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Original article

Effect of Selected Conservation Tillage Practices on Soil Moisture Content and Sorghum Yield under Rainfed Conditions on Sandy Loam Soil

Ayman Hassan Sulıman Khalıl Ayman *

Department of Agricultural Engineering, Faculty of Natural Resources and Environmental Studies, Alsalam University, Sudan

Abstract

In arid and semi-arid regions, the key to increase crop production is maximizing infiltration at the expense of surface runoff. One way of achieving such objectives could be the introduction of conservation tillage practices using appropriate equipment. A field experiment was carried out 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, El fula, Sudan. The objective was to observe the effect of selected conservation tillage practices on soil moisture content and sorghum grain yield on sandy loam soil under rain-fed conditions. The treatments consisted of five tillage practices viz: Chisel plowing, cultivator, offset disc harrowing, chisel plowing + offset disc harrowing and no-tillage (traditional) as a control. The experiment was laid out in a randomized complete block design with three replications (RCBD). The soil moisture content (%) at three depths of 0-15 cm, 15-30 cm and 30-45 cm was measured. Sorghum grain yield (kg ha-1) was determined. The results of analysis showed that different tillage practices had no significant effect on soil moisture content at the three depths for both seasons, except at 0-15 cm depth during the first season. Whereas, no-tillage practice increased soil moisture content by 37.8 %, 35.3 %, 28.5 % and 13.3 % as compared to the chiseling, chiseling + harrowing, cultivator and harrowing, respectively. The results also indicated that sorghum grain yield was not influenced by conservation tillage practices in the first season. However, the chisel plowing and cultivator practices were significantly increased the sorghum grain yield by 28.3 % and 27.5 %, respectively, as compared to no-tillage practice during the second season.

Keywords: Conservation tillage, Cultivator, No-tillage, Soil moisture, Sorghum yield.

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* **Corresponding author:**

Ayman Hassan Sulıman Khalıl Ayman, Department of Agricultural Engineering, Faculty of Natural Resources and Environmental Studies, Alsalam University, Sudan.
Email: aymanhassan09@yahoo.com

INTRODUCTION

Agriculture is the main driver of the national economy, employing 49 per cent of the labour force and accounts for 32 per cent of the country's economic output (African Development Bank, 2020). Sudan has around 68.2 million hectares of arable land (approximately 183.3 million feddans), which makes up about 36.2 per cent of the country (FAO, 2018 a). Rain-fed agriculture accounted for 29.5 million feddans (12.4 million hectares), representing 96.1 per cent of the total area under cereals (Ministry of Agriculture and Forests, 2018). Low productivity and declining yields have become major concerns for the country's agricultural sector. Soil moisture is the source of water for plant use particularly under rain-fed agriculture. Soil moisture is highly important in ensuring good and uniform seed germination and seedling emergence, crop growth and yield (Arsyid et al., 2009). Soil moisture content is affected by tillage practices as observed by Zougmoré et al. (2004). Preserving soil moisture is important means to maintain the necessary water for agricultural production, and also helps minimize irrigation needs of the crops. There are several methods that can be used to conserve soil moisture. Conservation tillage is any tillage system that conserves water and soil while saving labour and traction needs (Rockström et al., 2001). Conservation tillage is a collective umbrella term commonly used to refer to no-tillage, direct-drilling, minimum-tillage and/or ridge-tillage to denote that the specific practice has a conservation goal of some nature (López-Garrido et al., 2011). According to Lampurlanés et al. (2001), conservation tillage increases stored soil water by increasing infiltration and reducing evaporation, but depending on the soil type and climatic conditions, this leads to higher, equal or even lower yields than conventional tillage systems. The increase in soil water storage under conservation tillage can be attributed to reduce evaporation, greater infiltration and soil protection from rainfall impact (Sarauskis et al., 2009 a).

In arid and semi-arid regions crop productivity is strongly influenced by moisture retention capacity. In the Sudan, most of the main food and cash crops are produced under the rain-fed areas. Sorghum is one of the major crops grown in the traditional rainfed sub-sector. It ranks first in term of both area and volume of crop production and is sown all over Sudan in both irrigated and the rainfed sectors. Traditional rain-fed farming is the most widely practiced and most vulnerable to crop failure due to insufficient and/or unequal rainfall distribution (Abdalla & Abdel Nour, 2001). Crop and soil management practices must be designed to ensure sustainability of long term of cropping systems. In Sudan, several studies have been carried out to study the effect of the different tillage practices on soil moisture in the clay soil. Thus, studies their effects on the sandy loam soils are highly needed. Therefore, the objective of this study was to assess the effect of some conservation tillage practices on the soil moisture and sorghum grain yield in sandy loam soil under rain-fed conditions.

