EFFECT OF IRRIGATION QUANTITY ON WATER USE EFFICIENCY OF GUAR UNDER NEW HALFA CONDITION, SUDAN

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ABSTRACT

An experiment was conducted at the Demonstration Farm of New Halfa Research Station, during season 2017/2018 with the objectives of determining the crop water requirements for Guar (Cyamopsistetragonoloba) and investigating the effect of irrigation quantity on crop water productivity (kg/m3) under furrow irrigation system. The treatments included four irrigation quantities namely; T1500mm3, T2400m3, T3300m3 and T4200m3. These treatments were arranged in randomized completely block design (RCBD) with four replicates. The parameters tested were irrigation efficiency (IE%), crop water requirements for guar (mm/day), growth parameters (plant height, stem diameter and no of branches), crop productivity (kg/ha) and water use efficiency (kg/m3). The results showed that, irrigation efficiency of furrow system was very low (45%). Crop water requirements for guar were differ among the growing season which was recorded the lowest values in March (3.73mm/day) and the highest in April (8.61mm/day). Growth parameters significantly ($P \leq 0.05$) affected by the different irrigation quantities. 500m3 of applied water significantly increased the plant height (32cm), stem diameter (5.3cm) and no of branches (14) as compared to 200m3 which ranked the least (28.11cm, 4.83cm and 13, respectively. Crop productivity and water use efficiency significantly affected by the different irrigation quantities. Irrigation quantity of 500m3 gave the highest value of crop productivity (2288kg/ha) while 200m3 recorded the highest mean values of water use efficiency (9.22 kg/ m^3). It concluded to maximize crop productivity and water use efficiency, the management of irrigation systems via; when to irrigate and how much irrigation water to be applied with regard to crop water requirement should be followed and adopted.

Keywords: Guar (Cyamopsistetragonoloba), irrigation quantity, crop, water use efficiency, water productivity, irrigation efficiency (IE%), crop water requirements.

1. INTRODUCTION

Surface irrigation is the most commonly used and oldest type of irrigation that transports water from the source to the irrigated field via gravitational forces (Haile, 2015).The uncontrolled water application methods usually lead to huge losses of irrigation water (AbdAlrahman, 2005).Irrigation efficiency (IE) which, defined as the ratio of the volume of water that is taken up by the crop to the volume of irrigation water applied, (ASCE, 1978).In recent years, the modern irrigation systems application has taken great section in irrigation techniques and obtained substantial attention in the world, especially in developing countries(Tawheed.et. al 2019). Over the past few decades, water conservation practices in many places did not result in reduced agricultural water use as expected, though agricultural water use efficiency had increased significantly (Grafton. et all. 2018). Water use efficiency (WUE) has been defined as the ratio of total dry matter per unit of Et (Begg and Turner, 1976); as the ratio of dry matter produced per unit area (t/ ha) per unit of Et (mm) (Jensen et al., 1990), and as the ratio of Photosynthesis per unit of water transpired (Sinclair et al., 1984). Some studies concluded that the high-efficiency water-saving technology can ideally save a lot of water resources (Yao L. 2017)

The agricultural sector in Sudan is the most pioneering of all economic activities employing about 70% of the labour force, (E.I.U. 1992). Farmers are still using traditional surface irrigation systems to irrigate their crops. These traditional methods have less efficiency and a huge amount of water is lost in conveyance systems and at the farm level. Low crop productivity is one of the major problems that are facing agricultural production in Sudan. Low water use efficiency is normally associated with poor timing and a lack of uniformity in water applications.

Guar is a multi-purpose legume crop with its uses including vegetable for human consumption, green manure to improve soil fertility, fodder for animals and industrial applications, such as textile, paper, explosives, pharmaceutical, cosmetic and hydraulic fracturing (Mathur, 2011), (Chudzikowski, 1971; Mudgil et al., 2014).

