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Correlation between Water Deficiency, Yield Components and Crop Productivity of Banana

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Abstract: Water is a limited factor that significantly influence productivity of banana and is needed to ensure optimum yield. Currently, Grand Nain is becoming a popular banana cultivar in Sudan, but the yields are low due to improper water management and agricultural practices. To investigate the effect of irrigation water quantity on the growth and yield of banana crop, a field experimental was conducted during the period of 2009-2010 on the eastern bank of the Nile River, 54 km of North Khartoum, Sudan. In the concerned experiment a randomized complete block design was used, where three different irrigation water quantities of 1.0 ET_c, 0.75 ET_c and 0.5 ET_c at an irrigation interval of two days using gated pipe (hydroflume). The results showed that the growth parameters, hydraulic performance, water use efficiency and the productivity were significantly response to the water quantities, where all parameters increased with increase of water amount. The highest values of above mentioned parameters were obtained by 1.0 ET_c followed by 0.75 ET_c and 0.5 ET_c respectively. Using hydroflume improved irrigation efficacies, also the production indicators showed that the banana crop agronomic parameters response negatively with water deficiency. To improve productivity of banana in Sudan, and other semi ecological areas, more attention should be given to research geared towards improved water and unlike environmental conditions stress management.

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1. Introduction

Surface irrigation is still undoubtedly the most important method of applying water to crop accounting for more than 95% of the 250 (million ha) of land irrigated worldwide, and this is likely to remain so for the fore-seeable future (Molden, 2007). Increasing irrigation efficiency is important in raising crop production because a larger area can be irrigated with the same amount of water (Paul, et al., 2013). Generally banana in arid and semiarid conditions such as Sudan is irrigated by surface irrigation, which requires more water and faces many problems. Semiarid areas are characterized by high evaporation so, the banana planted in such these areas are exposed to high water deficit due its shallow root system and high evapotranspiration. Hence and due to that bananas are thought to require an abundant and constant supply of water for optimal production (Van Asten et al., 2011). Consequently, to prevent reduction in productivity and fruit quality irrigation water demand will increase during dry periods (Goenaga and Irizarry, 1995).

Morphologically banana plant characterized by large shoot system i.e. broad leaves, these usually associated with high evapotranspiration rate. In addition to that banana has low potentiality to uptake water and nutrients from deep soils layers it shallow root system particularly, when there are water stress and conditions of high evaporation (Robinson and Villiers, 2007). Depending on prevailing climatic conditions management, irrigation interval and method of measurement evapotranspiration rates for banana could range from 1200 to 2690mm yr^{-1} (Robinson, 1996). Similarly, Stover and Simmonds (1987) reported that the amount of water that banana plants grown in a tropical environment needs per season is 900 to 1800mm. Anyway, water requirement of banana are met by effective rainfall and by supplemental irrigation. Further, banana plant show signs of water shortage before the wilting point is reached (Robinson, 1996). This is an indication that banana plant is high sensitive to drought stress and can strongly limit banana production in large parts of East Africa including Sudan. In Sudan the irrigated sector plays a very important role in the country's agricultural production. The hydroflume irrigation system was first introduced in a small scheme in Zaied Elkhair which is located on the eastern bank of the Blue Nile, Sudan (Dafalla, 2007). It lays under surface irrigation category, introduced to allow more uniform irrigation of many surface irrigated fields. With gated pipe, the water flows in each furrow can be less than with siphon tubes. Moreover, hydroflume allows for surface irrigation with conservation of water, reduced irrigation induced erosion, and lower leaching potential (Abdel and Adeeb, 2014). More durable plastic gated pipe was introduced and supported the growers for converted the water delivery systems from siphons off open ditches to gated pipe on approximately 25 000 ha of cropland. Hydroflume decreased water use by 35-40% (Clinton and Candace, 2012).

