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IMPACT OF IRRIGATION INTERVALS AND TILLAGE SYSTEMS ON SOIL MOISTURE DISTRIBUTION AND MAIZE (ZEA MAYS L.) GROWTH IN EASTERN SUDAN

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ABSTRACT A field experiment was conducted to investigate the effect of different irrigation intervals and tillage systems on soil moisture distribution and maize (Zea mays L.) growth and yield. The field work was carried out at Demonstration Farm of the Faculty of Agriculture and Natural Resources, University of Kassala, New Halfa (Sudan) for two consecutive seasons (2009/2010 and 2010/2011). The irrigation intervals were 14 days (I1) and 21 days (I2). While the tillage systems were {(disc plowing + harrowing + leveling + ridging (TS1)), (chisel plowing + harrowing + leveling + ridging, (TS2)), (disc harrowing + leveling + ridging, (TS3)), and ridging only, (TS4)}. The experiment was organized in split plot design with three replications. The soil moisture distribution was estimated before and during the experiment, while the measured crop growth and yield parameters were emergence percentage, plant height, leaf area index, biological yield, grain yield, and harvest index. The results showed that moisture content (%) tend to increase significantly ($P \leq 0.05$) with depth before running the treatments and during the different stages of the experiment, while the highest values of moisture content were observed with I1 and TS2. Moreover, irrigation intervals and tillage systems showed high significant ($P \leq 0.01$) effect on the leaf area index, grain yield and harvest index in both seasons. Hence, the combination of I1 and TS2 showed the highest grain yield across the two seasons (8.5 and10.4 ton/ha) compared to I2 with TS3 and TS4 which revealed the lowest ones, (6.5 and 3.9 ton/ha, respectively). The conclusion drawn from this study is that I1 and TS2 were showed the best soil moisture distribution and significant improvement of maize growth and yield parameters.

KEYWORDS : Tillage Systems; Irrigation Intervals; Maize; Soil Moisture

INTRODUCTION

Maize (*Zea mays L.*) is one of the oldest food grains, which belongs to the grass family Poaceae (Gramineae), tribe Maydeae and is the only cultivated species in this genus. Maize growths over wider geographical and environmental ranges than any other cereal. Among the world's cereal crops, maize ranks second to wheat in production, while milled rice ranking third. However, among developing economics, maize ranks first in Latin America and Africa but third after milled rice and wheat in Asia (CIMMYT 1989). Maize is considered as one of the promising crops, recently introduced to Sudan. There are no standard practices in the country as far as tillage system and planting methods or irrigation regimes are concerned. Many studies have been carried out to determine the yield potential under different irrigation levels; most of these studies were conducted during summer and indicated that frequent irrigation intervals produce the highest yield. Although there were differences in grain yield from season to season (Saliem, 1991). Water and soil are the most limited and precious natural resources, as indicated by recent studies according to Tayel *et.al.*,(2014). Due to climate vagaries, water availability for agricultural activities is getting limited and scarcer, as well as these vagaries worst the situation, because it increasing crop's evapotranspiration, (López-López, R., *et al.,* 2014). Therefore, appropriated management for these precious resources is highly needed to barrage the gap in food requirements. Tillage is one of the most important inputs which influence crop production under irrigated agriculture. Furthermore, tillage has been an important aspect of technological development in the evolution of agriculture, in particular for food production, water and soil conservation and weed control. Also it is effective method for soil moisture conservation, as reported by El-Awad, (2000). Soil disturbance by different tillage implements is costly and very demanding, but it is of great importance for high crop yield. Various types of tillage are practiced throughout the world, ranging from the use of a simple stick or bar to the sophisticated para-ploughs. On the other hand the limited water resources are becoming to be a limiting factor of irrigation applications worldwide. Therefore, the fresh water available supplies in some locations do not enable to cultivate all irrigable land, hence will not provide the maximum crops production. In some regions, water for irrigation is regulated leading to insufficient irrigation. For many surface water projects, the annual supply of irrigation water is limited by reservoir capacity and annual reservoir inflow. These examples highlight the need for deficit irrigation management for different crops (Martin *et al.,* 1989). An important aspect in an irrigation system is to know the optimum quantity of water to be applied at optimum time to get maximum return per unit volume of irrigation water. Wanjural *et al.,* (2002) reported that application of excessive water can reduce crops yield and growth characteristics as several references indicated. Moreover, DeTar (2008) stated that plant height strictly linked to the depth of water applied. Due to the competition of irrigated agriculture and the other sectors, Sudan expected to face water shortage problem, thus to overcome this problem, improving water use efficiency is highly required (El-Awad, 2000).This study is designed to assess the status of soil moisture and productivity of maize (*Zea mays* L.) (kg/ha) under different irrigation intervals and various tillage systems in eastern Sudan

