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Effect of Chisel Plow Depth and Rainfall Amount on Yield and Rainwater Productivity of Sorghum (*Sorghum bicolor* L.) Under Dryland Farming in Gadaref State, Sudan

Ahmed Mohammed Mohammed Babiker[1], Khidir Suleiman Elkhidir[1], Elebaid Jabir Ibrahim[1]
[1]Faculty of Agricultural Sciences, University of Gezira, Wad Medani, Sudan
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Absrtract

Knowledge of crop water requirement and water productivity are important in agriculture. Therefore, this study was conducted to determine the crop water requirement and water productivity of sorghum under different chisel plough depths in dry-land farming of Gedaref State during three consecutive rainy seasons (2009/10, 2010/11 and 2011/12). The experiment was arranged completely randomized design with three replicates and the analysis of variance procedure and ($LSD_{0.05}$) were used to test the differences among treatments. Three chisel plow depths namely 20, 25 and 30 cm were used to test their effect on soil moisture content, plant parameters and water productivity compared to the wide level disk (control). Rainfall, climate data and soil moisture content were measured and recorded at the site of the experiment. Results in the three seasons showed that chisel plowing at different depths highly significantly ($P \leq 0.01$) obtained higher soil moisture content over the control in both early and late periods of season. Rainfalls were higher than the crop water requirements in the first and second seasons, while they were lower than the crop water requirements in the third season. Results showed that chisel plowing at different depths affected the most of plant parameters studied in the three seasons; it was almost produced the highest plant height, stem diameter, root depth, 1000 seeds weight over the control. Results showed that 30 cm depth highly significantly ($P \leq 0.01$) obtained the highest grain yields. On the other hand, the lowest grain yields were obtained by the control in the three seasons. The third season with low rainfall amount highly significantly ($P \leq 0.01$) attained the highest water productivity, while the lowest water productivity was attained by the first season. It is recommended to use chisel plow at different depths to maximize the yield and water productivity of sorghum and meets the water demand and low rainfall.

Keywords: Chisel Plow Depth, Rainfall Amount, Yield Rainwater Productivity, Crop Water Requirement.

Introduction

In Sudan, sorghum (*Sorghum bicolor* (L.Moench) is the stable food crop utilized in various forms for humans and animal feed. In Sudan the area under irrigated sorghum is about 8% while 92% is under rain-fed (Fadlelmula, 2009).Gedarif State, Eastern Sudan is the most important rain-fed sector. It is the largest rain-fed areas for sorghum production, the staple crop. Gedarif rain-fed area extends from North to South through three climate zones. According to Ibrahim (2015) sorghum productivity in traditional rain-fed agriculture in Sudan approximately 215-430 Kg/ha. This low yeild is attributed to number of factors among which are the use of inappropriate machinery such as wide level disc that accelerates soil erosion by constituting hardpans and causing poor soil water retention. Rainfall is the most important climatic index of productivity. At the same time, it is the most variable climatic elements both in time and space. Effective rainfall may be defined as the fraction of rainfall that is effectively intercepted by the vegetation or stored in the root zone and used by the plant-soil system for evapotranspiration. A number of empirical formulas have been developed for the estimation of effective rainfall (Adam, 2005). Babu *et al.*, (2014) defined effective rainfall as that a part of the rainfall which is effectively used by the crop after rainfall losses due to surface runoff and deep percolation has been accounted for. The effective rainfall is the rainfall ultimately used to determine the crop irrigation requirements.Crop water requirement (CWR) is the quantity of water utilized by a crop, irrespective of its source, for obtaining maximum yield in a particular area without adverse effects on soil properties. The crop water requirement is influenced by prevailing weather conditions, available water in the soil, crop species and growth stage. The data of reference evapo-transpiration (ET_o) for agricultural crops depends not only on the meteorological elements, but also on factors related to crop, soil environment, and management. It is reasonable to expect that improved crop water requirement estimate may make a substantial change in system specifications and profitability **(**Abu-ZeidandHamdy, 2002). Crop water productivity is defined as the ratio of the product (usually measured in kg) over the amount of water depleted (measured in m^3). Crop water productivity means raising crop yields per unit of water consumed. The best option for increasing crop water productivity lies in combining tillage practices with soils and maximize plant water uptake through timeliness of farming operations and soil management strategies that enhance infiltration of rain, increase the water-holding capacity of the fertilization (Perry,1996 and Molden, 1997).Ahmed and Adeeb (2010) tested chisel plowing and furrows as *in-situ* rainwater harvesting techniques (IRWHT) in the semi dry zone of the central Sudan. The tested IRWHT resulted in substantial increases in sorghum grain yield. The percent of increase ranges between 50 and 300%. A direct relation was found between percent of increase in yield and increase of rainfall amount. IRWHT therefore can enhance the sustainability of traditional rain-fed through increasing yield and water productivity and minimizing environmental impacts on natural resources.The main problem found was the low rate (0.1%) of adoption of rainwater harvesting by traditional farmers. This is attributed to lack of technical knowhow and fund.Elkhidir (2018) also stated that chisel plow is recommended *in-situ* rainwater harvesting techniqueto obtain high crop production on clay soils in a semi- arid region of Sudan.It was also found to be the superior in improving soil moisture storage at different depths and increasing both soil infiltration rate and porosity compared to the other in-situ rainwater harvesting techniques. Ibrahim *et al.*, (2015) found that higher grain yield was obtained by chisel plowing which has proved to be a viable practice for in-situ water harvesting followed by disk plowing and ridging compared to the control (untreated plots).The study was conducted with the objective of determining the yield and water productivity of sorghum under different chisel plow depths in dry-land farming of Gedaref State.