Banana belongs to the genus Musa of the family (*Musaceae* spp). Banana cv. Grand Nain is identified to be the major export variety worldwide and released in Sudan in 2001 (Ahmed et al., 2014). It's one of the most important fruit crop grown successfully in different parts of the Sudan and represents one of the most important cash crops (Ehassan et al., 2005). Areas under banana cultivation are now about 23000 hectares mainly used for local consumption (Bakhiet et al., 2011). Banana its nutritive value, low price and availability all year round, with an annual production approximately of 122.85 million-tones (Ravi et al, 2013). Besides its primary use as desert fruit and stable starch, banana provides various other products like vitamins, carbohydrates, fiber, wrappers and confectionery. Also, it functions as a medicine, keeps nervous system healthy, increases the production of red blood cells and regulates hormonal activities in the blood (Debabandya et al., 2010). In Sudan relatively a few researches has been implemented regarding banana plant to promote the traditional practices especially in the areas of fertilizer application, system of planting and irrigation programming which includes optimum irrigation water quantities and irrigation intervals. Therefore, this study was undertaken to investigate the effect of different water quantities i.e. different water levels on growth and yield of banana. Also it aims to evaluate the irrigation efficiencies of gate pipe irrigation system under semiarid conditions.

2. Materials and Methods

2.1 Study area and field conditions

Field experimental was conducted in North Khartoum state at the Wadramli Agricultural Project (late. 16º 11' N, long. 32° 58') during the winter growing seasons (2009-2010). The climate of the study area is semi-arid with relatively cool winters and hot summers with maximum temperature 38 °C and minimum of 20 °C, and average rain of 160 mm falling between June and September. The dominant soil type of the experimental site is clay with low percentage of organic matter Table 1.

Table 1. Physical soil characteristics of study area

Properties	Average
Sand %	12.5
Silt %	32.5
Clay %	55
Field capacity%	31.19
Bulk density	1.23 (gm cm^{-3})
Organic matter %	1.3
pH	7.4

The experimental soil was prepared by deep plough to 0.5 m followed a second deep plough to 0.3 m, harrowing, leveler and ridging for irrigation system. The study area is 2.3 ha was divided into three blocks planted with banana (Grand Nain, was imported from South Africa where it was produced from tissue culture under controlled conditions) with natural slope and spacing of 3 m between the rows and 1 m between plants. The furrows were 84 m in length and spacing of 0.25 m. The experiment was organized in a randomized complete block design where three water quantities were used 1.0 ET_c, 0.75 ET_c and 0.5 ET_c as designed.

2.2 Determination of infiltration rate and soil moisture

Soil infiltration rate was measured by using the double ring infiltrometer as described by Michael, (1978) to determine the infiltration rate (mm h^{-1}) and accumulated infiltration (mm) of the soil. The soil samples were taken at 0.2 m increments from the soil surface to a depth of 0.8 m to determine soil moisture content.

2.3 System design, calibration and operation

The gated pipe irrigation system (Hydroflume) employed includes discharge valve, joiner, clamps, end clamp, outlets, punch, and riser, two brick basins were constructed with the dimensions of 0.85 m width, 120 m length and 0.75 m height. An outflow pipe was fixed at the bottom of the basin. The hydroflume was clamped to the outflow pipe to supply water to the furrows. A two inch centrifugal pump was used to draw water from irrigation ditch into the basin. The system was operated when the water level in the basin reached 0.75 m. The outlets were calibrated in situ to estimate their discharge per unit time and to select the suitable irrigation stream size.

$$Q = \frac{v}{t} \quad [1]$$

Where:

Q= Discharge (mm/sec); v =Volume of water (lit); t = Time required to fill the bucket (sec).

The depth of irrigation water applied was calculated using the following equation:

$$d = \frac{Q \times t \times 60}{1000 \times w \times l} \times 100 \quad [2]$$

Where:

d = depth of water applied in irrigation (cm); Q =stream size (mm\sec); t = irrigation period (advance time, min); w = furrow width (m); l = furrow length (m).

2.4 Measurement of the system parameters

To evaluate the irrigation efficiencies in surface irrigation, the experimental procedure was three uniform furrows with 0.3 m spacing and 84 m length were chosen. Stakes were set at 10 m spacing along the furrows. Streams were adjusted to give 1.0 ET_c, 0.75 ET_c and 0.50 ET_c into each furrow using three outlet sizes of the gated pipe (hydroflume). Water application efficiency (Ea %) for an irrigated area is the ratio expressed in percent, of depth of water stored in root zone to the water applied during irrigation. Ea % was calculated using the equation stated by Merriam et al., (1980).

$$Ea = \frac{ws}{wf} \times 100 \quad [3]$$

Where Ea% = water application efficiency in percentage; ws = the average depth of water stored in the root zone; wf = the average depth of water diverted to the field.