The importance of guar among industrial crops is due to the unique thickening ability and stabilizing, binding and strengthening properties of the seed galactomannans (Giovanni, *et, all,*2020). Guar is irrigated 3-4 times during cultivation period when it is cultured underirrigation system. It is an extremely drought tolerant plant and very easy to cultivate with a limited supply of water (Singh, 2014). Guar seeds have been produced with 2650m3/ha average water supply (Gresta et al., 2013**)**. However, under optimum water management practices reported that water use efficiencies expected for guar crop ranged from about 0.40 to 0.60 kg/m^3Alexander, W.et al (1988)

Therefore, the objectives of this study were to study the effect of irrigation Quantity of water use efficiency of guar under new Halfa condition and investigate the effect of irrigation quantity (500mm^3, 400m^3, 300m^3 and 200m^3) on crop water productivity (kg/m^3)

2. MATERIALS AND METHODS

The experimental site

An experiment was conducted at the Demonstration Farm of New Halfa Research Station located at Latitude 15.31N, Longitude 35.6E and Altitude 451 m above sea level, clay soil with 57-65% clay content and the bulk density is 1.8gm/cm^3. The climate is semi-arid with low relative humidity and daily mean maximum and minimum temperature are 35.4^o C and 21.2^o C, respectively. The annual rainfall is limited and usually occurs in the form of short intense thunder storms.

Experimental design and layout

Irrigation water amounts used were 500m^3, 400m^3, 300m^3 and 200m3. These treatments were arranged in randomized completely block design (RCBD) with four replicates.

Guar crop (*Cyamopsistetragonoloba*)

Guar crop (species L53) was sown manually in 2/3/2017 with seeding rate of three seeds per hole, 10cm spacing between holes and 70cm between furrows.

Crop water requirement (CWR)

Crop water requirements (CWR) are defined as the depth of water [mm] needed to meet the water consumed through evapotranspiration (ETc) by a disease-free crop, growing in large fields under non-restricting soil conditions including soil water and fertility, and achieving full production potential under the given growing environment (L.S. Pereira, *et al*, 2005)

Crop water requirement (CWR) is dependent on prevailing environmental conditions and crop variety, growth stage and irrigated method. It is generally related to reference evapotranspiration (ETo) which is calculated from meteorological data (Smith *et al.*, 1998). Crop water requirements are usually expressed in units of water volume per unit land area (m^3/ha) or depth per unit time (mm/day) as stated by Jensen (1990). It can be calculated according to the following equation:

ETc=ETo×Kc…………………………………. (1)

Where:

ETc= Crop evapotranspiration (mm/day)

ETo= Reference crop evapotranspiration (mm/day).

Kc= Crop coefficient

Reference crop evapotranspiration (ETo)

Reference crop evapotranspiration (ETo) can also be calculated by the Penman-Monteith formula (2.22) as stated by Smith *et al*., (1998).

$$ET_o = \frac{0.408\Delta(Rn - G) + \gamma\left(\frac{900}{T} + 273\right)U_2(es - ea)}{\Delta + \gamma(1 + 0.34U_2)} \quad \text{....................(2)}$$

Where:

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

R_n = Net radiation at crop surface ($Mjm^{-2}day^{-1}$)

T = Average temperature at 2m height (°c).

e_s = Svp, kPae_a = Actual vp (kPa)

(e_s – e_a) = Saturation pressure deficit for measurement at 2m height (kPa).

U_2 = Wind speed at 2m Hight (ms^{-1}).

Δ = Slope of vapor pressure curve (k Pa °c).

Γ = Psychometric constant (k Pa °c)

900 = Coefficient for reference crop (kj Kg Day^{-1})

0.34 = Wind coefficient for the reference crop (sm^{-1})

G = Soil heat flux (Mj m^{-2} day^{-1})

Irrigation water amounts

Irrigation water amounts were measured using a V-notch 90o weir. The discharge over the weir was calculated using the following equation as stated by Michael (1978) as follows:

Q = 0.0138 $H^{5/2}$ ………………………………………….. (3)

Where:

Q = discharge over the weir in l/s.

