PJ PALGO JOURNAL OF AGRICULTURE
ISSN 2476-8359
Volume 3 Issue 6,December 2016.Page 207-211
http://www.palgojournals.org/PJA/Index.htm
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# WATER PRODUCTIVITY OF TOMATO (*Lycopersicon esculentum*) UNDER SUDAN DRY LAND CONDITIONS

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**Accepted 11 December, 2016**

This study was carried out to determine water productivity of tomato (Lycopersicon esculentum) under south Darfur State (Nyala) conditions located at longitude 24o 53′E , latitude 12o 3′N and altitude 674 amsl, during the winter season 2013/014 in an area of 0.42ha. Meteorological data such as rainfall, temperature, humidity, wind speed and sunshine hours were obtained from local meteorological station and used to determine the irrigation requirement through CROPWAT model using Penman Monteith equation for producing tomato. Two irrigation systems (drip and furrow) were used to apply full crop water requirement (100% ETc). Water distribution uniformity (Du%), application efficiency (Ea%) and water productivity (kg/m3) were determined from field data collected during the study period. SAS statistical package was used to analyze the data. The variations among the means were checked by the least significant difference (LSD). The results showed that, water productivity significantly ($P \leq 0.05$) affected by water distribution uniformity and application efficiency. The highest water productivity (20.5 kg/m3) was obtained under drip irrigation system, while the lowest mean values (9.2kg/m3) was recorded in furrow irrigation system.
It is concluded that water productivity can be maximized by the following proper technical guidelines for system management, operation and scheduling.

**KEYWORDS**: Water productivity; Tomato; Drip irrigation system

## 1. INTRODUCTION

With growing water scarcity and increasing competition among water using sectors, innovations are needed to increase irrigation water productivity and to provide water savings (Mohammed and Saleh, 2011). Micro Irrigation systems are excellent management tool to meet the increasing demand of water for food production and sustainability of the agricultural sector. Drip irrigation system can play a significant role in overcoming the scarcity of water mostly in water shortage areas to uniformly distribute water in agricultural fields especially where water is limited (Megersa and Abdulahi, 2015). The optimum use of irrigation water is a fundamental aspect to reach a sustainable agriculture (Ortega, 2002). Drip irrigation system is widely recognized as potentially one of the most efficient irrigation methods. However, potential efficiency is often not achieved mainly due to issues related to design or maintenance of drip irrigation. Poor technical skills of farmers to assess the crop water requirements and to monitor the soil moisture conditions in the field are also limiting factors to wide adaptability of drip irrigation (Darouich et al., 2014). Non-uniformity in drip irrigation system potentially due to pressure differences, unequal drainage and unequal application rate also hinder to achieve full efficiency of system (Bush et al., 2016). The causes of non-uniformity include unequal drainage and unequal application rates. Application uniformity may be directly related to yield (Burt, 2004).
Tomato (Solanum lycopersicon L.) is one of the most widely grown vegetables in the world (Alomran, et al., 2012). Different irrigation techniques are available to irrigate crops, but not all of them are suitable for irrigation of tomato. If water can be applied efficiently in an irrigated field, water is saved and both crop quantity and quality are increased. The drip irrigation is one of the most efficient irrigation systems that are used to irrigate tomato. Abdelgawad et al. (2005) reported that water productivity was higher with drip irrigation over traditional methods. In Sudan the total area under irrigation which is almost entirely under surface methods is estimated to be about two million hectares while area under drip irrigation system is estimated to be about 13000 hectares less than 1% mainly in the Northern, River Nile and

Khartoum states. Taking into consideration that there is little information regarding the operation and management of the drip system in Sudan and the limited scope under which these systems are used now. Irrigation water management involves the managed allocation of water and related inputs in irrigated crop production, such as economic returns which are enhanced relative to available water. Irrigation water is managed to conserve water supplies, reduce water-quality impacts and improve producer net returns. Producers may reduce water use per hectare by applying less than full crop-consumptive requirements (deficit irrigation), shifting to alternative crops or high yield varieties of the same crop that use less water, or adopting more efficient irrigation technologies (Virupakshagowda et al., 2014). Water productivity significantly affected by the climate change especially in arid and semi-arid regions (Adam, 2014). The changes in cultural practices and crop rotations increase the water productivity effectively. Garcia et al. (2009) revealed that, water productivity is influenced by management practices, location of the farm, local weather conditions of the irrigated schemes, soil texture, water applied, distance of water resource from farm, water logging, timeliness of planting date, planting depth, quality of tillage practices, new seed varieties, applied fertilizers, experience of farmers and extension services which affect plant growth and development and ultimately yield. Low water productivity is normally associated with poor timing and a lack of uniformity in water applications, which leaves parts of the field over or under irrigated relative to crop needs (Shajari et. al., 2008). Water productivity in addition to high production costs, low prices and high taxes had all resulted in a general deterioration of the agricultural sector. This has contributed in converting agriculture from an attractive business to a repellent activity and caused many farmers to abandon agriculture and migrate to cities. Low water productivity of tomato is one of the major problems that are facing agricultural production in the Sudan and the quantity of irrigation water applied depends on the farmer’s judgment and the plantations either receive irrigation water in excess or less than required (Bush and Mohamed 2016). Hence, studies on water productivity and management of water application methods for tomato are highly needed. Therefore the objective of this study was to investigate water productivity of tomato (Lycopersicon esculentum) under Southern Darfur State (Nyala) conditions, Sudan.

