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WATER PRODUCTIVITY OF CUCUMBER UNDER DIFFERENT COVERS OF GREENHOUSES USING DRIP IRRIGATION SYSTEM

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ABSTRACT The objective of this study was to evaluate water productivity of cucumber (*Cucumis sativus* L.) under different covers of greenhouses using drip irrigation system. The experiments were carried out at the Demonstration Farm of the Faculty of Agriculture, University of Khartoum - Shambat, Sudan (32º 51`E, 15º 65`N and 380 m above mean sea level) during the summer season of 2018. Greenhouses were designed and installed to accommodate different treatments namely; double-layers of polyethylene with 9cm air gap (D-PE), single-layer of polyethylene (S-PE), and single-layer of polyethylene with green net with 50% opening (S-PE+N). These treatments were arranged in randomized completely block design (RCBD) with three replicates. Crop water requirement was determined using CROPWAT version 8 computer model. 100% of ETc was applied using drip irrigation system. Increasing crop evapotranspiration was due to change in weather parameters inside the greenhouses. The parameters tested were the hydraulic characteristics of the irrigation system which were Christiansen's coefficient of uniformity (Cu%), emission uniformity (Eu%) and scheduling uniformity (Su) and water productivity (kg/m^3). A computer program (SAS statistical package) was used to analyze the data while the variations among the means were checked by the Least Significant Difference (LSD). The results showed that, average hydraulic performance of drip irrigation system was fallen below the recommended values (Cu 80%, Eu 76% and Su 1.4). Greenhouse covers significantly ($P \leq 0.05$) affected the water productivity. S-PE increased the water productivity of cucumber (21.3 kg/m^3) followed by D-PE (19.77 kg/m^3) and S-PE+N (15.8 kg/m^3). The reduction in water productivity was attributed to the excessive quantities of water applied by drip irrigation system which recorded lower values of hydraulic performance as compared with the recommended values. It is concluded that selection of more suitable greenhouse cover under local climate conditions as well as managing water, irrigation scheduling and reduced crop's diseases were the main factors affecting water productivity.

KEYWORDS : Water productivity; Greenhouse covers; Drip irrigation system

1. INTRODUCTION

Water is becoming an economic scarce resource in many areas of the world, especially in arid and semi-arid regions (Stanghellini *et al*., 2003). 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). Scheduling water application is very critical, as excessive or inadequate irrigations reduce yield, while inadequate irrigation also causes water stress (Locascio and Smajstrla, 1996). Drip irrigation system offers an opportunity for application of water soluble fertilizers and thus reduces loss of nutrients and water. Improving the efficiency of water use is so important in order to secure water for agricultural production and increasing the crop productivity (Jacobsen *et al*., 2012). A crop consuming less water with higher yield is more efficient than crop consuming more water with low water productivity. The reduction in the water productivity was due to the huge quantities of water applied by the irrigation systems during the season (Parameshwarareddy *et al.,* 2018). Greenhouses provide a suitable environmental condition for improving crop growth and productivity. Cucumber (*Cucumis sativus* L.) is one of the popular vegetable crops grown broadly throughout the world (Soleimani *et al.,* 2009). It grows successfully under conditions of high light, high humidity, high soil moisture, temperature and fertilizers in greenhouses. Solar radiation and ambient temperature are the main climatic parameters needed to evaluate the climate suitability in a region for protected cultivation. However, the temperature distribution in a greenhouse is one of the main factors affecting the uniformity of the crop growth (Sauser *et al.,* 1998). Cucumber varies in responding to polyethylene covers which depending on materials used and environmental conditions (Fonsecal *et al.,* 2003). El-Aidy *et al.* (2007) reported that, the highest yield of cucumber was obtained in plastic tunnels and the lowest yield was produced by crops shaded directly with perforated film. Hashem *et al*., (2011) studied the effect of different greenhouse cover treatments on water productivity using different irrigation regimes. They found that, the interaction between greenhouse covers and irrigation treatment for water productivity was significant effect. Reducing water supply at seedling stage, controlling water supply at flowering stage and increasing water supply at fruiting stage of cucumber can increase yield and water productivity. According to Spehia (2015), the productivity of cucumber inside polyhouses was more than four times as compared to open field cultivation. Lorenzo *et al.* (2006) reported that, greenhouses under shading provide better environmental conditions for plant growth, reduced crop transpiration and improved the productivity of cucumber by 62%. According to Abbouda *et al.* (2012) there is little information regarding the operation, management and the economic efficiency of greenhouses. In Sudan, low crop 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 (Mohamed *et al.,* 2017). Therefore the main objective of this study was to evaluate water productivity of cucumber under different greenhouse covers using drip irrigation system.