Storage efficiency (Es %) was determined using the following equation (Michael, 1978):

$$Es = \frac{ws}{wn} \times 100 \quad [4]$$

Where Es% = water storage efficiency in percentage; ws= water stored in root- zone during the irrigation; wn= water needed in the root zone during the irrigation.

Distribution efficiency (Ed %) expresses the extent to which water was uniformly distributed along the run. The distribution efficiency was calculated by the mean at 10, 40 and 70 m from the upper end of the furrow using the following equation (Ronald and Marlow, 1999):

$$Ed\% = 1 - \frac{y}{d} \times 100 \quad [5]$$

Where Ed% = water distribution efficiency in percentage; d = Average depth of water stored along the run during the irrigation; y = Average numerical deviation from (d).

2.5 Crop water requirement (CWR)

Metrological data were collected from Sudan metrological authority were presented in Table 2. Crop water requirement was calculated using the following formula (Allen et al., 1998):

$$ET_c = ET_o \times Kc \quad [6]$$

Where ET_c = Crop water requirement (mm/day); ET_o = Reference crop evapotranspiration (mm/day); Kc = Crop coefficient.

Data on the net crop water requirement (NCWR) was calculated by subtracting the monthly effective rainfall (ERF) from crop water requirement (CWR) as follows:

$$NCWR = CWR - ERF \quad [7]$$

The effective monthly rainfall (ERF mm) was calculated from the total rainfall (TRF mm) according to the USDA soil conservation service (Doorenbos and Kassam, 1986).

2.6 Plant growth parameters, yield and water use efficiency

Eight weeks after planting data collection started and continued on monthly basis for nine months, thirteen plants from each plot were randomly selected for plant height (cm) the measurement was taken monthly; the same samples were also used for the determination stem diameter (cm) and number of leaves per plant. Data on amount of irrigation water used $m^3\ ha^{-1}$, yield kg ha^{-1} and water use efficiency (WUE) (Eq.8) for the banana crop were also determined.

$$WUE = \frac{\text{Yield (kg ha}^{-1})}{\text{Amount of water used (m}^3\text{ha}^{-1})} \quad [8]$$

Where: WUE: water use efficiency kg m^{-3}.

2.7 Statistical analysis

The data obtained from different experiments were recorded as mean ± standard deviation (SD) and subjected to two-way analysis of variance (ANOVA) using SPSS software. Differences between means were considered significant at $P < 0.05$.

3. Results and discussion

3.1 Infiltration rate and soil moisture content

The infiltration rate (mm h^{-1}) and the accumulative infiltration values (mm) were presented in Fig 1 which show the best fitted curves for the mean values. The soil for the area under study which characterize by clay silt loam showed a high initial infiltration rate of 25 mm h^{-1} during the first five minutes of elapse time and a low final infiltration rate of 4.8 mm h^{-1}. The high initial infiltration rate was essentially due to the extensive soil cracking as mentioned by Michael, (1978) and the low rates can be attributed to the swelling of the soil after wetting. Additionally, these results and according to the field observations may be refer to the percentage of sand, silt, and clay which is the major inherent factor affecting infiltration. Water moves more quickly through large pores of sandy soil than it does through small pores of clayey soil, especially if clay is compacted and has little or no structure or aggregation.

Depending on the amount and type of clay minerals, some clayey soils develop shrinkage cracks as they dry. The cracks are direct conduits for water entering the soil, causing clayey soils to have high infiltration rates under dry conditions. Where cracks do not occur, clayey soils have slow infiltration rates. These results supported by Michael, (1978) and Bautista, (2009) who indicated that, the mean values best represent the soil infiltration in the evaluation of furrow. The sensitivity of banana to variations in soil moisture can be seen from the data in Fig. 2 which shows soil moisture content as affected by the hydroflume system from the upper end of the furrow and different water quantities.