H = the head over the weir in cm.

Irrigation Efficiency;

The term of irrigation efficiency (IE) was used to define the effectiveness and the irrigation system in delivering all the water beneficially used to produce the crop as reported by Hamza and Almasraf (2016) as follows:

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$$IE = \frac{\text{Total water requirements}}{\text{Total applied water}} * 100 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(4)$$

Crop Parameters Measurements

1. **Plant height**

Ten plants were randomly selected from each block, and then plant height was measured using a ruler and meter stick. The height was measured from the soil surface to the tip of the youngest leaf. The mean for each block was recorded.

2. **Stem diameter**

The stem diameter was measured in Vernia.Ten tagged plants were selected from each block and the stem diameter was measured.

3. **Number of branches**

Ten plants were selected randomly from medium furrow used to count the number of branches manually.

4. **Forage yield:**

Fresh forage yield was appraised by clipping three middle row- plants from each block and weighed then converted to yield kg/ fed. Fresh forage from each treatment was dried at 70 ºC to constant weight and dry forage yield (kg/fed) was determined.

5. **Water use efficiency (WUE):**

The amount of biomass produced per unit of water consumed; WUE values (kg/m³) of green and dry forage yield of Guar. It was calculated according to the following equation (Jensen, 1990).

WUE (kg/m³) = Green or dry forage yield (kg/ fed) / Seasonal applied water (m³ / fed) ……………………………………………………. (5)

Soil Physical Properties

a. Infiltration rate; Infiltration of water into the soil was determined under field conditions using the double ring infiltrometer as described by Michael (1978).

b. Soil moisture content; Moisture content was determined using the gravimetric technique (Michael, 1978). The moisture content on dry weight basis was calculated as follows:

$$M\% = \frac{W1 - W2}{W2 - W3} * 100 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (6)$$

M% = Soil moisture content by weight %.

W1 = Weight of the tin with wet samples (g).

W2 = Weight of the tin with dry samples (g).

W3 = Weight of empty tin (g).

c. Soil bulk density; Bulk density was calculated using the equation mentioned by Aamer (2002) as follows:

$$\text{Bulk density} = \frac{Drywt.ofthesoil}{Volumeofthecylinder} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (7)$$

d. Field capacity; Field capacity is the moisture content at the upper limit of the available water or drainage lower limit. It was determined by the method adopted by Cassel and Nielsen (1986).

$$Fc\% = \frac{W1 - W2}{W2} * 100 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (8)$$

Fc% = Field capacity %.

W1 = Mass of wet soil (g).

W2 = Mass of dry soil (g).

Data analyses:

A computer program software (SAS Package) was used to analyze the data, while the variations among the means was checked by the least significant difference (LSD).

3. RESULTS AND DISCUSSION

Irrigation Efficiency (IE) of Furrow System

The irrigation efficiency was low (45%) comparing with the furrow irrigation efficiency (60%) Merriam and Keller J (1978). The results indicated that, there is a huge amount of water lost in conveyance systems due to runoff, evaporation and deep percolation. Therefore, various management practices to enhance efficiency of applied water as well as the efficient use of water on field level, will lead to save water and can efficiently be utilized to bring the fallow land under cultivation as mentioned by Rajesh *et al.* (2015).

Crop water requirement of Guar

As shown in Table 1 Guar crop water requirement significantly difference among different months of growing season. This result may be due to climate variations which significantly affected the crop water requirement as stated by Adam (2014). Crop water Requirement (ETc mm/day or month) was affected by crop Kc and crop stage.