2. MATERIALS AND METHODS

2.1 Experimental area and design

The experiments were conducted at the Demonstration Farm of the Faculty of Agriculture, University of Khartoum - Shambat, Sudan (32° 51` E, 15° 65` N and 380 m above the mean sea level) under greenhouses conditions during the summer season of 2018. After the land ploughed, harrowed and leveled, drip irrigation system was designed to irrigate the cucumber. Greenhouses were designed and installed to accommodate different treatments namely; double-layers of polyethylene with 9cm air gap (D-PE), single-layer of polyethylene (S-PE), and single-layer of polyethylene with green net with 50% opening (S-PE+N). These treatments were arranged in randomized completely block design (RCBD) with three replicates. Soil physical properties and textural class were determined at the Laboratory of the Department of Soil and Environment Sciences, Faculty of Agriculture, University of Khartoum. The climate is semi-arid with low relative humidity and daily mean maximum and minimum temperature are 36° C and 22° C, respectively. The annual rainfall is limited and usually occurs in the form of short intense thunder storms. This means that water is deficient and crop production must be based on irrigation.

2.2 Soil physical properties

Soil physical properties and textural class were determined at the Laboratory of the Department of Soil and Environment Sciences, Faculty of Agriculture, University of Khartoum.

2.3 Design of evaporative cooling system

Evaporative cooling system consists of cooling pads and extracting fans. A cross fluted cellulose pad was mounted in a vertical fashion at the end of the greenhouse. A PVC pipe (1 inch diameter) suspended immediately above the cooling pads. A water sump mounted under the pads to collect the water and return it into the water tank (1000 liters), from which it can be recycled to the cellulose pads by means of the water pump. In order to bring the cold air onto the plants throughout the growth period, the cooling pads were located 20 cm above the ground surface of the greenhouse. Two extracting fans (single speed, direct drive and 90 cm diameter) were located on the leeward side of the greenhouse and the pads on the aid toward prevailing wind. It was calculated by the following equation mentioned by Boulard and Baille (1993) as follows:

$$\eta\,\% = \frac{T_{dd}}{T_{wd}} \times 100 \;\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ (1)$$

Where:

T_{dd}= cooling effect °C.

T_{wd}= wet-bulb depression °C.

2.4 Environmental factors

Environmental parameters are generally recognized to have a major impact on the production of protected cropping. These parameters have been included ambient air temperature and air relative humidity. Temperature and relative humidity inside, outside greenhouses were measured using ISOLAB Laborgerate GmbH, ambient (outside, inside) temperature and relative humidity were recorded.

2.5 Plant parameters

Cucumber seeds (LEADER F1 Hybrid, Syngenta company) were sown in nurseries of the CTC company, Sudan (controlled environment) and after the appearance of the third true leaf, seedlings were transplanted into the three greenhouses, one plant was placed in a hole with spacing of 0.4m between holes, each location was irrigated by a drip irrigation system The crop commenced to flower after 21 days, and fruited after 45 days. Leaves number, plant length, stem diameter and the total fresh yield were measured.

2.6 Cucumber water requirement

Crop water requirement (ETc) is derived from crop evapotranspiration (100% crop water use) which is the product of the reference evapotranspiration (ETo) and the crop coefficient Kc (FAO, 2010).

ETc = ETo*Kc*Ks*Kr ....(2)

Where:

ETc = Crop evapotranspiration (mm/day).

ETo = Reference evapotranspiration (mm/day).

Kc = Crop Coefficient (dimensionless).

Ks = Soil water availability factor = 0.9 due to the soil type (sandy loam).

Kr = A reduction factor.