MATERIALS and METHODS

The experimental site

The experiment was carried out for two consecutive seasons (2016/2017 and 2017/2018) in the demonstration farm of the faculty of Natural Resources and Environmental Studies, Alsalam University, El fula, West Kordofan State (latitude10°50́-12°30́ N and longitudes 27°40́ -29°E), (Figure 1).

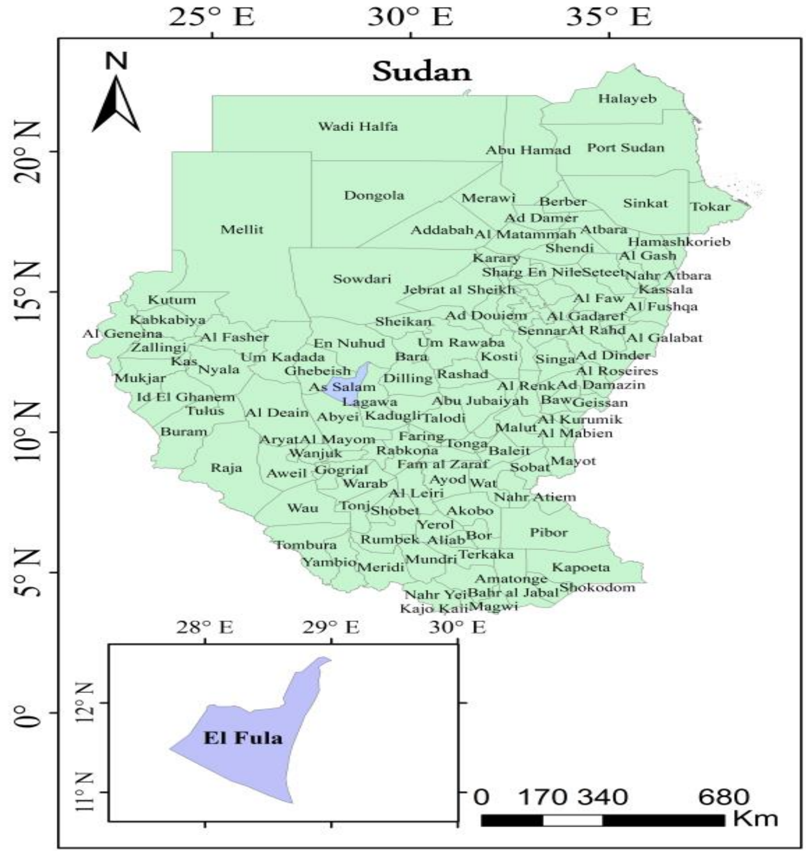

Figure 1. Location of the experimental site

The climate is semi-arid relatively cool in winter and hot in summer, and the annual mean rainfall is 500 – 600 mm, most of it occurs from July to October. The rainfall distribution is erratic within the year and from year to year.

The soil type is ranging from sandy clay to sandy loam characterized relatively by high content of sand (more than 60 %) with an average pH value of 6. Soil physical and chemical properties for the experimental site were analyzed and were presented in Table 1.

The experimental treatments and layout

The treatments consisted of five conservation tillage methods namely chisel plowing, offset disc harrowing, cultivator, chisel plowing + offset disc harrowing and no-tillage method (manual) as a control. A randomized complete block design with three replications was used. An experimental block of 30 m long and 3 m wide was used for each treatment. Sorghum (local cultivar) was used as a test crop. Standard cultural practices for rain-fed sorghum as suggested by the research centers were applied.

Experimental procedures

The field was cleared manually before implementing of the different tillage operations. A set of tillage implements namely chisel plow, offset disc harrow and cultivator were used. Tillage operations were carried out by running one pass for each implement with straw incorporated. Working depth was adjusted to be 30 cm for chisel plowing, 20 cm for offset disc harrowing and 15 cm for cultivator practice.

Moisture content of the experimental site was measured twice for each season. Samples were taken from the soil 72 hours after rainfall at depths of 0 - 15 cm, 15 - 30 cm and 30 - 45 cm. An auger was used for taking soil samples. Then the soil samples were weighed to obtain the wet weight, soil samples then were dried in the oven at 105 ^{o}C for 24 hours to obtain the dry weight. The moisture content of each sample was calculated on a percent dry weight basis. The following formula was used to calculate the moisture content of the soil as described by Black et al. (1993)

$$M.C\% = \frac{w_{wet} - w_{dry}}{w_{dry}} * 10$$

Where:

M.C% = Moisture content, (%).