On the other hand, the results obtained revealed significant differences ($P < 0.05$) in soil moisture reserves under treatment with different soil depth and different water quantities. While, 1.0 ETc produced higher moisture content than the other treatments, followed by 0.75 ET_c and 0.50 ET_c. Furthermore, 1.0 ET_c provided more moisture at upper layers (0.0 -0.2 m) immediately above the furrow, which was reflected by the good crop performance and yield. Soil moisture measurement at three points in the furrow showed that the soil moisture levels were generally high at the upper head of the furrow than at the tail end. These results can be attributed to the good control of the irrigation water by the gated pipe system. Different locations along the furrow gave different soil moisture content at 0.2 m to depth of 0.8 m. The results are expressed as a ratio of the mass of water lost to the mass of dry soil. These results agreed with previous results obtained by Abdel and Adeeb, (2014), who found that, due to the continuous wetting effect of irrigation, higher percentage of the volumetric moisture content accumulated at the top layers of the soil.

3.2 Irrigation efficiencies

Irrigation efficiencies are affected by the different quantities of water as shown in Fig. 3. The highest application efficiency (Ea %) of 80% was recorded when using 1.0 ET_c and the lowest Ea % of 70% was recorded under 0.50 ET_c. Whereas, the highest distribution efficiency (Ed %) of 85% was obtained from 1.0 ET_c whilst the lowest Ed% of 78% was obtained from 0.50 ET_c (Fig. 3).

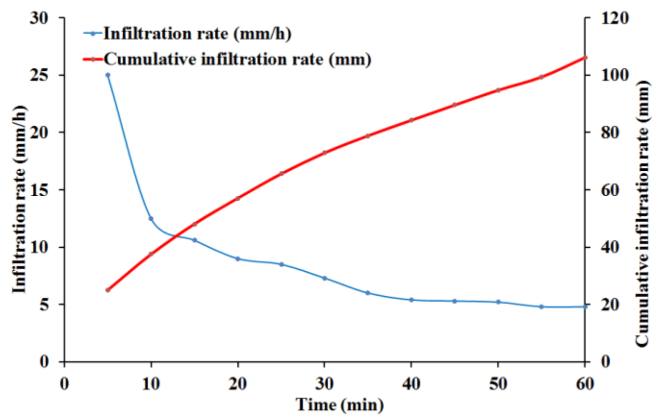

Fig. 1: Infiltration rate (mm h^{-1}) and accumulative (mm) for the experimental area.

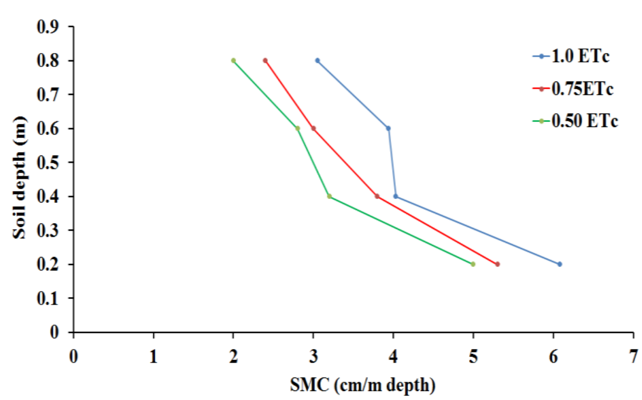

Fig. 2: Soil Moisture content (cm/m depth) for the different water quantities.

These results of 1.0 ET_c may be due to the acceleration of the advance of the flow. On the other hand, low efficiency may be attributed to fact that 0.50 ET_c was fell below to the recommended values. Also may be refer to the some factors affecting scheduling uniformity such uncompleted maintenance of gated pipe and the overall management of the irrigation system.

These results were in line with Asough and Kiker, (2002); Hassan and Omran, (2012) who stated that, the dryness of the soil; the percolation through the cracks and deep percolation of irrigation water below the root zone in the first irrigation affected application efficiencies. Abdeen, (1999) stated that the Ea decreased as the furrow length increased. These results also confirmed by Walters and Boss, (1989), when reporting on small scale irrigation development, that with good care, Ed of 90 % can be reached. Abdel and Adeeb, (2014), stated that the gated pipe provides more uniform water distribution along the irrigated furrows and has a high value of application efficiency (79% - 88%).

Regarding to results of storage efficiency (Es %), the highest values were obtained by 1.0 ET_c followed by 0.75 ET_c, respectively. While 0.50 ET_c was ranked the last Fig. 3. These results might be due to the long period left for the water to infiltrate into the soil after the flow. Often high water application efficiency indicates that water storage efficiency may be the most important index for better irrigation practice (Amir et al., 2015).