## 2. MATERIALS AND METHODS

### 2.1Experimental area

The experimental work was carried out to determine water productivity of tomato (Lycopersicon esculentum) under south Darfur State (Nyala) conditions located at longitude 24o 53′E , latitude 12o 3′N and altitude 674 amsl, during the winter season 2013/014 in an area of 0.42ha. Meteorological data such as rainfall, temperature, humidity, wind speed and sunshine hours were obtained from local meteorological station and used to determine the irrigation requirement through CROPWAT model using Penman Monteith equation for producing tomato. Two irrigation systems (drip and furrow) were used to apply full crop water requirement (100% ETc). During study period limited annual rainfall was recorded with short intense thunder storms. The mean annual rainfall is about 500mm. This means that water is deficient and crop production must be based on irrigation.

### 2.2 Description of drip irrigation system

Drip irrigation system consisted of a head control unit, filter, pressure gauges, fertilizer injector, pressure regulators and polyvinyl chloride (PVC) distribution network. The distribution network consisted of a main line (16 cm diameter), sub main (6 cm diameter) and 20 laterals per sub main (2.5 cm diameter). Turbo pressure compensating emitter was installed in the laterals.

### 2.3 Parameters for Emitters Evaluation

Following parameters were used to evaluate drip irrigation system:

#### 2.3.1 Uniformity of water application (CU%)

Christiansen’s (CU %) valuates the mean deviation, which is presented in ASAE Standards (2008) as follows:

$$CU\ \% = 100\left[1-\frac{1}{n\,q_a}\sum_{i=1}^{n}|q_i-q_a|\right] \quad \ldots\ldots (1)$$

Where:

qa = the average emitter discharge rate (m3/h).

qi = the flow rate of the emitter (m3/h).

#### 2.3.2 Distribution uniformity (DU %)

Low quarter distribution uniformity DU% (Merriam and Keller, 1978) as applied to all types of irrigation systems can be expressed as follows:

$DU=100q_m/q_a$ ……………………………………………………..……...(2)
Where:
qm = the average flow rate of the emitters in the lowest quarter(m3/h).
qa = the average emitter discharge rate (m3/h).

### 2.3.3 Scheduling uniformity (SU)

$SU=1/DU$ ……………………………………………………………….. (3)
Where:
DU= Distribution uniformity (decimal).

### 2.3.4 The coefficient of variation of emitter flow (CV%)

The coefficient of variation of emitter flow (CV%) evaluates the variability of flow and was computed by dividing the standard deviation by the average emitter discharge rate. Manufacturers usually publish the coefficient of variation for each of their products and the system designer must consider this source of variability (ASAE, 2008). CV can be expressed as:

$CV=S_q/q_a$ …………………………………………………………... (4)
Where:
CV = the coefficient of variation of emitter flow.
Sq = the standard deviation of emitter flow rate.
qa = the average emitter discharge rate (m3/s).
$S_q=\sqrt{1/(n-1)}\sum_{i=1}^{n}(q_i-q_a)$ …………………………………………......... (5)

### 2.4 Crop water requirement of Tomato (Lycopersicon esculentum)

Estimation of alfalfa water requirement (ETc) is derived from crop evapotranspiration (crop water use) which is the product of the reference evapotranspiration (ETo) and the crop coefficient (Kc). The reference evapotranspiration was estimated based on the FAO Penman-Monteith equation, using climatic data (Hanson and May, 2004) as follows:
ETc = ETo*Kc…………………………………………………….. (6)
Where:
ETc = Crop evapotranspiraion (mm/day).
ETo = Reference evapotranspiration (mm/day).
Kc = Crop Coefficient (dimensionless).

### 2.5 Water measurement

The amounts of irrigation water were measured by flow meters, which were fixed in the main line to read the cumulative amount of water before and after each irrigation event.