Materialsand Methods

The experimental work was conducted for three consecutive rainy seasons (2009/10, 2010/11 and 2011/12) at the pilot farm of the Faculty of Agricultural and Environmental Sciences, University of Gedarif at Twawa area (longitude 35º24′E latitude 14 º 02′N and Altitude 602 m a.s.l.) to determine the impact of chisel plow depth and rainfall amount on yield and rainwater productivity ofsorghum production (*Sorghum bicolor* L.) under dry-land farming in Gadaref State, Sudan using chisel plow to prepare the land at three depths which they were 20, 25 and 30 cm representing conservation tillage and the control was the fields of local farmers under their normal practices (wide level disk). The soil of the study area is a heavy clay soil (clay content of 40-65%, with a gentle slope of 0.04 % from east to west direction (Omer, 2005). Climate is characterized by higher summer temperatures and warm winters. Most of rainfalls happen during the period of May to October. Seasonal rainfall ranges from 200 mm in the arid area at the far northern areas to 800 mm in the savannah zone at the far southern areas (Mohamed *et al.,* 2012). A local sorghum variety, "*ArfaGadamak*" was sown in July and harvested in October in the three seasons. Seeding was carried manually in ridge, the spacing between holes 30 cm. Five seeds per hole were placed and thinned later to two plants per hole.

Measurements

Meteorological data

Daily meteorological data which were rainfall (mm), maximum and minimum temperatures (C°), relative humidity (%), wind speed (m/s) and sunshine (hr) were recorded for the three seasons from the Gedarif Metrological Station.

Reference evapo-transpiration (ET_o)

Reference evapotranspiration was determined from available climatic data for the different months. CROPWAT 8.0 software programme was used to calculate ET_o using the model suggested by Penman- Montecito's (Allen ,1992):

$$ET_o = \frac{0.408\ \Delta Rn\ +\ \gamma\ [\ 900\ /\ t + 273]\ \ (es - e)\ u_2}{\Delta + \gamma\ (1 + 0.34\ u_2\ )} \qquad \ldots\ldots\ldots\ldots\ldots\ldots(1)$$

Where:

ETo = reference evapotranspiration (mm day^{-1})

Rn = net radiation at top of crop surface (Mj m^{-2} day^{-1})

t = average air temperature (^oC)

u_2 = wind speed at 2 m height (ms-1)

es = saturation vapor pressure (k Pa)

e = actual vapor pressure (k Pa)

Δ = slope of saturation vapor pressure curve (k Pa $^oC^{-1}$)

γ = psychrometric constant (k Pa $^oC^{-1}$)900 = conversion factor.