MATERIALS AND METHODS

The experiment was conducted at the Demonstration Farm of the Faculty of Agriculture and Natural Resources, University of Kassala at New Halfa town, during the seasons 2009/2010-2010/2011. The study

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area lies at the intersection of (15º 33` N, and 35º 41` E), and its elevation is about 450m above mean sea level (El Hussein, 2009). The soil of the area is Vertisol with clay content of 45-60%. The climate is semi-arid and the average annual rainfall ranges between 50-250mm, the rainy season is during June to September. The temperature ranges from 15-42ºC, while, the hottest month is June and the coldest month is January (Ali, 2001).

The experimental was laid out in split plot design whereas the main plot assigned for irrigation intervals, while tillage systems were located in the subplot. On the other hand each treatment was replicated three times. The size of each plot was ($5\times4m^2$). The two irrigation intervals were: Every 14 days, (I_1) and Every 21 days (I_2). While, the tillage systems included:

1. Disc plowing followed by Harrowing, Leveling and Ridging, respectively (Ts_1).
2. Chisel plowing followed by Harrowing, Leveling and Ridging, respectively (Ts_2).
3. Harrowing followed by Leveling and Ridging, respectively (Ts_3).
4. Ridging only (Ts_4).

The crop supplied with the same amount of water, while the date of suppling water was according to the interval treatments (14 and 21 days). Soil moisture was determined before tillage treatments, after tillage treatments, three days after suppling water, and at harvesting.

Sampling of vegetative growth and yield parameters were measured as follows:

Emergence percentage: This was taken after 7 days from sowing. The emergence percentage was obtained using the following equation as stated by (Carlson and Clay, 2016):

$$Emergence\ percentage = \frac{Plant\ population\ after\ emergence}{Seeding\ rate} \times 100$$

Plant height (cm): Ten random plants per plot were selected, then after each one measured from the soil surface to the base of the tassel after full tasseling.

Leaf area index (LAI): As in plant height ten plants randomly selected to determine the leaf area index using the following formula according to the Mokhtarpour *et al.* (2010):

LAI= max. length× max. width× no. of leaves/plant×0.75×no.of plants/m^2

Yield parameters (grain yield, Harvest Index,): An area of one square meter was selected in each plot to determine the final yield and yield components for each treatment by using the following relation:

$$\text{grain yield}\ ton/hectare = \frac{yield\ (ton)}{area\ (hectare)}$$

Harvest Index (HI) and Biological yield: After drying, the harvested plants from each plot, they weighed to obtain the biological yield. Then, the crop was manually threshed, and the grain yield obtained. Moreover, the Harvest Index obtained by using the following equation:

$$\text{Harvest Index} = \frac{\text{Grain yield}}{\text{Biological yield}}$$

RESULTS AND DISCUTION

Soil moisture content (%) distribution in the experimental site before irrigation intervals and tillage treatments application, is illustrated in figure (1). It recognized that during the two seasons, soil moisture content tend to increase with depth from the surface downwards to 60-80 cm soil depth. Moreover, the second season presented higher moisture content across the tested depths. The current result supported by the finding of Olanrewaju and Abubakar (2015) , who reported that soil moisture increasing with increasing in soil depth.

The effect of irrigation intervals and tillage systems on soil moisture distribution was shown in figures 2 and 3. The irrigation interval (I_1) has advantage of distributing soil moisture in the both seasons over the second interval (I_2). The same results were recorded by tillage treatments, whereas, the tillage system (TS_2) revealed the highest values followed by tillage systems (TS_1, TS_4 and TS_3) respectively. Moreover, statistical analysis of the interaction of irrigation intervals and tillage systems (table 1) showed significant differences ($P\leq 0.05$) on distribution of soil moisture content (%). Whereas, the interval (I_1) with tillage system (TS_2) revealed the highest values, while the interval (I_2) with tillage system (TS_3) recorded the lowest values. These results may be attributed to that Irrigation intervals can change spatial distribution of soil moisture and soil water storage. Moreover, short intervals always produce high soil moisture content. Moreover, irrigation interval is a crucial factor affecting soil moisture distribution (Assouline, (2002) and Wang*, et. al.,* (2006)), and then soil water storage (Cao, *et. al.,* 2003).