Reference crop evapotranspiration (ETo) was determined by the following equation mentioned by Smith *et al.* (1998) as follows:

$$\text{Eto} = \frac{0.408\Delta(Rn - G) + \gamma\left(\frac{900}{T} + 273\right)U_2(es - ea)}{\Delta + \gamma(1 + 0.34U_2)} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3)$$

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, kPa e_a = Actual vp (kPa)

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

U_2 = Wind speed at 2m height (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 (S m^{-1})

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

Soil heat flux (G) may be ignored if the period is less than 10 days which can be calculated according to the following equation:

G_{month} = 0.14(T_{month} – $T_{month-1}$) ….……………………..……(4)

Where:

T_{month} = Average temperature for the mentioned month (°C)

$T_{month-1}$ = Average temperature for the month before (°C)

e_a = e_s × relative humidity as a fraction ……………………….. (5)

2.7 Measurement of rainfall

Daily rainfall was measured using the standard ordinary rain gauge exposed 1 m above ground level away from buildings and trees. The diameter of the standard gauge is 5 inches (12.7 cm). There was 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 was used to give a continuous record of rainfall, this type of rain gauges is very important because it gives the intensity of rainfall (Adam, 2014).

2.7.1 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 ………………………. (6)

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.

2.8 Hydraulic performance of drip irrigation system

The following parameters were used to evaluate drip irrigation system:

a. Uniformity of water application (Cu%)

Christiansen's Cu (%) evaluates the mean deviation, which is represented in ASAE standards (1999) as follows:

$$\text{Cu}\,\% = 100\,\left[1 - \frac{1}{nqa}\sum_{i=1}^{n}|qi - qa|\right] \ldots\ldots\ldots\ldots\ldots\ldots\ (7)$$

Where:

q_a = the average emitter discharge rate (m^3/s).

q_i = the flow rate of the emitter (m^3/s).

b. Emission uniformity (Eu%)

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

$$\text{Eu}\% = 100\left[\frac{q_m}{q_a}\right] \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (8)$$

Where:

q_m = the average flow rate of the emitters in the lowest quarter.

q_a = the average emitter discharge rate (m^3/s).

c. 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, 1999). Cv can be expressed as

$$Cv = \frac{S_q}{q_a} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (9)$$

Where:
Cv = the coefficient of variation of emitter flow.
$S_{q=}$ the standard deviation of emitter flow rate.
$q_{a=}$ the average emitter discharge rate (m^3/s).

2.11 Water productivity (kg/m^3)

According to Virupakshagowda *et al.* (2014) irrigation water productivity (WP) was determined by dividing the yield (kg/ha) to the consumptive use (m^3/ha).
WP (kg/m^3) = dry yield (kg/ha) ÷ consumptive use (m^3/ha) ……….. (10)

2.12 Data analysis

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

3. RESULTS AND DISCUSSION

3.1 Hydraulic performance of drip irrigation system

Hydraulic performance significantly ($P \leq 0.05$) affected by the different covers of greenhouses (Table 1). S-PE cover gave the higher performance of drip system compared to S-PE+N cover which ranked the lower. Due to the losses of water as surface runoff and deep percolation in D-SE and S-PE+N greenhouses drip irrigation performance fall below the recommended values (90% or more) as stated by Vermeiren and Jobling (1980).This result may be due to the some factors affecting the drip performance such as selection of greenhouse covers, emitters, lateral diameter and length, ideal manufacturer's coefficient of variation (CV%), slop, pressure variations and the minor head losses need to be taken into account in addition to frictional losses along the lateral in hydraulic analysis. The results were agreement with the result obtained by Bush *et al.* (2016) who mentioned that, poor technical skills of farmers to assess the crop water requirements and to monitor the soil moisture conditions in the field as well as climate variations, non-uniformity which include unequal drainage and unequal application rates are factors affecting the irrigation system.

3.2 Crop water requirement

As shown in Table 2, crop water requirements of cucumber were varied within the growing season due to the variation in climate conditions e.g. mean temperature, relative humidity, sunshine,….etc. The amount of water increased as irrigation decreased up to the 5th irrigation then decreased maturity stages. Increasing crop evapotranspiration was due to change in weather parameters inside the greenhouses. The use of crop water requirement technique inside the greenhouses resulted on saving the amount of water applied by 15% compared with the open field conditions. The results agreed with the result obtained by Adam (2014) who reported that crop water requirements and water productivity significantly affected by the local climate change especially in arid and semi-arid regions.