Moisture Content

A known weight of sample of moist soil was taken by auguring from the field, then dried in an oven at 105 C^o for 24 hr and weighed again. The moisture lost by heating represents the soil moisture in the moist sample. Water stored in each treatment was determined as the depth (mm) of water stored in the top 0.6 m soil depth (assumed as the depth of the sorghum root zone in this type of heavy soil). The soil water stored (θ_w%) in each 0.2 m incremental depth down to 0.6 m was determined gravimetrically or weight basis (equation 2). It was then converted to volumetric soil moisture content (θ_v%) by multiplying θ_w by the soil bulk density (equation 3). Soil moisture content in depth basis (mm) was obtained by multiplying the result by the incremental depth of 200 mm (equation 4) as described by NurEldeen (2008). Two periods of soil moisture content were measured (viz: at early and late season) in three growing season.

$$\theta_w\% \quad = \frac{(Ww - Dw) * 100}{Dw} \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (2)$$

$$\theta_v\% = \quad \theta_w\ \%\ *\ \rho_b \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots.. \ (3)$$

$$D \quad = \frac{\%\ \theta v \times d}{100} \qquad \ldots\ldots\ldots\ldots\ldots\ldots.. \ (4)$$

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where:

ρ_b: soil bulk density (g/cm^3),
D: soil moisture content in depth basis (mm),
W_w: wet sample weight (g),
D_w: dry sample weight (g),
θ_w%: soil moisture content in gravimetric basis,
θ_v%: soil moisture content in volumetric base,
d: depth of soil layer (200mm).

Effective Rainfall

The effective rainfall was calculated as 0.75 from the total rainfall according to Mohamed *et al.*, (2015).

$$ER = P * 0.75 \quad \ldots\ldots\ldots\ldots (5)$$

Where:

ER =Effective Rainfall (mm)
P= Total rainfall (mm)

Crop water requirement (CWR)

The crop water requirement was obtained by multiplying ET_obythe crop coefficient (K_c) as follows (Allen *et al.*, 1998):

$$CWR = ET_o \times K_c \quad \ldots\ldots\ldots\ldots (6)$$

Where:
CWR = Crop water requirement (mm/day)
ET_o= Reference crop evapotranspiration (mm/day)
Kc= Crop coefficient

Crop parameters

Five plants in each plot were randomly selected to determine the following:

Plant height

The height measurements were performed throughout each season at flowering stage from the ground surface to the tip of panicle and recorded in cm using a 2 m long measuring rod.

Stem diameter at maturity

The stem diameter was measured in mm at the middle of plant stem using a vernier measuring instrument.

Root Depth

The soil profile was dug at the end of the season.Therefore, roots of adjacent plants were uncovered,andthen length of roots was measuredincm using a 30 cm ruler.

1000 seeds weight

Three samples of 1000 seeds from panicles harvested per plot were taken and weighed ing using adigitalbalancedevice.

Grain Yield

At the end of the growing season, the one- half meter quadrant was thrown randomly over the growing plants in each plot. The grain yield per square meter was recorded.

Rainwater productivity

Water applied into the experiment site during the growing rainy seasons was measured as an effective rainfall from the total rainfall in mm. The following equation was used to determine rainwater productivity (Ahmed, 2008):

$$RWP = \frac{Y}{R} \quad \ldots\ldots\ldots\ldots (7)$$

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Where:

RWP= Rainwater productivity (kg/m^3)

Y= Yield (kg/ha)

R= Rainfall (m^3/ha)

Rainfall in depth (mm) was multiplied by 4.2 factor to obtain rainfall in volume (m^3) as described by Ismaeil (2009).

Statistical analysis of data

The data collected was subjected to analysis of variance using Statistic-8 program where F-test was observed and means comparison test carried out using Least Significant Difference (LSD) at $P \leq 0.05$ to separate treatment means.

Resultsand Discussion

Reference evapotranspiration (ET_o)

Climatic data for the three seasonsis presented in Table (1). However, results showed that the highest ET_o of 8.6, 8.0 and 8.1mm were recorded in October for the first, second and third seasons, respectively, whereas the lowest of 4.74 and 4.62 mm were recorded in June for the first and third seasons with exceptional difference for the second season in which the lowest ET_o of 4.41 was recorded in May.