W_{wet} = Weight of the fresh soil sample, (g).

W_{dry} = Weight of the dry soil sample, (g).

Sorghum grain yield (kg ha^{-1}) was determined as follows: at each plot a specific area in (m^2) was selected randomly. The plant heads were cut and the grains were threshed and weighed. Yield per square meter was determined to have grain yield, then the yield was converted to kg ha^{-1}.

A simple rainfall gauge was installed near the experimental site to measure the amount of rainfall. The total amounts of annual rainfall were 505 mm and 700 mm for the first and second seasons, respectively. A monthly amount of the rainfall for two seasons is presented in (Figure 2).

Statistical analysis

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

Table 1. Soil physical and chemical properties of the experimental site.

Soil sample depth (cm)	0 —15	15 — 30
Saturation percent (%)	26	25.2
pH	6.50	6.54
Ec (ds/m)	0.23	0.18
Na (m eq/l)	0.32	0.23
K (m eq/l)	0.16	0.12
N (%)	0.02	0.02
P (ppm)	2.5	2.7
Organic carbon (%)	0.05	0.05
SAR	0.32	0.46
Bulk density (cm^3/g)	1.42	1.47
Particle density(cm^3/g)	2.64	2.67
Porosity (%)	46.21	44.94
Clay (%)	19.85	19.71
Silt (%)	14.98	14.61
Sand (%)	65.16	65.68

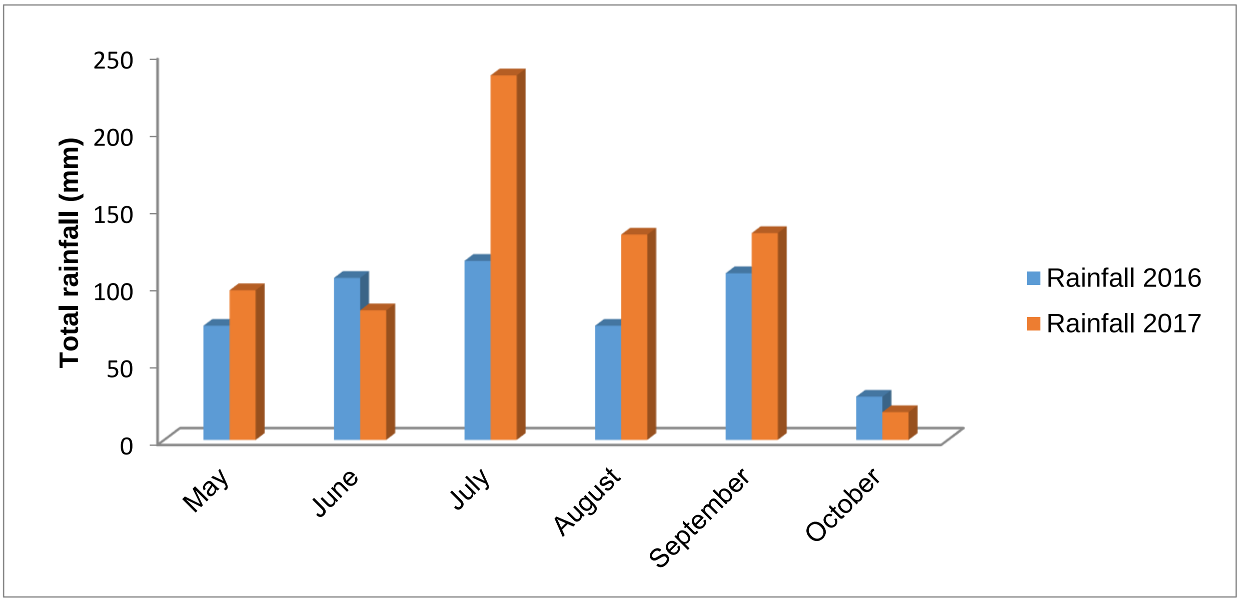

Figure 2. Amount of monthly rainfall of the experimental site for the two seasons

RESULTS

Soil moisture

Table 2 shows the soil moisture content at the 0-15 cm depth was higher under no tillage practice as compared to the other tillage practices during the first season. No-tillage practice resulted in increase in the soil moisture content by 37.8 %, 35.3 %, 28.5 % and 13.3 % as compared to the chiseling, chiseling + harrowing, cultivator and harrowing, respectively.

