Asian Journal of Agricultural and Horticultural Research

Volume 11, Issue 4, Page 107-114, 2024; Article no.AJAHR.125022
ISSN: 2581-4478

Effect of Drip Irrigation Regimes and Mulching on Cucumber Production under Cooled Plastic Tunnel Conditions, Kassala State, Sudan

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

Article Information

DOI: https://doi.org/10.9734/ajahr/2024/v11i4345

Open Peer Review History:
This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here: https://www.sdiarticle5.com/review-history/125022

Original Research Article

Received: 13/08/2024
Accepted: 15/10/2024
Published: 19/10/2024

ABSTRACT

An experiment was conducted in a cooled plastic tunnel greenhouse during March-August of 2022 and 2023, the objectives of this study to investigate the effect of drip irrigation regimes and mulching on yield and yield components of cucumber under greenhouse conditions, Kassala,

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Cite as: *Khalifa, Ahmed B. A., Ebtihal, H. M. Hamid, Amir B Saeed, Abdelhamed M. Magboul, and Shaker Babiker Ahmed. 2024. "Effect of Drip Irrigation Regimes and Mulching on Cucumber Production under Cooled Plastic Tunnel Conditions, Kassala State, Sudan". Asian Journal of Agricultural and Horticultural Research 11 (4):107-14. https://doi.org/10.9734/ajahr/2024/v11i4345.*

Sudan. Seedlings of the most popular cucumber hybrid (Fatin) were planted on 40cm and 50 cm inter and intra-row spacing, respectively. The experiment was composed of two factors; the irrigation regimes (75%, 100% and 125% of recommended irrigation water) and the other was mulching (mulching and no mulching). These factors were arranged in split plot design with three replications. The main plots were allocated for irrigation regimes and subplots for mulching. The subplot size was 200cm×70cm (bed/mastaba). Results reported that125% of recommended irrigation water (RIW) under drip irrigation recorded highest yield and yield components in both seasons. Moreover, the highest values of yield and yield components; fruit length, fruit diameter and fruit weight were obtained under 125% of (RIW) with mulch while, the lowest were obtained with75% of (RIW) without mulch on both seasons. The highest values of water productivity and economic water productivity were recorded under 125% of (RIW) with mulch. On the other hands, the highest marginal rate return (MRR) was obtained under 100% of (RIW) with no mulch.

Keywords: Drip irrigation regimes; mulching; cooled plastic tunnel; Water Productivity; yield components and economic water productivity.

1. INTRODUCTION

"Water is a main component for successful vegetable production especially under greenhouse" [1]. "Greenhouses are one of the most important facilities for the production of winter-spring vegetables all over the world" [2]. "The technology of greenhouse introduced to the Sudan in 1994 represents one of the most important facilities for the production of off-season vegetables" [3].

"Drip irrigation is a promising system for applying water more precisely and uniformly at a high irrigation frequency compared to furrow and sprinkler irrigation for economizing the available irrigation water. Drip irrigation is necessary to manage the available water efficiently for maximum crop production" [4].

"In Sudan, drip irrigation has been used to produce crops of high value in open field as well as in greenhouses. However, the national crop husbandry committee (NCHC) in the Sudan has recommended the use of drip irrigation system for producing banana, onion and citrus" [5,6,7]. Khalifa et al. [6] found that drip irrigation system saved irrigation water by 67% and increased the total yield of onion by 43% compared to surface irrigation. Irrigation regimes had significantly affected the cucumber yield, irrigation water use efficiency and water saving [8].

"Mulch is a protective layer of either organic or inorganic material that is spread on the top soil" [9]. "Mulches can be composed of plant materials or plastic sheets" [10]. "Plastic mulches substantially reduce evaporation of water from the soil surface, especially under deficit irrigation" [10]. "The use of polyethylene mulch in vegetable production was reported to control weed incidence, reduce nutrient and evaporation loss and improve hydrothermal regimes of soils" [11]. Jalota and Prihar [12] reported that mulches have been used to improve soil water retention, reduce wind velocity at the soil surface in arid lands.

There is need to focus research work in Sudan on proper water management as cucumber requires regular watering throughout growth period for maximum production particularly in Kassala State eastern Sudan. Jalota and Prihar [12] found that drip irrigation in combination with mulch is one of the best irrigation methods, which can improve the water management practice significantly. Therefore, the objective of this study was to study the effect of drip irrigation regimes and mulching on cucumber production under greenhouse conditions.