Table (1): climatic data for the three seasons (2009/10, 2010/11 and 2011/12)

Season	Month	Temperature (C°) Max.	Min.	R.H (%)	W.S (km/hr.)	ET_o (mm/day)
2009	May	39	24	46	15	5.64
	June	36	20	47	14	4.74
	July	35.6	23.4	61.5	8.0	6.8
	August	33.6	22	71.8	5.7	5.3
	September	34.5	23	67.7	6.0	5.6
	October	37.3	30.2	51.9	3.9	8.6
2010	May	37	22	40	15	4.41
	June	35	20	48	12	5.65
	July	37.0	23.6	53.6	8.5	7.2
	August	36.7	23.5	56.0	6.5	5.1
	September	35.7	23.1	63.6	4.6	5.8
	October	38.1	23.6	50.9	6.0	8.0
2011	May	40	25	47	14	5.48
	June	37	21	48	13	4.62
	July	34.9	21.3	72.6	8.7	6.5
	August	27.9	21.3	86.5	7.8	5.7
	September	34.2	22.7	68.5	7.8	5.4
	October	37.4	24.4	47.3	7.1	8.1

Source: Gedaref Meteorological Station.

RH= Relative humidity, W.S= Wind speed, ETo= Reference evapotranspiration

Control (Wide level disk = 12 cm)

Soil moisture content

Table (2) shows the effect of chisel depths on soil moisture content inearly and late season in the three seasons. However, results in the three seasons showed that 30 cm depth highly significantly ($P \leq 0.01$) attained the highest soil moisture contentfollowed by 20 and 25 cm depths in both early and late periods of season. On the other hand, the lowest soil moisture content was recorded by the control. Soil moisture content tended to increase with increased depth of soil resulted from using chisel plow implement. Similar result was obtained by the findings of EKhidir (2008).

Table (2): Soil moisture content at different chisel depths at early and late periods of seasons for 2009, 2010 and 2011 seasons.

Seasons	Chisel depth (cm)	SMC-E mm	SMC-L mm
2009	20	198.9 c	98.8 c
	25	212.7 b	108.3b
	30	247.1 a	135.1a
	Control	185.4 d	97.4 c
	CV%	1.03	1.85
	SE+	1.7739	1.6648
	LSD	4.0906	3.8391
2009	20	220.2 c	109.3 c
	25	244.0 b	124.2 b
	30	271.2 a	148.1 a
	Control	115.3 d	100.5 d
	CV%	0.94	1.7
	SE+	1.6	1.6
	LSD	3.8	3.8
2011	20	178.5 b	88.6 c
	25	191.6 b	97.5 b
	30	216.6 a	118.6 a
	Control	177.1c	80.2 d
	CV%	3.6	2.02
	SE+	5.6	1.6
	LSD	12.9	3.7

SMC-E = Soil moisture content in early season
SMC-L = Soil moisture content in late season
Control (Wide level disk=12 cm)

Rainfall (RF) and effective rainfall (ER)

The amount of monthly effective rainfall (mm) measured in the three seasons is shown in Table (3). The total annual rainfall for the growing period was 509, 628 and 377 mm for the first, second and third seasons, respectively. On the other hand, the total effective rainfalls were 382, 471 and 283 mm for the first, second and third seasons, respectively. It was observed that the lowest annual rainfall was received during the third season. July, August and September were the rainiest months in the three seasons.

Table (3): Monthly rainfall and effective rainfall in 2008, 2009 and 2010 seasons

Season	Month	RF (mm)	ER (mm)
2009	May	10.5	7.9
	June	14.6	11
	July	179.7	134.8
	August	116.5	87.8
	September	188	141
	October	20.8	15.6
	Total	**509.3**	**382**
2010	May	8.9	6.7
	June	50.2	37.7
	July	191.6	143.7
	August	174.6	131
	September	89.9	67.4
	October	17.6	13.2
	Total	**627.8**	**471.0**
2011	May	25.6	19.2
	June	67	50.3

July	63.5	47.6
August	101.4	76.1
September	98.8	74.1
October	20.8	15.6
Total	**377.1**	**283.0**

Crop water requirement (CWR)

Figure (1) shows the crop water requirement (mm) of sorghum for the three seasons. However, the highest crop water requirement (174 mm) was attained by the second season in September followed by thefirstand third seasons (162 mm for each), while the lowest 31, 34 and 44 mm ofcrop water requirements were obtained in July for the third, first and second seasons in sequence. The total crop water requirements for the length of season in this study were 451, 463 and 462 mm in the first, second and third seasons, respectively. These values were in agreement with Jewitt*et al.*, (2009) and Hensley*et al.*, (2000) who reported that sorghum water requirement ranged between 450 mm and 650 mm.