However, at the 15 -30 cm depth, the result of analysis showed no significant differences were observed among the tillage practices (Table 2). But the cultivator showed a slight increase in the soil moisture content by 18 % as compared to no-tillage practice.

The same trend was observed at the depth of 30 - 45 cm, soil moisture was not significantly affected by the tillage practices (Table 2). However, each of the harrowing, cultivator practice and chiseling + harrowing showed an increase in the soil moisture content by 9 %, 6 % and 2 % as compared to no-tillage method.

Table 2 also reveals the effect of the different tillage practices on soil moisture content in the second season. Different tillage practices had no significant effect on the soil moisture at the three depths. At the first depth, the chiseling + harrowing practice tended to increase in the soil moisture content by 11 % when compared to no-tillage practice. At the second depth, both the harrowing and the chiseling as compared to no tillage showed a slight increase in the soil moisture content by 3 % and 2.7 %, respectively. While, at the third depth the chiseling, the chiseling + harrowing and the cultivator showed an increase trend in the soil moisture content when compared to no tillage practice by 9.6 %, 6.3% and 3 %, respectively.

Table 2. Soil moisture as affected by tillage practices at three depths for two seasons

Treatment (Tillage practices)	First season (2016/2017) Moisture content (%) Depth 0-15 cm	Depth 15-30 cm	Depth 30-45 cm
Chiseling	3.70 ^{b}	5.17 ^{a}	5.27 ^{a}
Cultivator	3.97 ^{ab}	6.17 ^{a}	5.97 ^{a}
Harrowing	4.50 ^{ab}	5.13 ^{a}	6.13 ^{a}
Chiseling + Harrowing	3.77 ^{ab}	5.07 ^{a}	5.73 ^{a}
No-tillage (traditional)	5.10 ^{a}	5.23 ^{a}	5.63 ^{a}
L.S.D	1.35	1.82	1.72
	Second season (2017/2018)		
Chiseling	6.78 ^{a}	8.33 ^{a}	8.98 ^{a}
Cultivator	7.24 ^{a}	7.83 ^{a}	8.43 ^{a}
Harrowing	6.91 ^{a}	8.35 ^{a}	8.01 ^{a}
Chiseling + Harrowing	8.23 ^{a}	7.78 ^{a}	8.71 ^{a}
No-tillage (traditional)	7.43 ^{a}	8.11 ^{a}	8.19 ^{a}
L.S.D	2.58	1.51	2.40

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

Sorghum grain yield

During the first season, the result of analysis didn’t show any significant differences among tillage practices. However, all tillage practices when compared to no-tillage practice showed an increasing trend in sorghum grain yield (Figure 3).

However during the second season, sorghum grain yield significantly affected by the tillage practices. The chisel plowing and cultivator practice significantly increased the sorghum grain yield by 28.3 % and 27.5 %, respectively, as compared to no-tillage practice (Figure 4).

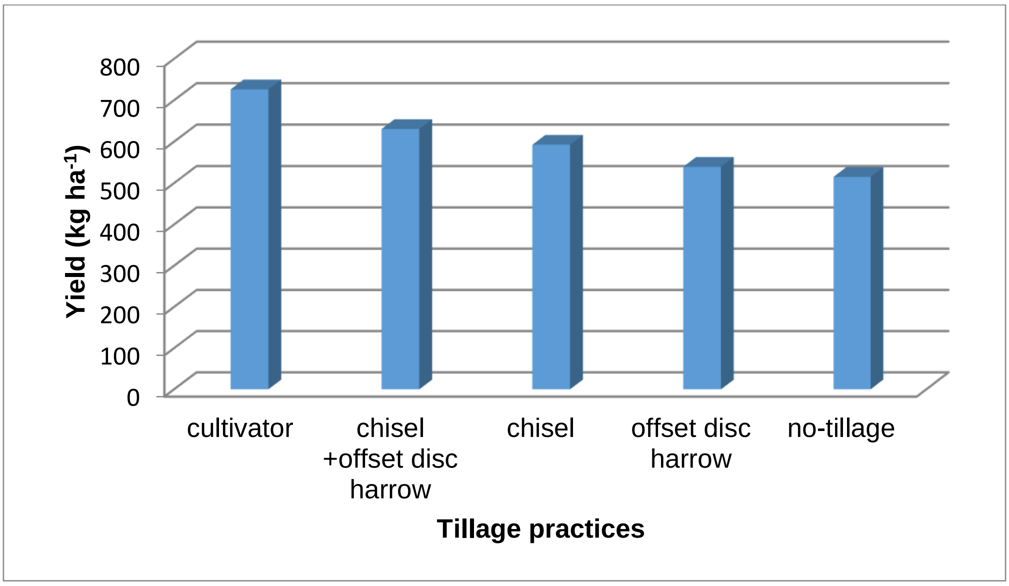

Figure 3. Effect of tillage practices on the yield of sorghum during the first season

