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Effect of Irrigation Systems and Watering Amount on Yield of Eggplant (*Solanum melongena*) Under Arid Conditions

Yassir Mohamed Ibrahim[1], Maysa Moustafa Abdalla[2], Osama Osman Ali[3], Mohmed Abdallah Mohmed Abdalhi[3, *]

[1]Department of Agricultural Engineering, Faculty of Agriculture, University of Nile Valley, Atbara, Sudan
[2]Department of Agricultural Engineering, Ministry of Agriculture, Atbara, Sudan
[3]Department of Agricultural Engineering, Faculty of Agricultural Technology and Fish Sciences, Al-Neelain University, Khartoum, Sudan

Abstract

The experiment was carried out in Barbar locality, Sudan during two successful years (2015 and 2016) in an area of 0.2 ha. The objective of the study was to quantify the effect of different irrigation systems and different water quantities on Eggplant (*Solanum melongena*) production under dry conditions. The treatments were three irrigation systems (surface drip irrigation, subsurface drip irrigation and furrow) and three amounts of irrigation water: (100%, 75% and 50% of ETc). The parameters measured were yield components and plant yield (ton/ha). Class A Pan was used to estimate the eggplant evapotranspiration. The experiment was organized in spilt plot procedure accordingly complete randomized block design. SAS statistical package was used to achieve the data statistical analysis. The results showed that yield parameters were significantly ($P \leq 0.05$) affected by all treatments. Surface drip and subsurface drip irrigation systems gave the highest values of eggplant yield and yield components as compared to furrow irrigation system, which recorded the lowest values of yield parameters. On the other hand, the aforementioned parameters were increased with increasing in the amount of irrigation water. The highest values of all parameters measured were recorded with 100% ETc and the lowest values appeared in 50% ETc. The conclusion of this study is that surface drip and subsurface drip irrigation systems are convenient for eggplant production under dry conditions.

Keywords

Eggplant, Evapotranspiration, Irrigation Systems, Watering, Yield Components

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1. Introduction

Global climate change and increasing competition for fresh water may have serious impacts on water resources and agriculture sector in the near future. Access to irrigation water is key to reduce the impacts of climate variability and change on food security. Irrigation is an increasingly important practice for sustainable agriculture in the arid and semi-arid regions [1]. In order to solve the problem of water shortage in agriculture, it is necessary to develop water saving management technologies. One of the main reasons for the low coverage of irrigation is the predominant use of flood (conventional) method of irrigation, where water efficiency is very low due to various reasons. In recent years, however, growing competition for scarce water resources has led to apply modified techniques for maximizing water efficiency and improving crop yields and quality. Drip irrigation method is very efficient for supplying irrigation water precisely because only the immediate root zone of each plant is wetted and hence should be adopted on a large scale

* Corresponding author
E-mail address: mohmedabdalhi@yahoo.com (M. A. M. Abdalhi)

for various horticultural crops. In this method water is supplied at slower rate over a longer period of time at regular intervals through low pressure delivery system to meet evapotranspiration demand of water. In addition of that drip irrigation system applies water slowly to keep soil moisture within the desire range of plant growth [2]. The optimal response of crops to drip irrigation is due to the system operation in which water is delivered by drippers in slow process for a relatively long period. This process enables better water control and distribution through the soil profile, therefore, the losses due to evaporation and deep percolation are reduced and the crops can use almost all of the delivered water. Surface drip and subsurface drip irrigation is most effective way to convey directly water and nutrients to plants, save water and it also increases yields of vegetable crops [3]. Drip systems generally gave higher water productivities compared to surface irrigation systems [4]. This was mainly because of the higher volume of water applied in the surface irrigation system as compared to drip irrigation systems. Its important advantages as compared to other irrigation systems as following: increased crop yields, water and energy saving, increased water and fertilizer use efficiency, tolerance to windy atmospheric conditions, decreased labour cost, protection from the diseased and improved the pest control, using with no problems in sloppy lands conditions, suitability with different types of soils and improved the salinity conditions [5]. The drip irrigation generally achieves better crop yield and balanced soil moisture in the active root zone with minimum water losses [6]. On the average, drip irrigation saves about 70 to 80% water as compared to conventional flood irrigation methods. Drip irrigation method saved 56.4% water and gave 22% more yield as compared to that of furrow irrigation method [7]. The plant height, stem size and yield of tomatoes irrigated by drip system have superiority over that irrigated by furrow system. Study of drip and furrow irrigation obtained that 18-42% of the irrigation water was saved with drip systems as comparison with furrow [8]. Surface drip performance was superior to subsurface drip in considering yield and quality of eggplants [9]. Crop yields in drip system exceeded furrow system and water use is significantly less when compared with furrow system. The drip irrigation produced higher crop yield as compared to furrow irrigation method. Drip irrigation has proved to be a success in terms of water and increase yield in a wide range of crops [10, 11]. Yield and yield components were significantly improved under drip irrigation compared to furrow irrigation method [12-14]. The yield of vegetable crops was increased significantly after the adoption of drip irrigation system which indicates the positive impact of drip irrigation system. Therefore, the objective of this study was; to determine the appropriate irrigation system for yield and yield components of eggplant under River Nile State conditions.