Tillage systems affect directly and indirectly storing of water in soil, through influencing soil hydraulic properties as stated by Blanco-Canqui *et. al.* (2017). Also the current result agrees with (Hatfield et. al., 2001; Franzluebbers, 2004 and Jalota *et. al*. 2006) who reported that conservation tillage systems reducing evaporation, improving soil water content and water infiltration. Based on the volume of soil disturbance, tillage affect soil water adsorption and retention (Blanco-Canqui *et. al.,* 2017).

In the same way the plant growth and yield parameters affected by irrigation intervals and tillage systems. Moreover, the interaction of irrigation intervals and tillage systems showed the I_1 and TS_2 recorded high significant difference ($P\leq 0.05$) in increasing plant growth, while the I_2 and TS_3 revealed less significant difference ($P\leq 0.05$), as presented in table (2) and figures (5a, 5b and 5c). The obtained results in agreement with finding of Prodhan *et. al.,* (2001), who reported that plants such as Jute when subjected to water stress regimes gave shorter plant height than that grown under normal water regime. Also Shiwachi, *et. al.,* (2008), stated that less availability of water in soil decrease crop growth.

Table (3) and figures (6a, 6b and 6c) revealed the effect of irrigation intervals and tillage systems on yield parameters. The results explain that the I_1 and TS_2 gave the highest values of biological yield, harvest index, and grain yield, while the I_2 and TS_3 showed the lowest values of aforementioned parameters. Therefore, for a perfect crop growth and high yield water needs to be distributed efficiently at the right time with an effective quantity, which supported by the finding of Cooper *et. al.* (1987) who stated that soil moisture has a great effect on yield and sustaining crop production in arid and semi-arid regions. Optimal irrigation interval and water amount improve water use efficiency and increasing crops yield, (Irmak *et. al.,* 2016). Moreover, Zhang *et. al.,* (2019) reported that optimal irrigation interval is affected by some factors such as soil texture, climatic factors, and irrigation amount. Excessive or inadequate water application influence water use efficiency and crops yield.

McMaster *et al.,* (2002) stated that grain yields always higher with no-tillage than conventional tillage, in contradiction with finding of Unger (1994) who reported that yield in long-term trials dose not affected by tillage system, and with that of Guzha (2004) and Taa *et al.,* (2004) who stated grain yield under no-till is lower than under conventional tillage systems. Furthermore, research results indicated that disc ploughing followed by harrowing resulted in greater groundnut yield (Ishag et al., 1987) and in greater sorghum yield than ridging only (El-Awad, 1990).

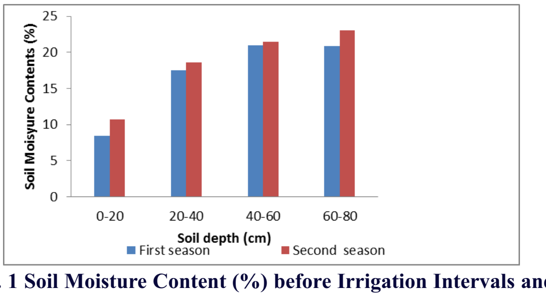

Fig. 1 Soil Moisture Content (%) before Irrigation Intervals and Tillage Treatments.

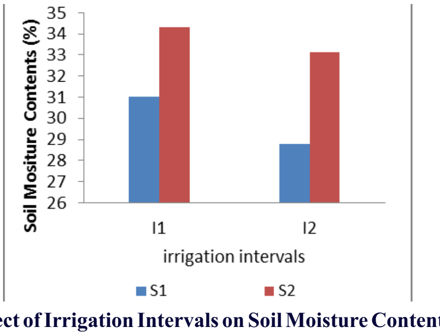

Fig. 2 Effect of Irrigation Intervals on Soil Moisture Content (%)

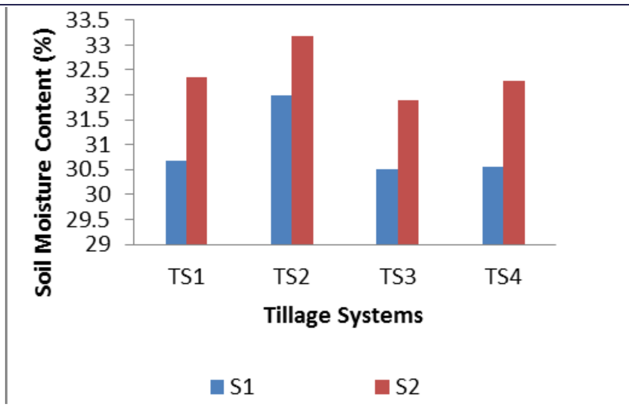

Fig. 3 Effect of Tillage systems on Soil Moisture Content (%)