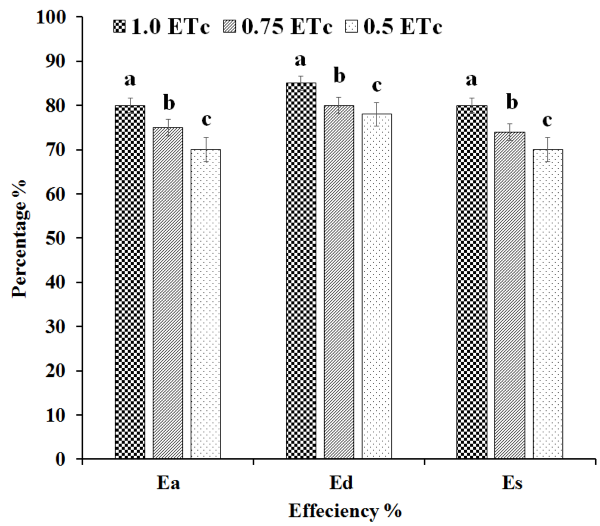

Fig. 3: Irrigation efficiencies for the different water quantities, Ea%: application efficiencies; Ed%: distribution efficiency; Es%: storage efficiency.

3.3 Crop water requirement (CWR)

Table 2 shows the climatic data and the reference evapotranspiration (ET_o). The mean monthly reference crop evapotranspiration for the thirteen months (December 2008, to December 2009) was found to be 8.85 mm day^{-1}. Table 3 shows the calculated banana water requirement for those months which represents the length of its growing season.

Table 2. Mean monthly climatic data and reference crop evapotranspiration (2009-2010)

Month	Temperature °C		Relative humidity (%)	Wind speed (m/h)	Sunshine hours	ET_o mm/day
	T max	Tmin				
Dec.	32.4	18.3	32	6.90	9.8	6.8
Jan.	31.5	14.8	32	8.45	10.2	6.6
Feb.	34.1	17.9	27	8.06	9.6	9.1
Mar.	35.6	17.9	17	5.90	10.0	12.5
Apr.	42.1	32.0	16	7.70	9.9	13.4
May	41.0	26.0	19	8.83	8.6	13.9
Jun.	24.9	27.8	25	8.50	7.8	13.0
Jul.	38.8	26.6	43	10.11	6.0	13.0
Aug.	38.8	28.5	37	10.02	7.8	9.5
Sept.	40.9	27.2	39	8.39	10.3	8.0
Oct.	38.5	23.8	30	8.39	9.4	8.6
Nov.	33.3	20.5	32	6.42	9.0	8.4
Dec.	31.3	15.0	29	9.42	6.9	5.9
Mean	35.6	22.4	29	8.19	9.0	9.8

T max: Daily maximum temperature (°C); T min: Daily minimum temperature (°C); ET_o: reference crop evapotranspiration (mm day^{-1}).

Table 3. Banana crop water requirement (2009-2010)

Month	ET_o (mm day^{-1})	K_c	ET_c (mm day^{-1})	ET_c (mm month $^{-1}$)
Dec.	6.8	1.5	10.2	306
Jan.	6.6	1.2	7.92	237.6
Feb.	9.1	1.0	9.10	273
Mar.	12.5	0.65	8.13	244
Apr.	13.4	0.6	8.04	241.2
May	13.9	0.55	7.65	229.5
Jun.	13.0	0.6	7.80	234
Jul.	13.0	0.7	9.10	273
Aug.	9.5	0.95	9.02	270.6
Sept.	8.0	0.85	6.80	204
Oct.	8.6	1.0	8.60	258
Nov.	8.4	1.0	12.6	278
Dec.	5.9	1.0	5.90	177
Mean	9.8	0.93	8.85	265

ET_o: reference crop evapotranspiration (mm day^{-1}); K_c crop coefficient (dimensionless): ET_c: crop evapotranspiration (mm d^{-1}).

It was found that the mean banana water requirement (ET_c) was 9.8 mm day^{-1} which started with low value during the initial stage and then increased to a peak in June. Haijun et al., (2015), stated that the Banana evapotranspiration rates can range from 1200to 3000 mm/year, also, yield potential in banana which depending on climate and management, resulting in increased photosynthetic capacity and efficiency. Similar findings on banana water requirement were obtained by other researchers (Ahmed et al., 2014; Haijun et al., 2015). Fathia, (1999) found the highest growth and yield of banana crop was obtained with water quantity of 2100 mm/season at intervals 5-7 days.