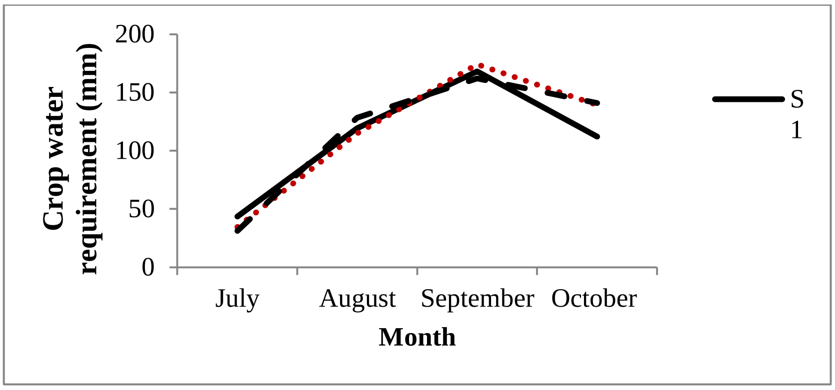

Fig. (1) Crop water requirement as afunction of time (month) for sorghum in 2009, 2010 and 2011 seasons

S1= First season, S2= Second season, S3= Third season

Effective rainfall and crop water requirement

Effective rainfalls (ER) were compared with crop water requirements (CWR) in the three seasons. However, the comparison revealed both periods of water shortage and water excess. Figure 2, 3 and 4 show the relationship between effective rainfalls and crop water requirements. In the first and second seasons rainfalls were higher than the crop water requirements in July, August and September, while in the third season it was observed that rainfalls were lower than crop water requirements for the same months. The balance might be compensated from the high stored water into the soil depths resulted from using chisel plowing. This result was in accordance with Elkhidir (2018). For the four growth stages (initial, crop development, mid-season and late-season), the mid- season stage during September was the most sensitive to water shortage. This was mainly because it was the period of the highest crop water needs.

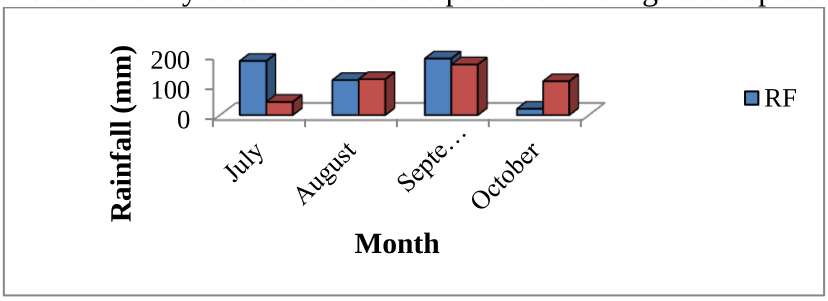

Fig. (2): Rainfall versus crop water requirement in the first season.

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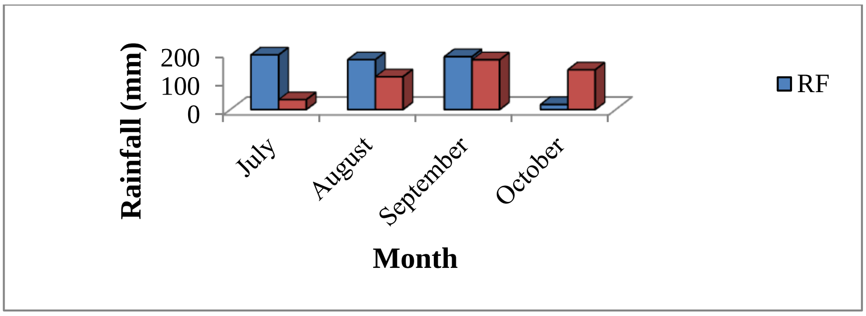

Fig. (3): Rainfall versus crop water requirement in the second season.