Table 1 Effect of irrigation intervals and tillage treatments interaction on soil moisture content (%)

		Season 2009/2010					Season 2010/2011				
Water Interval	Tillage treatments	third irrigation*	4th irrigation	5th irrigation	6th irrigation	At harvest	third irrigation	4th irrigation	5th irrigation	6th irrigation	At harvest
	TS$_1$	30.9^{b}	30.6^{bc}	30.3^{ab}	30.9^{a}	19.3^{c}	34.1^{a}	33.8^{ab}	34.3^{a}	35.5^{ab}	19.9^{a}
I1	TS$_2$	32.4^{a}	34.2^{a}	30.2^{ab}	31.2^{a}	20^{b}	34.7^{a}	34.7^{a}	35^{a}	34.1^{bc}	20.1^{a}
	TS$_3$	30.3^{bc}	30.7^{bc}	30.9^{a}	30.1^{ab}	20.4^{a}	34.1^{a}	34.0^{ab}	33.7^{ab}	32.7^{cd}	20.5^{a}
	TS$_4$	31.0^{b}	31.9^{b}	30.7^{a}	29.3^{bc}	19.1^{c}	34.3^{a}	33.74^{ab}	33.9^{ab}	35.9^{a}	20.2^{a}
	TS$_1$	28.7^{de}	27.4^{d}	27.7^{c}	27.8^{d}	19.2^{c}	32.3^{bc}	33.2^{b}	32^{bc}	35.1^{ab}	18.5^{b}
	TS$_2$	29.4^{cd}	29.6^{c}	29.4^{abc}	28.6^{cd}	19.3^{c}	33.5^{ab}	33.3^{b}	34.5^{a}	34.5^{ab}	19.9^{a}
I2	TS$_3$	28.5^{de}	30.2^{bc}	28.9^{abc}	28.4^{cd}	19.3^{c}	33.9^{ab}	33.9^{ab}	33.2^{abc}	31.8^{d}	20.2^{a}
	TS$_4$	27.8^{e}	31.0^{bc}	28.3^{bc}	28.6^{cd}	19.1^{c}	31.6^{c}	32.1^{c}	31.5^{c}	32.4^{d}	20.2^{a}
LSD		1.16	1.72	2.12	1.18	0.34	1.73	1.01	2.06	1.49	0.67

means in a column followed by the same letter(s) are not significantly different at P≤ 0.05.

Table 2 Effect of Irrigation Intervals and Tillage systems interaction on some crop growth parameters.

		Season 2009/2010			Season 2010/2011		
irrigation intervals	Tillage treatments	Emergence percentage	Plant height (cm)	Leaf area index	Emergence percentage	Plant height (cm)	Leaf area index
	TS$_1$	68.7^{c}	160.3^{ab}	4.51^{b}	85.7^{ab}	157.2^{b}	5.68^{b}
I$_1$	TS$_2$	78.3^{a}	163.8^{a}	5.28^{a}	86.0^{ab}	170.3^{a}	6.16^{a}
	TS$_3$	76.5^{ab}	151.3^{cd}	4.33^{bc}	86.7^{a}	159.8^{b}	5.29^{c}
	TS$_4$	77.0^{ab}	154.3^{bc}	4.52^{b}	85.3^{ab}	155.8^{b}	5.78^{b}
	TS$_1$	67.8^{c}	155.5^{bc}	3.71^{d}	85.3^{ab}	146.3^{c}	4.64^{d}
I$_2$	TS$_2$	78.7^{a}	156.0^{bc}	4.14^{c}	87.5^{a}	148.3^{c}	5.34^{c}
	TS$_3$	74.0^{b}	150.3^{cd}	3.71^{d}	83.33^{b}	144.7^{c}	4.44^{d}
	TS$_4$	74.0^{b}	146.8^{d}	3.89^{d}	86.7^{a}	146.5^{c}	4.63^{d}
LSD		3.7	6.8	0.21	2.9	6.4	0.29

means in a column followed by the same letter(s) are not significantly different at P≤ 0.05.