### 2.6 Measurement of rainfall

Daily rainfall is measured using the standard ordinary rain gauge exposed 1 m above level ground away from buildings and trees. The diameter of the standard gauge is 5 inches (12.7 cm). There is a measuring Jar calibrated to read the rainfall in mm this Jar should only be used with 5in diameter rain gage. A recording rain gauge is used to give a continuous record of rainfall to type of rain gauges is very important because it gives the intensity of rainfall (Adam, 2014).

### 2.6.1 Effective rainfall

Effective rainfall is defined as the fraction of rainfall that is effectively intercepted by the vegetation or stored in root zone and used by the plant – soil system for evapotranspiration. It can be estimated by the following equation mentioned by Adam (2014):
Pef = E. Ptot + A …………………………………………………… (7)
Where:
Pef = Effective rainfall over the growing season.

E = Ratio of consumptive use of water (cubic) to Ptot.65.
Ptot = Total rainfall over the growing season.
A = Average irrigation application.

### 2.7 Water productivity (kg/m3)

Water productivity (WP) was determined from field data collected during the study period. According to Virupakshagowda et. al. (2014) irrigation water productivity (kg/ m3) was determined by dividing yield (kg/ha) to the consumptive use (m3/ha).
Water productivity (kg/m3) = yield (kg/ha)/consumptive use (m3/ha) ………….. (8)

### 2.8 Data analysis

A computer program (SAS statistical package) was used to analyze the data. The variations among means were checked by the least significant difference (LSD).

## 3. RESULTS AND DISCUSSION

### 3.1 Effect of irrigation water management on the hydraulic performance

As shown in Table 1. the hydraulic performance were significantly (P ≤ 0.05) affected by the management of irrigation system. In drip irrigation system, proper technical guidelines for system management, operation and scheduling were developed and followed. The highest values of system performance were recorded in drip irrigation system as compared to furrow irrigation system. The superiority of drip irrigation over furrow irrigation system may be attributed to the fact that, drip irrigation system applied the required amount of water with high efficiency. Non-uniformity in irrigation system potentially due to pressure differences, unequal drainage and unequal application rate also hinder to achieve full efficiency of system (Bush et al., 2016).

### 3.2 Effect of irrigation systems on water productivity (kg/m3)

Water productivity significantly (P ≤ 0.05) affected by two irrigation systems and irrigation management (Table 1 and Fig. 1). Drip irrigation system recorded the highest mean values of water productivity, while furrow irrigation system ranked the least. Due to their high efficiency and good management, drip irrigation system provided the crop with adequate water requirement at the root zone as compared to furrow irrigation. The results agreed with the results obtained by Garcia et al. (2009) and Adam (2014) who revealed that, water productivity is influenced by management practices, irrigation systems, location of the farm, local weather conditions of the irrigated schemes, soil texture, water applied, distance of water resource from farm, water logging, timeliness of planting date, planting depth, quality of tillage practices, new seed varieties, applied fertilizers, experience of farmers and extension services which affect plant growth and development and ultimately yield.

**Table 1.** Effect of irrigation water management the hydraulic performance

| Irrigation system | Performance of irrigation systems | | | | |
|---|---|---|---|---|---|
| | Cu% | Du% | Su | Ea% | Water productivity (Kg/m$^3$) |
| Drip | 90 $^a$ | 87$^a$ | 1.15$^b$ | 80 $^a$ | 20.5 $^a$ |
| Furrow | 58$^b$ | 55$^b$ | 1.82 $^a$ | 60 $^b$ | 9.2 $^b$ |
| LSD | 13.8 | 13.3 | 0.53 | 11.4 | 5.7 |

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

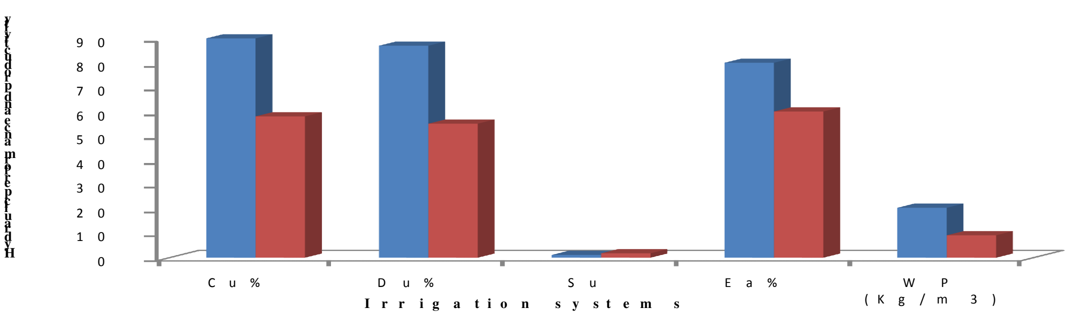


**Figure 1.** Effect of irrigation systems on water productivity (kg/m3)

## CONCLUSION

Proper technical guidelines for system management, operation and scheduling significantly increased the tomato productivity (Kg/m3).

