]	7.917[a]	17.78[a]	7[c]	186.67[b]
$LSD_{0.05}$	5.79	2.86	32.13	5.64	215.9
Wad Ahmed	6.90[b]	6.66[b]	26.33[a]	10.01[b]	149[b]
Zinnary	10.33[a]	9.06[a]	39.40[a]	17.99[a]	282.93[a]
$LSD_{0.05}$	2.19	0.40	42.10	2.00	98.89

Means share same superscript letter are not significantly different as separated by LSD test at 0.05 level of significance.

Plant population

The effect of tillage practices on plant population for two sorghum cultivars is presented in Table 2. No significant difference was detected among tillage practices during the first season. However, the plant population was significantly affected by different tillage practices during the second season. the chisel plow + offset disc harrow recorded the highest value in plant population followed by the chisel plow during the first season. While during the second season the highest value was obtained by the cultivator followed by the chisel plow. Zinnary cultivar resulted in significant increase in the plant population as compared to Wad Ahmed cultivar for both seasons (Table 2).

Grain yield

Table 2 reveals the effect of different tillage practices on sorghum grain yield. There was no significant difference was observed among tillage practices during the first season. However, the difference was significant during the second season. The chisel plow + offset disc harrow recoded the greatest value in sorghum grain yield. In the second season, the highest value in sorghum grain yield obtained by the chisel plow followed by the cultivator. Zinnary cultivar showed a significant increase in the sorghum grain yield as compared to Wad Ahmed cultivar in both seasons (Table 2).

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Technical performance variables:

Effective field capacity

Table 3 shows the effect of the tillage implements on the effective field capacity. The cultivator significantly increased

the effective field effective capacity as compared to the chisel plow and offset disc for both seasons. In the first season the cultivator gave the highest value of 2.60 ha/h followed by the offset disc harrow 1.57 ha/h, while the lowest value of 1.22 ha/h was obtained by the chisel plow. In the second season the cultivator recorded the highest value of 2.1 ha/h followed by chisel plow 1.00 ha/h, while the least value of 0.84 ha/h obtained by the offset disc harrow.

Field efficiency

The effect of tillage implements on the field efficiency is shown in Table 3. The field efficiency was significantly higher under the cultivator in both seasons. In the first season, the cultivator scored the highest value in the field efficiency of 84% followed by the chisel plow 78.7% while the lowest value of 77.27% obtained by the offset disc harrow during. In the second season the highest value obtained by the cultivator of 86 % followed by the offset disc harrow 84 %, while the least value of 83 % obtained by the chisel plow.

Slippage percentage

Slippage percentage significantly affected by the different tillage implements for both seasons (Table 3). In the first season the chisel plow led to increase in the slippage percentage to 12.33 % followed by the cultivator to 11.93 %, while the least value of 8% obtained by the offset disc harrow. The same trend was observed during the second season, the highest value in the slippage percentage obtained by the chisel plow of 14 % followed by the cultivator of 12 % while the lowest value of 11 % obtained by the offset disc harrow.

Table 3 Technical performance of the tillage implements for the two seasons

Implements	First Season			
	Effective field capacity (ha/h)	Field efficiency (%)	Slippage (%)	Fuel consumption (l/h)
Chisel plow	1.22[b]	78.7[b]	12.33[a]	11.87[b]
Cultivator	2.60[a]	84.0[a]	11.93[a]	10.46[c]
Offset disc harrow	1.57[b]	77.27[b]	8.0[b]	17.13[a]
L.S.D	0.48	1.84	1.06	1.22
Second season				
Chisel plow	1.0 [b]	83.0 [b]	14.1[a]	11.43[a]
Cultivator	2.1 [a]	86.1 [a]	12.0[ab]	11.0[ab]
Offset disc harrow	0.84 [b]	84.0 [ab]	11.1[b]	10.33[b]
L.S.D	0.35	2.27	2.19	0.79

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

IV. DISCUSSION

In this study, the sorghum growth and yield traits significantly differed in their response to the different tillage practices. Stem diameter, number of leaves per plant and plant height were not significantly affected by the different tillage practices in both seasons. This may be due to these parameters which are less sensitive to the tillage practices under sandy loam soil. The results are in agreement with El Naim et al., (2012) results. The significant reduction in plant population in the no-tillage method particularly during the second season may be attributed to the lack of proper seedbed preparation when compared to other tillage practices. Because an ideal seedbed is the one that allows for good seed-to-soil contact, conserves moisture needed for germination, and allows for vigorous and uninhibited root and shoot growth.

The positive impact of the different tillage practices on the sorghum grain yield when compared to the traditional particularly during the second season could be attributed to the favorable effects of tillage on the soil properties. In the rain-fed areas theses favorable effects of tillage include minimizing the surface runoff and maximizing the infiltration water. Consequently more of the rain water could be used in crop production. The results are in agreement with those of Ahmed et al. (2015) and El Naim et al., (2012).

The superiority of Zinnary cultivar over Wad Ahmed cultivar in the studied parameters for both seasons could be attributed to the adaptability of the local cultivar (Zinnary) to the prevailing conditions in terms of erratic rainfall and soil properties.

The significant increasing in the effective field capacity which obtained by the cultivator for both seasons could be attributed mainly to the increase in the operating speed with the decrease in tillage depth as compared to the chisel plow and the offset disc harrow. This in turn led to increase in the effective field capacity. The results agree with those of Muhsin (2017) and Al-jubory (2010). They found the effective field capacity was directly proportional to the operating speed.

Increasing in the field efficiency under the cultivator for both seasons may be due to the increasing in the effective field capacity in both seasons, as well as the reduction of the time utilization factor. Similar findings obtained by Gasim and Madlool (2011).

The higher slippage percentage which was recorded by the chisel plow for both seasons can be attributed to the increase in the tillage depth as compared to the offset disc harrow and the cultivator, because the slippage is directly proportional to the tillage depth. The result agrees with those of Moitzi et al., (2014) and Leghari et al., (2016).

V. CONCLUSION

It can be concluded from the results of this study that conservation tillage practices particularly the chisel plow, the cultivator and combined chisel plow + offset disc harrow result in an increase of the sorghum grain yield. In sandy loam soil the sorghum cultivar Zinnary proved to be superior to Wad Ahmed cultivar in all growth and yield attributes. Regarding the tillage implements performance the cultivator significantly increased the effective field capacity and the field efficiency as compared to the chisel plow and the offset disc harrow. The chisel plow showed an increase in the slippage percentage as compared to the cultivator and the offset disc harrow.

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