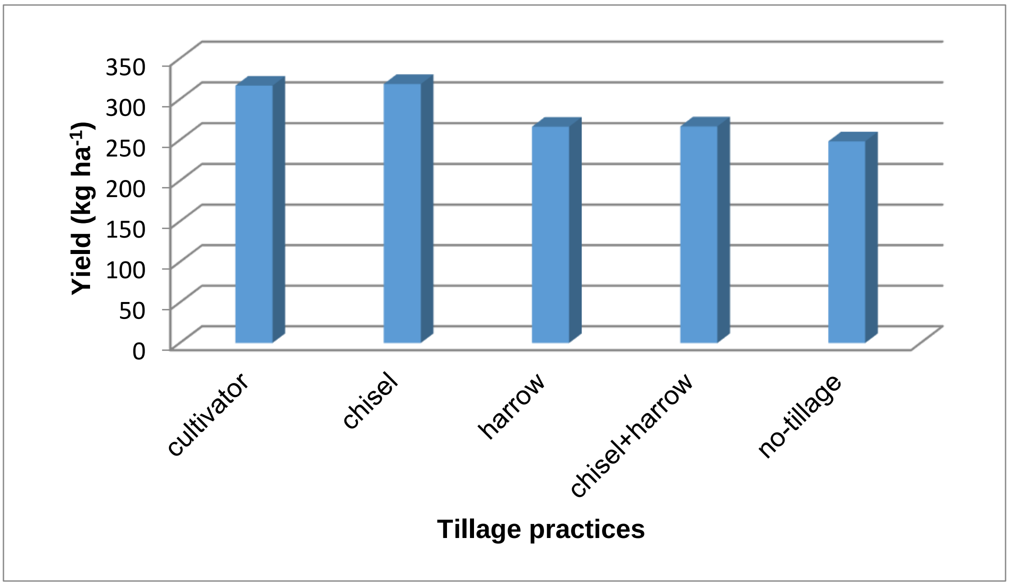

Figure 4. Effect of tillage practices on the yield of sorghum during the second season

Discussion

In this study, the response of soil moisture content to the different tillage practices was not varied with sampling depth, except for 0 - 15 cm depth under no-tillage during the first season. No-tillage practice showed an increase in soil moisture when compared to other tillage practices. The increase of soil moisture at no-tillage might be due to the maintaining of surface soil coverage, which in turn stores more moisture by reducing the evaporation of water from the soil surface. Similar findings were observed by (McVay et al., 2006; Ugalde et al., 2009). They stated soils under no-tillage practices have greater water storage capacity than the tilled soils.

However, soil moisture content hadn't affected by tillage operations in both seasons of the research (at depth 15 - 30 cm and 30 - 45 cm), and could be attributed to the soil type which having high content of sand (more than 60%) as a result allows more water flow into deeper layers particularly after plowing. Similar results were reported by (Dangolani & Narob, 2013). They found soil moisture content was not significantly affected by different types of tillage operations.

The applied tillage appeared to improve sorghum yields in comparison with no-tillage system for both seasons. The positive impact of tillage practices on the sorghum grain yield particularly during the second season when compared to no-tillage practice could be attributed to the favorable effects of tillage practices on the soil properties, such as minimizing the surface runoff and maximizing the water infiltration. As a result more of the rain water was used for crop production. Similar findings were reported by (Mohammed et al., 2011 b). Results also in agreement with Tesfahunegn (2012), who reported there was a decrease in sorghum grain yield under no tillage practice as compared to the tilled soils.

Conclusion

Soil moisture content at the three depths was not influenced by the different tillage practices for both seasons, except at 0 -15 cm depth during the first season, whereas no-tillage practice had higher soil moisture content as compared to other tillage practices. Tillage practices had no significant effect on sorghum grain yield during the first season. The chisel plowing and cultivator practice had higher sorghum grain yield when compared to other tillage practices during the second season. Therefore, such tillage practices could be adopted under rain-fed condition for improving sorghum grain yield particularly on sandy loam soil.

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