2. Materials and Methods

The experiment was conducted in Barbar locality, Sudan (latitude 17° 40’ N, longitude 33° 20’ E, altitude 334 m above mean sea level) during two successful years (2015/16 and 2016/17) in an area of 0.2 ha. The climatic zone of the study area is dry, characterized by a hot in summer and cool in winter with little rainfall. The soil of the experimental site is sandy loam soil with high sand content (68%) and low clay (26.7%). The soil analyses indicated that the soil is moderately alkaline, non-saline, non-sodic, has medium available phosphorous and low organic carbon. So, the soil of the current study was suitable for growing eggplant. The experimental field was ploughed with a standard integral mounted disk plough at a depth of about 0.25 m. The land was then left for about two weeks and then leveled with a general purpose blade. Ridging was done at a spacing of 0.75 m. An eggplant was planted in spacing of 0.5 m in accordance with the standard practice for growing eggplant as recommended by the State Ministry of Agriculture. The experiment was laid out in split plot design with three replications. There were nine treatment combinations comprising of three main treatments of irrigation systems (surface drip irrigation subsurface drip irrigation and furrow irrigation systems) and three sub treatments of levels of irrigation (50, 75 and 100% ETc). After transplanting, up to the seventh day common irrigation (100% ETc) was provided daily to all the drip irrigation and furrow treatment plots for the better and uniform initial establishment of the crop and it was included while computing the total water applied to respective treatments. The drip irrigation scheduling was imposed from the eighth day of transplanting. The daily evapotranspiration reading recorded by USWB class A Pan Evaporimeter was converted to reference ET (ET_0) by multiplying with Pan coefficient (Kp) or Pan factor (0.8) after considering relative humidity and rainfall. Then ET of the crop (ET_{crop} was obtained by multiplying ET_0 with crop coefficient (Kc)) and reduction factor (kr).

A reduction factor (Kr) was calculated from the ground cover value (GC). It is defined as the fraction of the total surface area actually covered by the foliage of the trees when viewed directly from above. In order to calculate GC, the diameter of shaded area (cm) was taken after midday. The ground cover, as percentage was calculated by the procedure described by [15] as follows:

$$\text{Area per tree} = \text{Row width} \times \text{Tree spacing within row} \quad (1)$$

$$\text{Shaded area per tree} = \text{Tree spacing within row} \times D \quad (2)$$

$$GC\% = (\text{shaded area per tree})/(\text{area per tree}) \quad (3)$$

Where:

D = Average width of measured shaded area between two trees.

GC = Ground cover (%).

The reduction factor (Kr) was estimated using equation as suggested by [16]:

$$kr = 0.1GC^{0.5} \tag{4}$$

Where:

Kr = The reduction factor.

GC = Ground cover (%).