2. MATERIALS AND METHODS

The experiment was conducted in the greenhouses of the tissue culture unit of Kassala and Gash Research Station, Kassala, Kassala State, Sudan, during March and August of the 2022 and 2023. The site is located at latitude 15° 45´ N and longitude 36° 36´ E with average elevation of 504 m above mean sea level. The greenhouses are plastic tunnel with an area was 306m^2 (34m×9m).

Seeds of the most cultivated cucumber hybrid (Fatin) were planted at an intra-row spacing of 40 cm with inter-row (beds) spacing of 50 cm as recommended by Khalifa et al. [13]. Irrigation was applied by drip irrigation system every 3 days (2.5 liter/plant) by using in line drippers (GR) according to Mohamed and Ahmed [14].

The recommended dose of fertilizer was (50g/m^2/week) of NPK (20:20:20) and the first dose was applied at 2 weeks after planting according to Khalifa et al. [15,16].

The experiment was composed of two factors; one factor was irrigation regimes (75%, 100% and 125% of recommended irrigation water) and the other factor was mulching (mulching and no mulching). These factors were arranged in split plot design with three replications. The main plots were allocated for irrigation regimes and subplots for mulching. The subplot size was 200cm×70cm (bed/mastaba). The six treatments were randomly distributed in each replicate.

The cultural practices (hoeing and weeding) were carried as recommended by ARC.

The measured parameters were; plant height (cm), fruit length (cm), fruit diameter (cm), fruit weight (g), yield (kg/m^2) and yield (t/306m^2).

Water productivity (WP) was calculated as the ratio of the crop yield to the total seasonal irrigation water applied (m^3/ha) using the following formula:

$$\text{WP}\ (\text{kg/m}^3) = \frac{\text{Yield (kg /ha)}}{\text{Total water applied (m}^3\text{/ha)}} \ldots\ldots \quad (1)$$

Economic water productivity (EWP) was calculated as the gross income in Sudanese Pounds (SDG) per gross water supplied in m^3 using the following relation:

$$\text{EWP} = \text{GI/GIWR} \ldots\ldots\ldots\ldots\ldots \quad (2)$$

where:

GI is the gross income from the sale of product (SDG/ha) and GIWR is the gross irrigation water applied (m^3/ha).

MRR was analyzed according to CIMMYT [17] and used the field information and data collected for evaluation.

$$\text{MRR} = \text{MNR} / \text{TVC} \ldots\ldots\ldots\ldots\ldots \quad (3)$$

Where:

MNR= marginal net return
TVC = total variable costs

Statistic 8 statistical package was used for data analysis and the least significant difference test was used for mean separation at the probability level of 0.05.

3. RESULTS AND DISCUSSION

3.1 Effect of Drip Irrigation Regimes and Mulching on Plant Height and Yield

Drip irrigation regimes showed significant differences on plant height and yield of cucumber under greenhouse. The plant height and yield increased with increasing the quantity of water applied under drip irrigation system and the stress was clearly observed in 75% treatment compared to 125% of recommended irrigation water (RIW) in both seasons. The taller plants and higher yield were recorded with 125% of (RIW) for both seasons (Table 1). These results are in agreement with those of Mehmet et al. [18] who found that fruit yield of cucumber was reduced significantly, as irrigation rate was decreased under drip irrigation.

For the interaction between irrigation regimes and mulching the results showed that there was significant difference in plant height and yield for both seasons. The taller plants and higher yield were recorded at 125% of (RIW) with mulch while the shorter plants and lower yield were observed at 75% of (RIW) without mulch in both seasons (Table 1). This might be due to positive effect of mulch on weed control and soil moisture improvement. These results are in close agreement with the findings of Paul et al. [19] who indicated that better plant growth of tomato was observed under drip irrigation system with linear low density poly ethylene mulch. On the other hands, Kumar [20] who found that application of polythene mulch of tomato recorded the highest fruit yield and it was significantly superior to all other mulch treatments and lowest fruit yield was recorded in no mulch.

3.2 Effect of Drip Irrigation Regimes and Mulching on Fruit Length, Fruit Diameter and Fruit Weight

The effect of drip irrigation regimes showed highly significant differences in the fruit length, fruit diameter and fruit weight for both seasons (Table 2). The highest fruits length, diameter and weight were observed 125% of (RIW) compared to 75% of (RIW) in both seasons (Table 2). These results are in conformity with the findings of Khalifa [4] who found that the best finger

length, finger weight and finger girth of banana were obtained with 120% of ET_c under drip irrigation compared to 75% of ET_c under drip irrigation.