Table 1 Crop water requirement of Guar

Months	ETo (mm/day)	Kc	ETc (mm/day)	ETc(mm/month)
March	8.47	0.44	3.73	111.9
April	8.36	1.03	8.61	258.3
May	8.81	0.63	5.55	166.5

ETo = reference crop evapotranspiration, Kc = crop factor, ETc = crop evapotranspiration

Effect of furrow system and irrigation quantity on growth parameters:

Table 2 and Fig. 1 shows there were, significantly ($P \leq 0.05$) affected by the different irrigation quantity. The application of 500m^3 of water gave highest values of growth parameters as compared to other treatment, there were no significant differences in plant heights between 400$m^{3,}$ 300$m^3$and 200m^3, while there no significant differences between treatment in the stem diameter, ether in no of branches there is significant differences between 500m^3 and other treatment and between 400m^3 and 300m^3, 200m^3. The results agreed with result obtained by Kang, *et al.* (2002) who revealed that, water shortage during different crop stages and crop water requirements until harvest are significantly affected crop yield.

Table.2 Effect of furrow system and irrigation quantity on growth parameters

Treatments	Growth parameters		
	Plant height (cm)	Stem diameter (cm)	No of branches
500 m^3	31.54 [a]	5.27 [a]	13.60 [a]
400 m^3	29.51 [b]	5.05 [a]	13.12 [b]
300 m^3	29.26 [b]	4.90 [a]	12.69 [c]
200 m^3	28.11 [b]	4.83 [a]	12.66 [c]
LSD	1.7	1.3	0.4

Means followed by the same letter (s) in the same column are not significantly difference at $P \leq 0.05$

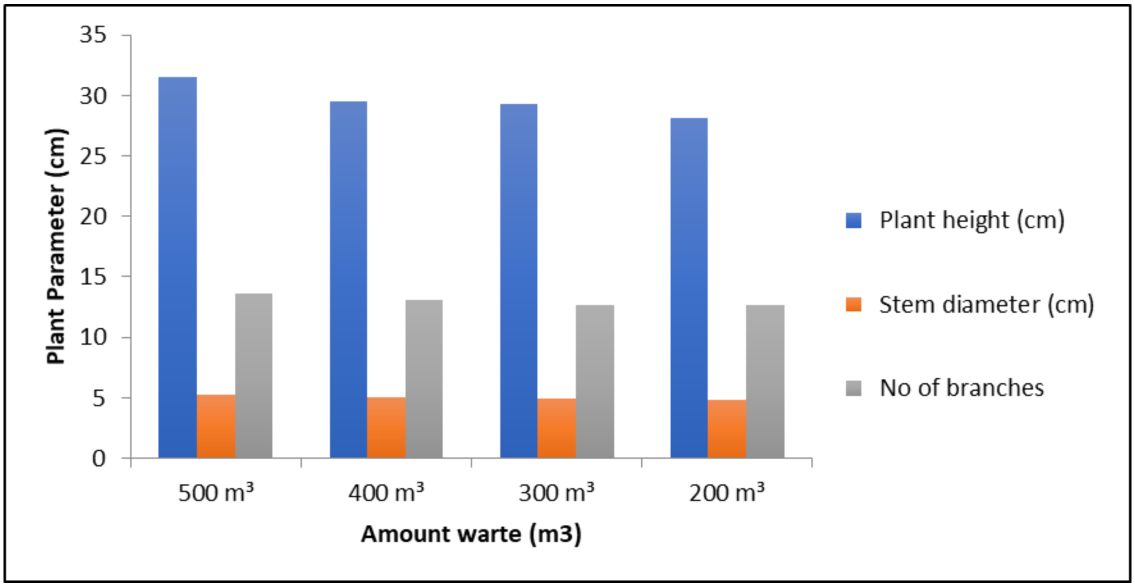

Fig. 1 Plant Growth Parameter (Plant height (cm), Stem diameter (cm) and Number of branches per plant as affected by irrigation water amount (m^3)

Effect of irrigation water amount on crop productivity (kg/ha) and water use efficiency (kg/m^3)

As shown in Table 3 and Figs. 2 and 3, crop productivity and water use efficiency significantly ($P \leq 0.05$) affected by the different irrigation water amount. Irrigation quantity of 500m^3 gave the highest value of crop productivity while the highest mean values of water use efficiency was recorded under the water applied of 200m^3. The lower water use efficiency may be due to some factors such genotype, management (soil, crop and water), local weather conditions of the irrigated schemes, available soil water and soil texture (Sadras and Rodriguez, 2007; Ben-Asher *et al.*, 2008; Ko and Piccinni, 2009; Katerji and Mastrorilli, 2009), The results were in conformity with the result obtained by Bush *et. al.* (2017) who reported that, low crop productivity in addition to high production costs, low prices, high taxes and low efficiency of irrigation system had all resulted in a general deterioration of the agricultural sector.