Table 4 shows the mean monthly data of the total rainfall, the mean monthly effective rainfall and the net banana water requirement, these results in line with findings of Allen et al., (1998).

3.4 Banana performance under the different water quantities

The results showed that there were significant differences ($P \leq 0.05$) in banana growth parameters under the different treatments of water quantities. Increase in plant height during the first months, but later the differences became greater with time showed in Fig. 4. Plant height increased with increasing amount of water applied and to a lesser plant. Amount of water applied with 1.0 ET_c, gave higher plant height (137 cm) followed by 0.75 ET_c (115 cm); while 0.5 ET_c gave the lowest plant height (97.5cm). These results may be attributed to the fact that soil moisture stored was presumably adequate for young banana plants with limited demand for moisture. The sensitivity of banana to small reduction in soil moisture status lead to fact that water is single factor affecting the growth and development of the crop (Turner et al., 2007).

Robinson, (1996) summarizes that considering the high sensitivity of banana to soil water deficit proper irrigation scheduling is the best strategy. In addition to the large amount of water that is needed for high production. Moreover, this could be explained by 1.0 ET_c was adequate, and might have led to more cell elongation and division in the stalk. On the other hand, the reduction in plant height may refer to the lesser the amount of water applied, the rapid is the attainment of maturity.

Table 4. Net crop water requirement (NCWR) of Banana crop (2009- 2010)

Month	ET_c (mm month^{-1})	TRF (mm)	ERF (mm)	NCWR (mm month^{-1})	NCWR (m^3 ha^{-1}month^{-1})
Dec.	306	0	0	306	3060
Jan.	237.6	0	0	237.6	2376
Feb.	273	0	0	273	2730
Mar.	244	0	0	244	2440
Apr.	241.2	0	0	241.2	2412
May	229.5	0	0	229.5	2295
Jun.	234	0	0	234	2340
Jul.	273	8	3.4	269.6	2696
Aug.	270.6	6.2	2.5	268.1	2681
Sept.	204	0	0	204	2040
Oct.	258	0	0	258	2580
Nov.	278	0	0	278	2780
Dec.	177	0	0	177	1770
Mean	265	1.18	0.49	265	2650

ET_c: crop evapotranspiration (mm d^{-1}), TRF: total rainfall (mm month^{-1}); ERF: mean monthly effective rainfall (mm); NCWR: net crop water requirement for Banana crop (mm month^{-1}).

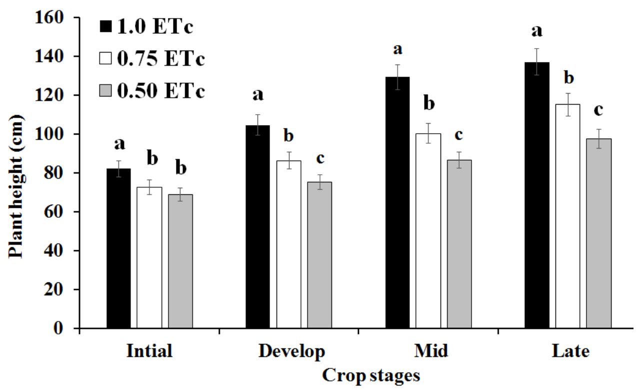

Fig. 4: Effect of different water quantities on plant height (cm).

Burham, (1999) obtained similar results as higher banana plant was recorded (127.33 cm) while, the lowest height was recorded (65.78 cm) in an experiment conducted at Kenana Sugar Scheme, Sudan.

Data concerning stem diameter of the banana plant are shown in Fig. 5. The higher diameter values were obtained by 1.0 ET_c (15 cm), followed by 0.75 ET_c (13.7 cm) and 0.5 ET_c (12.0 cm). Stem diameter in the experiment reached the maximum at the late stage for 1.0 ET_c, 0.75 ET_c and 0.5 ET_c respectively and significantly affected by the amount of water in the first stages of initial to development stages. However, towards later months of mid and late stages, stem diameter reached maximum size. This could be explained by the fact that under 1.0 ET_c treatment much water was applied, which may have led to more cell elongation and division increasing stem thickness, and it response to increase amounts of irrigation water. Similar result were obtain by Goenaga and Irizarry, (1995), who stated that increasing the amount of irrigation resulted in an increased stem diameter. These results are supported by the findings of Elhaj, (1983) in an experiment conducted at Kassala area, Sudan.