The water was drawn by the same tank to supply the control lines for the second part of the experiment, through a 25 mm inside diameter pipe in which the discharge (flow rate) was calibrated volumetrically. Similarly, furrows were prepared in furrow plot keeping same row-to-row 3 and plant-to-plant distances as those in the drip irrigation method. Drip irrigation system was designed and installed in on area of 0.2 ha. The drip irrigation system under study was supplied with water from a tank in the farm of 0.4 m^3 capacity. The main pipe line was made of Polyvinyl chloride (PVC) and buried under ground at depth of 30 cm, running for 9 m length and 25 mm diameter. The sub-main pipe line was also made of Polyvinyl chloride (PVC) and buried under ground at depth of 30 cm. There were 2 sub-main lines, each 6 m length and 16 mm diameter to deliver water from the main line to the lateral lines. Lateral lines were made of black low density polyethylene (L. D. P. E) built in at 13 mm diameter, were laid over the ground surface. The laterals were connected to sub main. There were 6 lateral lines in each sub-main pipe line, each line was connected by grommets. At the end of each lateral, there was an end stop to block the lateral line, thereby preserving water supply. Short path drippers per plant were used (the discharge of one emitter 4 l/h) at 50 cm spacing between them for surface and subsurface drip irrigation system. Emitters were fitted on laterals near the plant of eggplant. The emitters were fitted to the laterals after making a hole on the laterals at a distance equal to the plant spacing. Total number of emitters were used in plot was 42. Eggplant from each unit plot were harvested and weighed for determination of yield per plot. The net yield per plot was converted into yield per hectare basis and expressed in ton/ha. Yield and yield components include fruit length (cm), fruit diameter (cm), number of fruits per plant and fresh fruits weight (ton/ha). Statistical analyses were conducted using the Proc GLM (general linear models) procedure of SAS (SAS Institute, Inc., Cary, N. C.) at a significance level of $p \leq 0.05$. The analysis of variance (ANOVA) technique was conducted to determine the differences between treatments for each parameter as applicable to complete randomized block design arranged in split plots procedure. Treatment means were compared with least significant differences (L.S.D.) procedure at 0.05 probability level. These were done by SAS statistical computer program.

3. Results and Discussions

3.1 Effect of Irrigation Systems on Yield and Yield Components

As shown in Table 1. The comparison was made between irrigation systems at $P \leq 0.05$ level of significant.

3.1.1. Number of Fruits Per Plant

The results in Table 1, indicated that, in second seasons the number of fruits per plant measurement was affected significantly by the irrigation systems. Surface drip irrigation was found to be the best irrigation system in terms of number of fruits per plant followed by the subsurface irrigation, however the furrow irrigation led to lower number of fruits per plant in first and second seasons. Statistical analysis indicates that the surface drip irrigation, furrow irrigation system and the subsurface drip irrigation were similar in the first season, whereas surface drip irrigation and subsurface drip irrigation were similar and both different from furrow irrigation system in the second season. The superiority of drip irrigation may be attributed to the fact that drip system distributes water evenly among plants and provides the crop with adequate water requirement as compared to furrow irrigation system.

3.1.2. Fruits Length

It is clear from the results in Table 1, the fruits length measurement was affected significantly by the irrigation systems in both seasons. The highest significant values of fruits length were obtained under surface drip irrigation as compared to other treatments of subsurface, whereas the lowest one was recorded in the furrow irrigation. Statistical analysis indicates that the surface drip irrigation and the subsurface drip irrigation were similar and both different from furrow irrigation system. This may be due to drip irrigation system prevented weeds growth.

3.1.3. Fruits Diameter

Significant differences were found among the mean values of fruit diameter as affected by application of different irrigation systems, in both seasons (Table 1). The maximum fruit diameter registered under subsurface drip irrigation followed by surface drip irrigation, while furrow irrigation gave the lowest value in two seasons. Statistical analysis shows that the surface drip irrigation and subsurface drip irrigation were similar and different from furrow irrigation in first season. On the other hand, in the second seasons the irrigation systems were significantly different from each other's.

3.1.4. Fruits Weight

It was quite evident from the data presented in Table 1, the irrigation systems had significant effect on number of fruits weight. The fruit weight which produced under surface drip irrigation was higher than those under subsurface drip irrigation and furrow irrigation in both seasons. The subsurface irrigation and the surface drip irrigation were statistically similar and both different from furrow irrigation system. The superiority of drip irrigation may be attributed to the fact that drip system distributes water evenly among plants and provides the crop with adequate water requirement as compared to furrow irrigation system.

3.2. Effect of Irrigation Water Levels on Yield and Yield Components

Table 2. Shows the effect of irrigation water levels on aforementioned parameters.