## REFERENCES

Abdelgawad, G.; Arslan, A.; Gaihbe, A. and Kadori, F. (2005). Effect of Saline Irrigation Water Management and Salt Tolerant Tomato Varieties on Sustainable Production of Tomato in Syria. J. of Agric. Water Managegment, 73: 39-53.

Adam, H.S. (2014). Agroclimatology, Crop Water Requirement and Water Management. 2nd Edition. University of Gezira Press, Sudan.

Alomran, A.M.; Al-Harbi, A.A.; Wahb-Allah, M.A.; Alwabel, M.A.; Nadeem, M.E. and Al-Eter, A. (2012). Management of Irrigation Water Salinity in Greenhouse Tomato Production under Calcareous Sandy Soil and Drip Irrigation. J. Agr. Sci. Tech. Vol. 14: 939-950.

ASAE Standards. 50th Ed. (2008). EP 405. Design and installation of microirrigation system. St. Joseph, Mich,: ASAE

Burt, C. M. 2004. Rapid field evaluation of drip and microspray distribution uniformity. Irrig. Drain.Sys. 18(4): 275-297.

Bush, A. A. and Mohamed, A.E. (2016). Effect of Irrigation Systems and Irrigation Water Regime on the Vegetative Growth of Date Palm (Phoenix dactylifera) Plantation under Khartoum State Conditions, Sudan. SUST Journal of Agricultural and Veterinary Sciences (SJAVS) Vol. 17 No.(1) ISSN: 1858 6775.

Bush, A.A.; Mohamed, A.E.; Ali, A.B. and Hong, L. (2016). Effect of different operating pressures on the hydraulic performance of drip irrigation system in Khartoum State conditions Journal of Environmental and Agricultural Sciences (ISSN: 2313-8629).

Darouich, H.M., C.M.G. Pedras, J.M. Goncalves and L.S. Pereira. 2014. Drip vs. surface irrigation: A comparison focussing on water saving and economic returns using multicriteria analysis applied to cotton. Biosyst. Eng. 122:74-90.

Hanson, B.R. and May, D.M. (2004). Crop Coefficient of Drip Irrigated Processing Tomatoes. ASAE/CSAE Annual Intrernational Meeting. Sponsored by ASAE/CSAE. Fairmont Chateau Laurier, the Westin and Government Centre. Ottawa, Ontario, Canada. Paper No. 042087.

Megersa, G. and J. Abdulahi. 2015. Irrigation system in Israel: A review. Int. J. Water Resour. Environ. Eng. 7(3): 29-37.

Merriam, J.L. and Keller, L. (1978). Farm irrigation system evaluation: A guide for management. Utah State University, Logan, Utah. Dept. of Agricultural and Irrigation Engineering.

Mohammed H. and Saleh M. (2011). Effects of Precision Irrigation on Productivity and Water Use Efficiency of Alfalfa under Different Irrigation Methods in Arid Climates. Journal of Applied Sciences Research, 7(3): 299-308.

Ortega, J.F.; Tarjuelo, J.M. and De Juan, J.A. (2002). Evaluation of Irrigation Performance in Localized Irrigation System of Semiarid Regions (Castilla-La Mancha, Spain). Agricultural Engineering International: the Cigr Journal of Scientific Research and Development. Manuscript LW 01 007. Vol. I.

Ortega, J.F.; Tarjuelo, J.M. and De Juan, J.A. (2002). Evaluation of Irrigation Performance in Localized Irrigation System of Semiarid Regions (Castilla-La Mancha, Spain). Agricultural Engineering International: the Cigr Journal of Scientific Research and Development. Manuscript LW 01 007. Vol. I.

Shajari, S.; Bakhshoodeh, M. and Soltani, R. (2008). Enhancing Irrigation water productivity under production risk. Evidence from wheat farms in Iran. American-Eurasian Journal of Agricultural and Environmental Sci. 1:36-41.

Virupakshagowda, C.; Khalid, A.; Rangaswamy, M.; ElKamil H. M.; Samy M.; Ali, A.; Chandrashekhar M.; Biradar, M. and Prasanna H. G. (2014). Assessing Agricultural Water Productivity in Desert Farming System of Saudi Arabia. Journal of Selected Topics in Applied Earth Observations and Remote Sensing, 3: 1-14.