In the interaction between irrigation regimes and mulch there were highly significant differences in fruit length, fruit diameter and fruit weight in both seasons. The highest fruit length, fruit diameter and fruit weight were obtained with 125% of (RIW) under drip irrigation with mulch while, the lowest fruit length, fruit diameter and fruit weight were found under 75% of (RIW) under drip irrigation in both seasons. This might be due to better moisture conservation as consequent offers evaporation (Table 2). This result is in close agreement with the findings of Biswas et al. [21] who found that fruit size and fruit weight of tomato were maximum in drip irrigation with mulches.

Table 1. Effect of drip irrigation regimes and mulching on plant height and yield of cucumber under greenhouse conditions

Treatments	Plant height (cm)		Yield (kg/m²)		Yield (ton/306m²)	
	2022	2023	2022	2023	2022	2023
75% of recommended irrigation water (D_1)	82.3b	76.3b	17.3c	13.6c	5.4c	4.2c
100% of recommended irrigation water (D_2)	90.0ab	94.3a	21.0b	16.7b	6.5b	5.2b
125% of recommended irrigation water (D_3)	94.3a	98.2a	23.0a	20.8a	7.1a	6.4a
LSD	8.13	11.7	1.29	1.32	0.37	0.41
Significant level	*	***	***	***	***	***
CV%	5.71	9.12	3.95	4.83	3.65	4.84
No mulch (N)	86.4b	86.3b	19.7b	16.1b	6.1b	5.0b
Mulch (M)	91.3a	92.9a	21.2a	17.9a	6.5a	5.5a
LSD	3.85	2.43	1.42	0.49	0.41	0.16
D_1N	79.7c	68.7c	16.2c	13.4e	5.0c	4.2e
D_1M	85.0bc	84.0b	18.4c	13.8e	5.7c	4.3de
D_2N	86.7abc	92.7ab	20.7b	15.3d	64b	4.7d
D_2M	93.3ab	96.0ab	21.3b	18.2c	6.6b	5.6c
D_3N	93.0ab	97.7a	22.1ab	19.7b	6.8ab	6.1b
D_3M	95.7a	98.7a	23.8a	21.8a	7.4a	6.7a
LSD	9.39	12.0	2.16	1.45	0.62	0.45
Significant level	*	***	**	***	**	***
CV%	3.76	2.35	6.02	2.51	5.62	2.65

Table 2. Effect of drip irrigation regimes and mulching on fruit length, fruit diameter and fruit weight of cucumber under greenhouse conditions

Treatments	Fruit weight (g)		Fruit length (cm)		Fruit diameter (cm)	
	2022	2023	2022	2023	2022	2023
75% of recommended irrigation water (D1)	151c	149b	16.8c	13.8c	4.1c	3.9c
100% of recommended irrigation water (D2)	168b	162ab	18.5b	15.2b	4.2b	4.1b
125% of recommended irrigation water (D3)	181a	173a	19.3a	17.0a	4.3a	4.3a
LSD	7.13	15.4	0.38	0.93	0.13	0.12
Significant level	***	*	***	***	NS	**
CV%	2.67	5.95	1.29	3.77	1.9	1.82
No mulch (N)	159b	157a	17.7b	14.8b	4.1a	4.10b
Mulch (M)	174a	165a	18.8a	15.9a	4.2a	4.12a
LSD	6.84	21.24	0.90	0.27	0.17	0.06
D1N	141c	146b	16.0d	13.3d	4.0c	3.9c
D1M	162b	152ab	17.7c	14.3c	4.1bc	4.0bc
D2N	166b	161ab	18.0bc	14.7c	4.1bc	4.0bc
D2M	171b	163ab	19.0ab	15.7b	4.2ab	4.1ab
D3N	172b	165ab	19.0ab	13.6b	4.3ab	4.2a
D3M	189a	181a	19.7a	17.7a	4.4a	4.3a
LSD	10.98	30.17	1.17	0.98	0.19	0.14
Significant level	**	NS	**	***	NS	*
CV%	3.56	11.42	4.29	1.54	2.39	1.29

3.3 Effect of Drip Irrigation Regimes and Mulching on Water Productivity and Economic Water Productivity

The highest values of water productivity and economic water productivity recorded with 75% of (RIW) with mulch for season both seasons (Figs. 1 and 2). These results are in agreement with those reported by Halilm et al. [22] who found that use of drip irrigation with mulching in cucumber increased WUE and IWUE. This strategy might be used for vegetable production in semi-arid regions where irrigation water is limited.