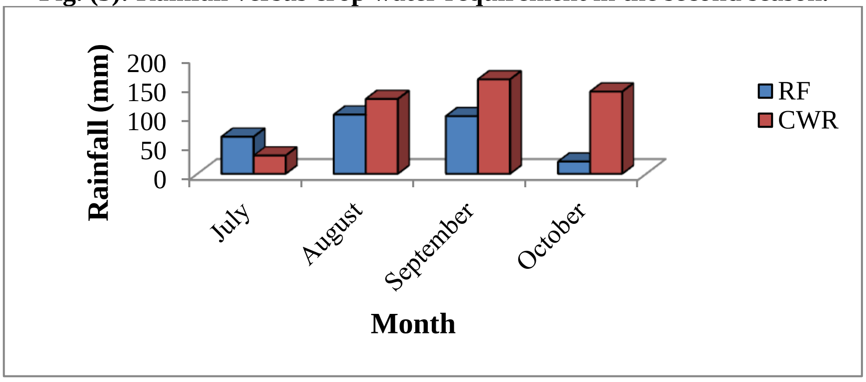

Fig. (4): Rainfall versus crop water requirement in the third season.

RF= Rainfall (mm), CWR= Crop water requirement (mm)

Plant parameters

Plant height

Table (4) shows the results of plant height in the three seasons. Chisel depths have significant (P≤ 0.05) effect on plant height. However, in the first and second seasons no significant difference was found among 20. 25 and 30 cm depths which all produced taller plants, while the control gave shorter plants**.** In third season no significant difference was found among all the treatments. Elkhidir*et al.*, (2013) found that plant height increased with increased chisel depths over the control which could be due to the deeper tillage operation which led to increased depth of stored water in chisel tilled plots as a result the tallest plants were obtained. The result was confirmed by El Naim*et al.*, (2012) who found that increased tillage depth increased plant height, panicle seed weight and grain yield.

Table (4): Effect of chisel depths on sorghum growth attributes and yield components in 2009, 2010 and 2011 seasons.

Seasons	Depth (cm)	Plant height (cm)	SD (mm)	Root depth (cm)	1000 SW (g)
	20	77.6 a	14.1 a	17.3 a	22.1 a
	25	82.6 a	15.5 a	19.9 a	24.5 a
	30	89.8 a	19.3 a	22.0 a	27.6 a
2009	Control	67.3 b	13.4 a	15.1 b	20.5 a
	CV %	12.75	25.68	16.15	16.90
	SE±	8.2698	3.2660	2.4495	3.2660
	LSD	19.070	7.5314	5.6485	7.5314
	20	88.5 a	20.6 a	16.0 a	25.6 a
	25	90.3 a	21.7 a	17.2 a	26.9 a
2010	30	99.5 a	23.2 a	19.8 a	30.5 a
	Control	70.1 b	12.3 b	15.2 a	21.2 b
	CV %	11.48	15.42	17.60	15.36

	SE±	8.1650	2.4495	2.4495	3.2660
	LSD	18.828	5.6485	5.6485	7.5314
	20	68.9 a	12.5 a	19.8 a	20.0 a
	25	73.5 a	13.3 a	21.6 a	22.0 a
	30	80.1 a	16.1 a	24.6 a	24.8 a
2011	Control	66.3 a	11.6 a	15.2 b	18.4 b
	CV %	13.85	22.43	19.70	14.08
	SE±	8.1650	2.4495	3.2660	2.4495
	LSD	18.828	5.6485	7.5314	5.6485

SD = Stem diameter, SW = Seeds weight,
Control = (Wide level disk = 12 cm)

Stem diameter

Table (4) shows the results of stem diameter in the three seasons. However, in the first and third seasons no significant difference was found among all the treatments. In the second season chisel depths have significant (P≤ 0.01) effect on stem diameter. In this regard, no significant difference was found among 20, 25 and 30 cm depths which all obtained higher stem diameter compared to the control which gave lower stem diameter.Stem diameter increased with increased *in-situ* rainwater harvesting techniques depth. Similarly, El Naim*et al.,* (2012) found that chisel plowing obtained the highest stem diameter over the control.

Root depth

Table (4) shows the results of root depth in the three seasons. However, in the first and third seasons chisel depths have significant (P≤ 0.05) effect on root depth. In this regard, no significant difference was found among 20, 25 and 30 cm depths which all obtained higher root depth compared to the control which gave lower root depth. In the second season no significant difference was found among all the treatments. The gradual deep penetration of roots made by chisel plowing might be due to the fact that deeper tillage had lower penetration resistance and soil bulk density but had higher soil porosity. Chisel plowing was found to increase penetration of roots vertically to deeper soil layers than that created by shallow *in-situ* rainwater harvesting techniques. These results were supported by the findings of Elkhidir (2018).