3.2.1. Number of Fruits Per Plant

As shown in Table 2, the number of fruits per plant was not affected by irrigation water levels. The 100% of ETc registered the highest number of fruits per plant followed by 75% of ETc, but 50% gave lowest number of fruits in both season. This may be due to fact that water applied at 100% ETc adequately meets the crop water requirement. This result is in agreement with the findings of [17, 18] who reported that plant yield components and yield decreased with increasing water deficit.

3.2.2. Fruits Length

Table 2 summarizes the results of an analysis of variance. The test results are significant at 0.01 probability for the effect of irrigation water levels on the fruits length, it indicated that the tallest fruits length obtained under 100% of ETc followed by 75% of ETc, whereas the 50% of ETc registered the lowest value in two seasons. The statistical analysis in reflect that there were different among the irrigation water levels in fist season. In second season the 100% of ETc were differed from 75% and 50% of ETc which were statistically similar. This may be due to soil moisture content under 100% of ETc is sufficient to plant growth. These results are in conformity with those obtained by [19] who stated that the yield was reduced under deficit irrigation.

3.2.3. Fruits Diameter

The effect of irrigation water levels on fruits diameter, monitored during two seasons for each treatment was listed in Table 2. In both seasons the fruits diameter measurement was affected significantly by the irrigation water levels. The fruits diameter under 100% of ETc were higher than those under 75% of ETc in two seasons, whereas the 50% of ETc ranked last. Statistical analysis indicates that the 100%, 75% ETc and the 50% ETc were significantly different from each other's in the first season. Moreover, the 100% and 75% were statistically similar and both different from 50% ETc in the second season.

3.2.4. Fruits Weight

For the two seasons, the data analysis of the fruits weight showed that there were significant differences among the irrigation water levels (Table 2). The 100% ETc registered the maximum fruits weight followed by 75% of ETc and 50% which gave minimum fruits weight in both seasons. The analysis indicates that the irrigation water levels significantly different from each other's. This result is in agreement with the findings of [17, 18] who reported that yield increased with increasing in water levels.

Table 1. Effect of Irrigation Systems on yield and yield components.

Irrigation system	Number of fruit		Fruits Length		Fruits diameter		Fruits weight	
	First season	Second season	First season	Second season	First season	Second season	First season	Second season
drip irrigation	3.84a	4.37a	19.17a	17.82a	6.93a	5.35b	263.33a	260a
Subsurface irrigation	3.5a	3.17a	22a	19.76a	6.97a	6.08a	242.5a	256.6a
furrow irrigation	2a	1.33b	8.55b	7.37b	3.63b	2.97c	68.33b	59.16b
LSD	2.55	1.54	2.93	2.9	0.9	0.71	67	30.5
C.V	16.9	28.3	7.7	8.55	7.2	12.5	11.32	3.9

Means followed by different letters in a column are significantly different at P≤0.05.

Table 2. Effect of irrigation water levels on yield and yield components.

Irrigation water levels	Number of fruit		Fruits Length		Fruits diameter		Fruits weight	
	First season	Second season	First season	Second season	First season	Second season	First season	Second season
100	3.66a	2.83a	19.6a	17.83a	6.83a	5.6a	230.83a	222.5a
75	2.66a	3.33a	17.25b	13.7b	5.71b	5a	189.17b	189.16b
50	3a	2.50a	12.83c	13.25b	5.03c	3.8b	154.17c	164.16c
LSD	0.74	1.1	1.8	1.8	0.59	0.84	30.6	10.53
C.V	16.9	28.3	7.7	8.55	7.2	12.5	11.32	3.9

Means followed by different letters in a column are significantly different at P≤0.05.

4. Conclusions

Surface drip and subsurface drip irrigation systems, and full irrigation application (100% ETo) gave overall better significant performance with respect to increase and enhancing yield of eggplant results in contrasts to furrow irrigation system and irrigation water levels (50% and 75% of ETo). Highest crop yield under surface drip irrigation due to the continuous supply of water in required quantity and owing to more water available to each plant due to less soil surface area was exposed to direct evaporation, where most wetted soil occurred around the root zone. Therefore, present study suggests farming community to adopt drip irrigation method instead of old traditional surface methods.

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