The effect of water quantities on number of leaves per plant are given in Fig. 6. Leaves production increased significantly with increasing water quantity; and the values of 10 and 11 leaves per plant were obtained by 0.75 ET_c and 0.5 ET_c, respectively, while 1.0 ET_c produced 14 leaves per plant. Results obtained by Robinson et al. (1992) showed that retention of eight leaves at flowering is sufficient to avoid significant reductions in yield and fruit size.

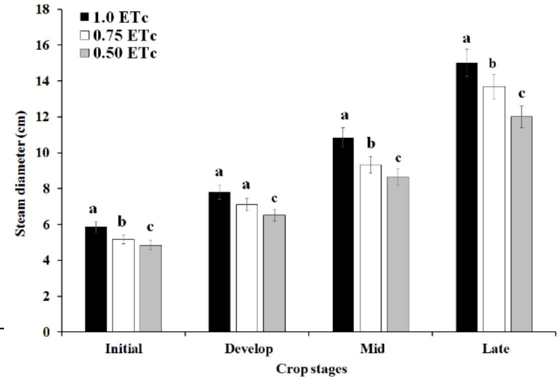

Fig. 5: Effect of different water quantities on steam diameter (cm).

It has been reported by Turner et al., (2007) that soil moisture together with climate factors, such as temperature, wind and relative humidity are significantly correlated to the expanding tissues such as emerging leaves and rate of leaf production. Also, Karam et al., (2002) reported that water stress caused by the deficit irrigation significantly reduced the rate of cell expansion and a decrease the number of leaf.

However, no significant differences were observed between treatments with respect to the rate of leaf production. This may be due to the soil moisture from the pre differential period and the early flowering. On the other hand, the decrease in production of leaves may be due to soil moisture stress after bunch emergence leading to the increase of the rate of senescence.

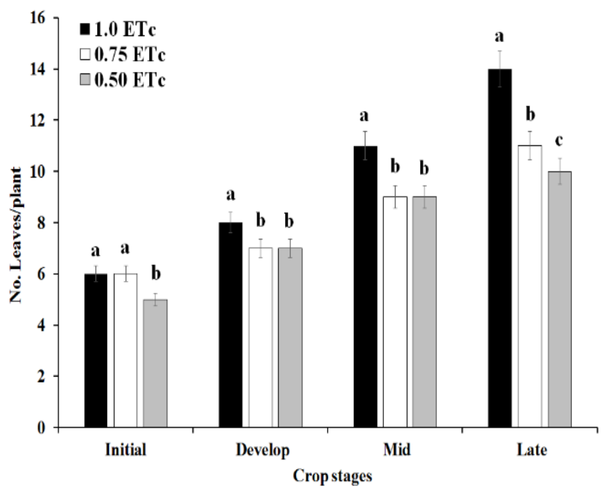

Fig. 6: Effect of different water quantities on number of leaves per plant.

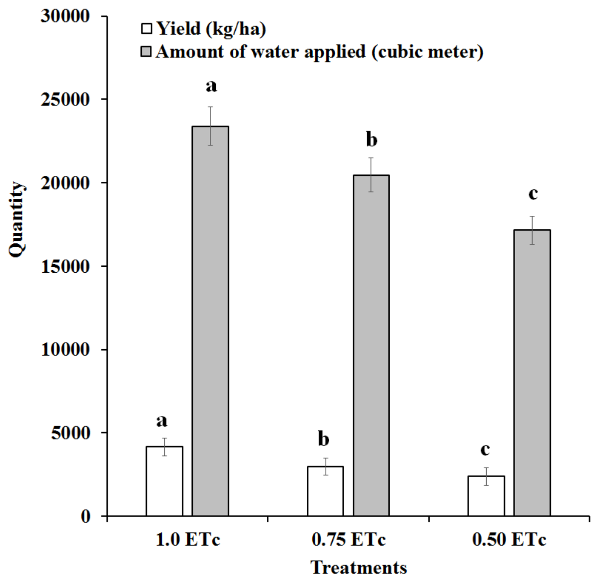

Fig. 7. Mean total yield of Banana crop (kg ha^{-1}).