1000-seeds weight

Table (4) shows the results of 1000 seeds weight in the three seasons. In the first season no significant difference was found among all the treatments. In the second and third seasons no significant difference was found among 20, 25 and 30 cm depths which significantly (P≤ 0.05) produced higher 1000 seeds weight, while the control recorded lower 1000 seeds weight. Increased 1000 seeds weight obtained by chisel plowing might be attributed to the increased depth of stored water on soils which led to improved size of grain and consequently increased seeds weight and final yield. These results were in agreement with the findings reported by Elkhidir (2008).

Grain yield

Table (5) shows the results of grain yield in the three seasons. Results showed that 30 cm depth highly significantly (P≤ 0.01) obtained the highest grain yield followed by 25 and 20 cm depths, whereas the control gave the lowest grain yield in the three seasons. The results revealed that the highest yields of sorghum were obtained under chiseling, while the lowest yields were obtained under no-till system. Similar result was obtained by Ibrahim *et al.,* (2015). Yields increased with increased chisel depths which might be due to increased soil moisture content. This result was in agreement with Babiker*et al., (*2015).

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Rainwater productivity

Results of rainwater productivity for the three seasons are shown in Table (5). In the first and second seasons no significant difference was found among all the treatments. In the third season both 30 and 25 cm depths highly significant ($P \leq 0.01$) gave higher water productivity, while no significant difference was found between 20 cm depth and the control which both produced lower water productivity. It was observed that the third season produced the highest water productivity with low rainfall amount. Increased water productivity obtained by chisel plowing might be attributed to the increased depth of stored water in the soil leading to increased plant growth and final yield. The result was confirmed with the findings of Elkhidir (2018). The results revealed that the highest water productivity was obtained by the third season, whereas the lowest was obtained by the first season. This is because the yield is divided by low rainfall amount in the third season (the low rainfall season). Therefore, the highest water productivity was obtained compared to the first and second seasons. This result was in agreement with Bashir *et al.*, (2018) who stated that with increased amount of water supplied, the water productivity decreased. Values of water productivity obtained ranged between 0.2 to 2.4 kg/m^3 was in agreement with Perry (1996).

Table (5): Main effects of chisel depths on grain yield and water Productivity for 2009, 2010 and 2011 seasons

Season	Chisel depth (cm)	Grain yield (kg/ha)	Water productivity (kg/m^3)
2009	20	1709.7 c	1.1 a
	25	1949.5 b	1.2 a
	30	2267.7 a	1.4 a
	Control	1520.2 d	0.95a
	CV %	5.37	43.01
	SE±	81.650	0.4082
	LSD	188.28	0.9414
2010	20	1970.6 c	1.0 a
	25	2132.3 b	1.1 a
	30	2505.4 a	1.3 a
	Control	1622.0 d	0.82a
	CV %	5.19	28.44
	SE±	87.401	0.2449
	LSD	201.55	0.5649
2011	20	1521.9 c	1.6 b
	25	1733.4 b	1.8 a
	30	2013.6 a	2.1 a
	Control	1320.3 d	1.4 b
	CV %	6.07	11.59
	SE±	81.650	0.1633
	LSD	188.28	0.3766

Effective rainfall = First season (1604.4 m^3/ha), Second season(1978.2 m^3/ha), Third season (970.2 m^3/ha)
Control = Wide level disk (12 cm)

Concolussion

The following conclusions could be drawn from the study:

Chisel plowing at different depths attained higher soil moisture content over the control in the three seasons. Chisel plowing at different depths produced higher plant height, stem diameter, root depth, 1000 seeds weight over the control in the three seasons. The highest grain yields were obtained by the second season compared to the first and third seasons. The third season produced the highest water productivity with low rainfall amount. On the other hand, the lowest water productivity was given by the first season. Effective rainfall was lower than the crop water requirement in the third season. Therefore, low yields of sorghum were pronounced.

Recomendations

It is recommended to use chisel plowing at different depths to maximize the yield of sorghum and meets the water demand and low rainfall.

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