Table 1. Hydraulic performance of drip irrigation system under different greenhouse covers

Treatments	Hydraulic Performance of Drip irrigation System				
	Cu%	Eu%	Su	Cv%	Ea%
S-PE cover	83^{a}	79a	1.30^{a}	3.5^{b}	75^{a}
D-PE cover	82^{a}	76b	1.32^{a}	4.5^{a}	63^{b}
S-PE+N cover	78^{b}	74^{b}	1.40^{b}	5.1^{a}	60^{b}
LSD	2.1	2.7	0.07	0.8	6.3

Means in the same column(s) followed by the same letters are not significantly different according to the LSD test.

Table 2. Crop water requirements and applied water

Month	Stage	Kc	ETc mm/day	ETc mm/decade	Effective rain mm/decade	Irrigation requirements mm/decade
May	Init	0.60	5.08	50.8	6.7	44.1
May	Init	0.60	5.05	50.5	9.1	41.4
May	Deve	0.60	5.10	56.1	10.9	45.2
Jun	Deve	0.69	5.96	59.6	12.7	46.9
Jun	Deve	0.83	7.25	72.5	14.5	58.0
Jun	Deve	0.97	8.14	81.4	16.1	65.2
Jul	Mid	1.11	8.88	88.8	18.1	70.6
Jul	Mid	1.16	8.91	89.1	20.0	69.2
Jul	Mid	1.16	8.46	93.0	20.0	73.1
Aug	Mid	1.16	7.85	78.5	19.5	59.0
Aug	Mid	1.16	7.32	73.2	19.5	53.6
Aug	Late	1.12	7.32	80.5	20.8	59.7
Sep	Late	1.00	6.82	68.2	23.1	45.1
Sep	Late	0.88	6.15	61.5	24.6	36.9
Sep	Late	0.81	5.65	11.3	4.5	11.3
Total				1015.1	240.2	779.4

3.3 Water productivity (Kg/m^3) of cucumber

As presented in Fig 1, water productivity significantly affected by the different covers of greenhouses and drip performance. S-PE cover increased the water productivity (21.3 kg/m^3) followed by D-PE (19.8 kg/m^3) and S-PE+N (15.8 kg/m^3). The reduction in water productivity was attributed to the excessive quantities of water applied by drip irrigation system which recorded lower values of hydraulic performance as compared with the recommended values reported by Vermeiren and Jobling (1980). Cucumber varies in responding to polyethylene covers which depending on materials used and environmental conditions. Hashem *et al*., (2011) studied the effect of different greenhouse cover treatments on water productivity using different irrigation regimes. They found that, the interaction between greenhouse covers and irrigation treatments was significantly affected the water productivity. The results were consistent with the result obtained by Mohamed *et al.* (2017).

4. Conclusion

Water productivity of cucumber was varies under different greenhouse covers and were very low comparing with other studies, due to the variations in climate parameters inside the greenhouses in addition the hydraulic performance of drip irrigation system was very low due to the losses of water as surface runoff and deep percolation. S-PE greenhouse cover is suitable under the summer season of Sudan which gave the higher water productivity comparing with D-SE and S-PE+N green house covers

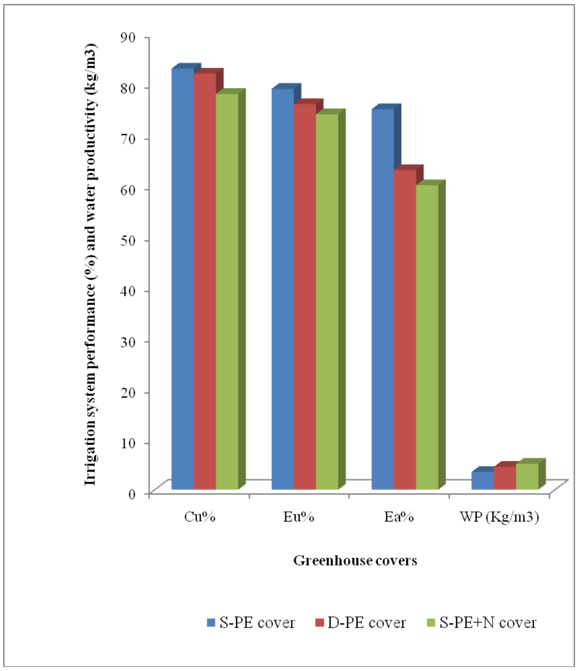

Fig 1 Water productivity of cucumber under different materials covers

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