Table 3 Effect of irrigation water amount on crop productivity (kg/ha) and water use efficiency (kg/m^3)

Treatments	Crop productivity (kg/ha)	Water use efficiency (kg/ m^3)
500 m^3	2288^a	4.58^d
400 m^3	2179.5^b	5.45^c
300 m^3	1972^c	6.57^b
200 m^3	1844^d	9.22^a
LSD	53	1.20

Means followed by the same letter (s) in the same column are not significantly difference at $P \leq 0.05$

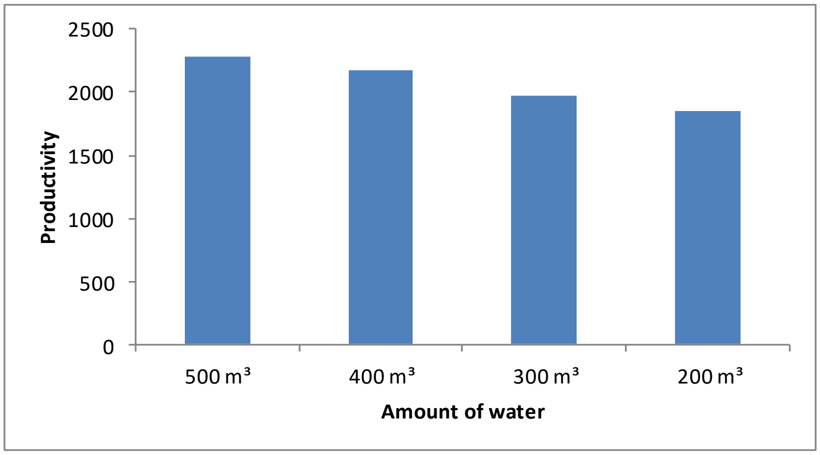

Fig. (2) Guar yield kg/ha under different water amount (m^3)

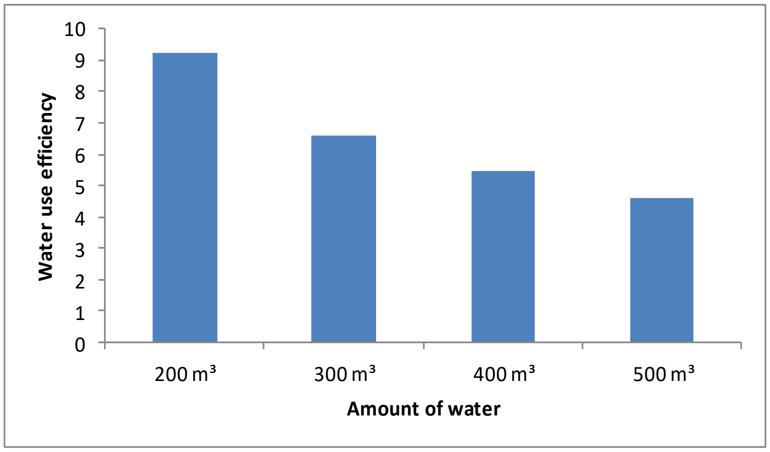

Fig. (3) Water use efficiency (kg/ m^3)

4. CONCLUSIONS

The results showed that the applying 500 m³ ETc amount of water gave the highest yield (kg/ha), the 500 m³ ETc amount of water recorded height plant parameters (plant height (cm), stem diameter (cm) and number of branches per plant) and the highest WUE was recorded when 200 m³ ETc amount of water was applied

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