Table 3 Effect of Irrigation Intervals and Tillage systems interaction on some yield parameters.

irrigation intervals	Tillage systems	Season 2009/2010			Season 2010/2011		
		Biological yield(ton/ha)	Harvest Index	Grain yield(ton/ha)	Biological yield(ton/ha)	Harvest Index	Grain yield(ton/ha)
	TS$_1$	30.5^{a}	0.25^{b}	7.5^{b}	32.2^{a}	0.30^{b}	9.8^{b}
I$_1$	TS$_2$	29.6^{ab}	0.29^{a}	8.5^{a}	33.0^{a}	0.32^{a}	10.4^{a}
	TS$_3$	28.3^{b}	0.19^{g}	5.3^{d}	27.3^{b}	0.28^{c}	7.6^{d}
	TS$_4$	25.7^{c}	0.24^{c}	6.1^{c}	32.8^{a}	0.27^{d}	8.8^{c}
	TS$_1$	22.3^{ef}	0.19^{e}	4.3^{f}	30.5^{a}	0.25^{e}	7.7^{d}
I$_2$	TS$_2$	24.1^{cd}	0.20^{d}	4.8^{e}	27.6^{b}	0.32^{a}	8.8^{c}
	TS$_3$	23.6^{de}	0.19^{f}	4.5^{ef}	27.3^{b}	0.24^{h}	6.5^{f}
	TS$_4$	21.8^{f}	0.18^{h}	3.9^{g}	26.4^{b}	0.27^{d}	7.2^{e}
LSD		1.6	0.1	0.4	2.7	0.1	0.3

means in a column followed by the same letter(s) are not significantly different at P≤ 0.05.

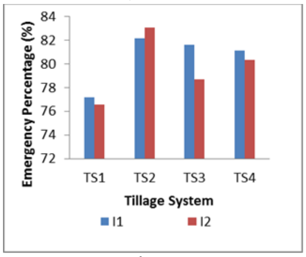

Fig. 5a

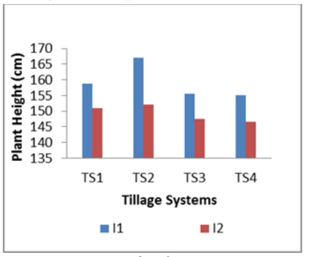

Fig. 5b

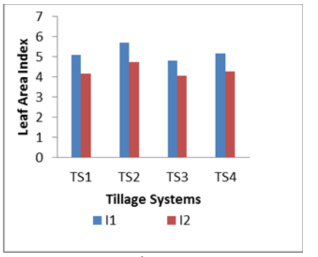

Fig. 5c

Fig. 5 (a, b and c) Effect of Irrigation Intervals and Tillage Systems on Plant Growth parameters

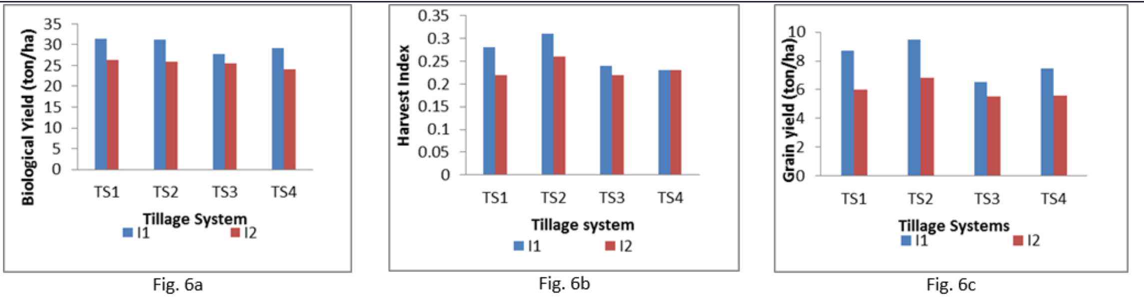

Fig. 6a Fig. 6b Fig. 6c

Fig. 6 (a, b and c) effect of Irrigation Intervals and Tillage Systems on Yield parameters

CONCLUSION AND RECOMMENDATIONS

The following conclusions and recommendations can be drawn from this study:

1. Soil moisture distribution is affected by irrigation intervals and tillage systems.
2. Soil moisture tends to increase with depth through soil surface layers.
3. Irrigation intervals ((I_1) 14 days) and tillage irrigation systems ((TS_2) Chesil followed by harrowing, levelling and ridging) in combination recorded the highest values of biological and grain yield of maize.
4. When planning for cultivating maize in irrigated schemes, I1 in combined with TS_2 is recommended as optimum method for producing maize. in Sudan.
5. Furthers studies for producing maize under Sudan conditions is highly needed

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