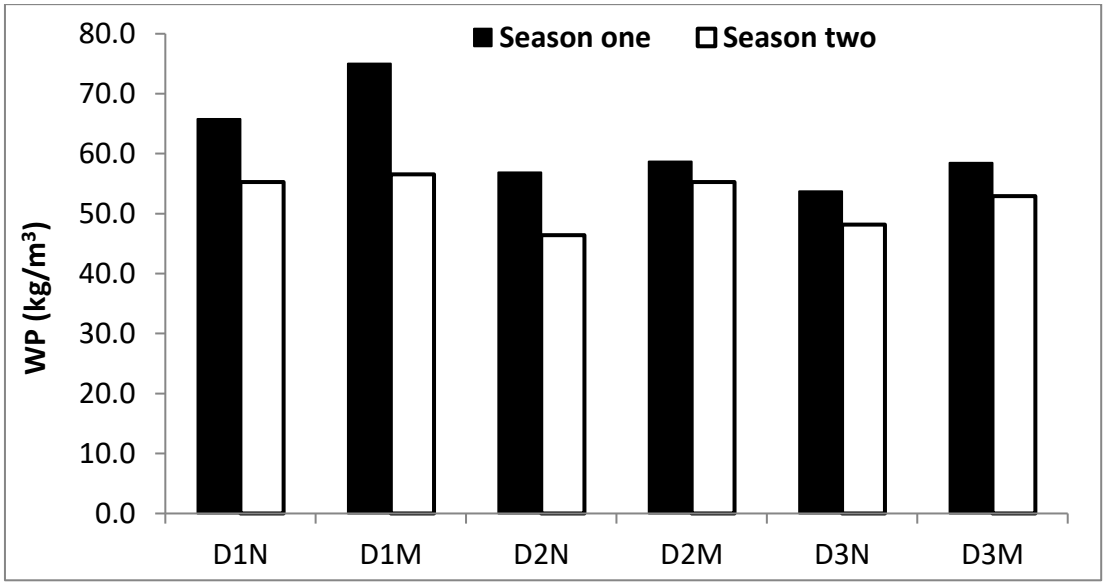

Fig. 1. Effect of drip irrigation regimes and mulching on water productivity (WP) of cucumber grown under greenhouse conditions