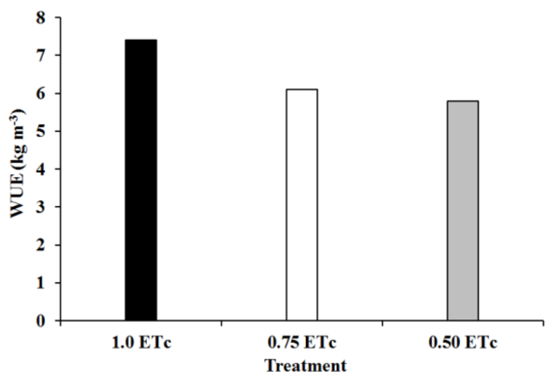

Fig. 8. Water use efficiency (WUE) (kg m^{-3}).

Burham, (1999); Al-Harthi and Al-Yahyai, (2009) found high number of leaves per plant of 11.5, while the lowest number of leaves per plant were 7.6. Turner et al., (2007) concluded that the number of leaves per plant tended to decrease in response to water deficit, especially since waters is involved in the unfolding of new leaves.

3.5 Banana productivity (kg ha^{-1})

The total yield of banana crop was highly affected with water quantities as presented in Fig. 7. Whereas, the greatest response to irrigation was recorded in the 1.0 ETc, which produced an maximum yield of 4167 kg ha^{-1} using 23400 m^3 of water . Whereas, 0.75 ET_c and 0.5 ET_c gave low yield 2976 and 2381 kg ha^{-1}, respectively. This reflected in terms of higher weight of bananas. The results also showed that higher values of yield were recorded in first, second and third harvests, respectively. The yield difference between the watering quantities and banana crop water requirement could be explained by the fact that crop evapotranspiration is a function of the crop coefficient, which varies with crop growth habit.

Furthermore, the reduction in the yield could possibly be due to poor aeration of the soil in the experimental site. Lowest yield also, may refer to decreasing the water requirement (0.5 ET_c) which reduced bunch mass by inducing fewer hands and fingers. Moreover stress after bunch emergence was found to delay fruit filling and reduce finger size. Obviously higher quantity of irrigation water application produced the highest banana yield. This indicates that increasing rates of irrigation according to the crops water requirement could increase yield.

These results illustrated by Goenaga and Irizarry, (2000), who confirm that a banana plantation requires large quantities of water for maximum productivity. Opfergelt et al., (2006); Carr, (2009) emphasized that water is the most important factor affecting growth and development of crop banana production. The results obtained are in agreement with the findings of Burham, (1999) who concluded that banana production is positively correlated with the quantity of water applied.

3.6 Water applied and water use efficiency

Fig. 8 represents water quantities applied as volume by hydroflume which were 23400, 20466 and 17150 m^3 indicate 1.0 ET_c, 0.75 ET_c and 0.50 ET_c. These different quantities directly affect the WUE through their effect on productivity. Thus, WUE associated with amount of water quantities applied and crop yield. So, high WUE 7.4 kg m^{-3} was recorded by 1.0 ET_c while 0.5 ET_c ranked the last. These results illustrate the fact that WUE is the relationship between unit produced and depth of irrigation water applied which also indicated that the highest yield indicated the highest WUE. Thus, 1.0 ET_c generally have high water use efficiency value. The results illustrated by Katerji and Mastrorilli, (2009) who reported that, water use efficiency of crops is affected greatly by irrigation management.

4. Conclusion

Differential application of water quantities exerted a significant influence on growth of banana as measured by plant height, stem diameter and production of leaves. These attributes of growth responded positively to different water application. High water application quantity with two days intervals gave more susceptibility vigorous growth. Results obtained showed that 1.0 ET_c, with the two days irrigation interval scored the best growth rate and final yield. In contrast, the use of 0.5 ET_c was resulted in significant reductions. However, 0.75 ET_c was recorded reasonable values in growth and yield. Thus, it can be use particularly in arid and semi-arid conditions where the conditions do not suitable for 1.0 ET_c. With respect to irrigation scheduling an accurate estimation of the water consumption will be indispensable. Since efficient water utilization is of vital importance in the improvement of banana production in Sudan, as farmers lack the scientific knowledge of how much water to apply.

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Competing Interests

Authors declare that they have no competing interests.

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