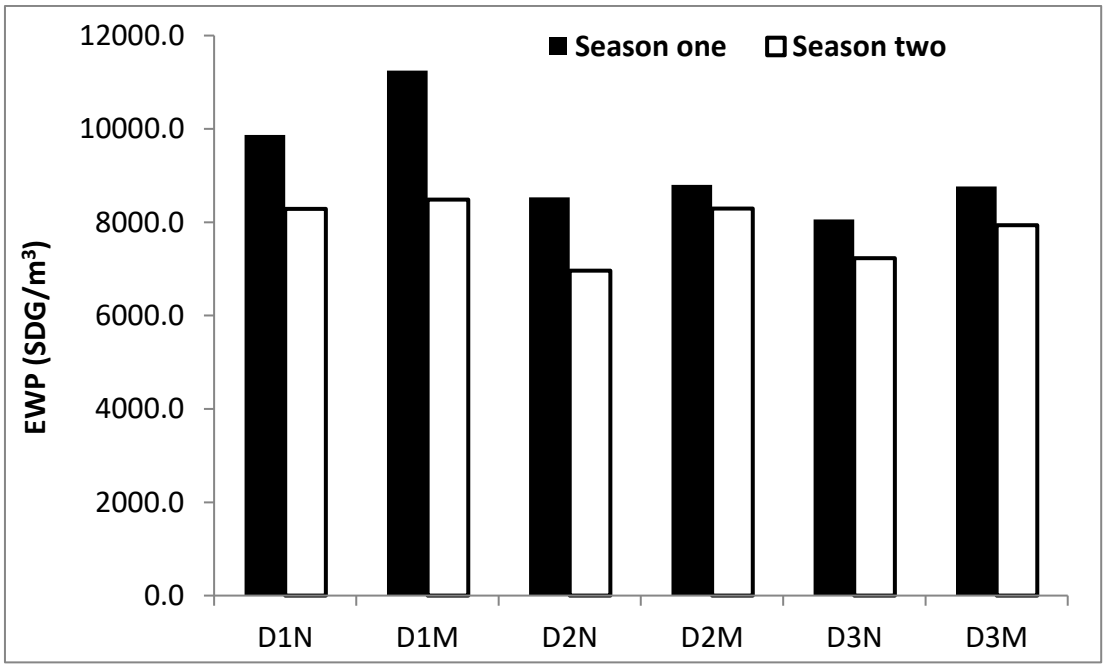

Fig. 2. Effect of drip irrigation regimes and mulching on economic water productivity (EWP) of cucumber grown under greenhouse conditions

3.4 Economic Evaluation

Partial, dominance and marginal analysis were conducted for the combined data of accumulated marketable yield (kg/306m^2) of cucumber under greenhouse for Kassala area (Tables 3 to 5). Results showed that treatment of drip irrigation at 100% of RIW + normal resulted in the highest return in investment at Kassala (Table 3). Return to investment was estimated in the form of marginal rate of return (MRR). The MRR for 100% of RIW + normal was found to be 62.2 for cucumber marketable yield at Kassala. This result indicates the profitability and superiority of using drip irrigation under greenhouse at 100% of RIW + normal for cucumber production in Kassala area. Therefore, the economic evaluation based on partial budget and marginal analysis indicated that using drip irrigation under greenhouse at 100% of RIW + normal method was the most stable and economically feasible treatment.

Table 3. Effect of drip irrigation regimes and mulching on variable cost of cucumber grown under greenhouse conditions

No.	Particulars	(% of RIW) under drip irrigation					
		75		100		125	
		Mulch	Normal	Mulch	Normal	Mulch	Normal
1	Variable cost (SDG/306m^2)						
	Seeds	50000	50000	50000	50000	50000	50000
	Labors	40000	40000	40000	40000	40000	40000
	Black plastic mulch	20000	0	20000	0	20000	0
	Fertilizers	234000	234000	234000	234000	234000	234000
	Chemicals	80000	80000	80000	80000	120000	120000
	Others tools	0	28800	0	28800	0	28800
	Power	29745	29745	32000	32000	34000	34000
	Fixed cost (SDG/306m^2)	150000	150000	150000	150000	150000	150000
2	Total cost (SDG/306m^2)	603745	612545	606000	614800	648000	656800

Table 4. Partial and dominance analysis for marketable yield (kg/306m^2) of cucumber grown under greenhouse conditions at Kassala area

Treatments	Average yield (kg/ 306m^2)	Gross return (SDG/ 306m^2)	Total cost (SDG/ 306m^2)	Net return (SDG/ 306m^2)	Dominated
75% of RIW + normal	4600	690000	603745	86255	
100% of RIW + normal	5550	832500	606000	226500	
75% of RIW + mulch	5000	750000	612545	137455	D
100% of RIW + mulch	6100	915000	614800	300200	
125% of RIW + normal	6450	967500	648000	319500	
125% of RIW + mulch	7050	1057500	656800	400700	

Table 5. Marginal analysis for marketable yield (kg/306m^2) of cucumber grown under greenhouse conditions at Kassala area

Treatments	Average yield (kg/ 306m^2)	Gross return (SDG/ 306m^2)	Total cost (SDG/ 306m^2)	Net return (SDG/ 306m^2)	MC	MR	MRR
75% of RIW + normal	4600	690000	603745	86255			
100% of RIW + normal	5550	832500	606000	226500	2255	140245	62.2
100% of RIW + mulch	6100	915000	614800	300200	8800	73700	8.4
125% of RIW + normal	6450	967500	648000	319500	33200	19300	0.6
125% of RIW + mulch	7050	1057500	656800	400700	8800	81200	9.2

4. CONCLUSION

The highest yield and yield components and benefit cost ration of greenhouse cucumber were obtained under 100% of RIW with no mulch. The use of drip irrigation system under greenhouse can increase the vegetative group and yield components of the crop.

5. RECOMMENDATION

Based on the findings the treatment of drip irrigation at 125% of RIW (3.125l/3day) with mulch is recommended for improving cucumber greenhouse in Kassala.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Authors hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

ACKNOWLEDGEMENTS

The authors would like to thank the IAEA Regional Project RAF/5/086 for supporting this work.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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