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Combined Effects of Different Irrigation Regimes and Irrigation Intervals on the Growth, Yield and Water Use Efficiency of Greenhouse Cucumber (*Cucumis Sativus* L, African Giant Variety) in a Humid Tropical Zone.

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Abstract.

*An experiment was conducted in a greenhouse at the Students Research and Demonstration Farm of the Federal College of Technology, Owerri, Nigeria during the periods, September, 2023 to November, 2023 and December, 2023 to March, 2024. A drip irrigation system was designed and installed in a greenhouse and operated under a hydraulic head of 1.5 m to evaluate the influence of full and deficit irrigation and irrigation intervals on growth parameters, fruit yield, yield components, and water use efficiency of cucumber (African Giant variety) during two cropping seasons of September - November, 2023 and December, 2023 – March, 2024. The treatments were laid out in a randomized block design (RBD) consisting of four levels of irrigation at 100%, 75%, 50% and 25% of ET_c and three levels of irrigation intervals of 1 day, 5 days, and 10 days(decade) with three replications. Results of analysis showed that irrigation treatments significantly affected growth parameters, yield and yield components and water use efficiency of cucumber. In first season single factors of irrigation amount or irrigation interval significantly ($p< 0.05$) affected plant height, leaf number, leaf area and stem diameter of cucumber while in the second season, only the single factor of irrigation interval significantly ($p < 0.05$) affected plant height. In both seasons, irrigation amount and irrigation interval as well as interaction between them very highly ($p< 0.001$) affected fruit yield. Single factors of irrigation amount or irrigation interval had very high significant ($p < 0.001$) interaction effect on cucumber fruit while the interaction between these factors did not produce any significant effect on fruit length. Interactions between irrigation amount and irrigation interval highly ($p <0.001$) affected fruit number. Yield differences in both seasons were found to be non- significant (p (0.21617 > 0.05). Results obtained further showed maximum marketable yield of 151 t/ha and 123.1 t/ha were obtained with100% ET_c daily irrigation while the lowest 16.3 t/ha and 11.5 t/ha were obtained with 25 % ET_c irrigation every 10 days. The irrigation water use efficiency ranged from 31 kg/m^3 to 73 kg/m^3 and 17.1 kg/m^3 to 46.7 kg/m^3 in 2023 and 2024 respectively while the water productivity ranged from 34 kg/m^3 to 81 kg/m^3 in 2023 and 19 t/ha to 50.8 kg/m^3 in 2024 respectively. This study shows that shorter interval with higher irrigation level had better performance on all studied parameters, while the most stressed had low performance on all studied parameters.
In2023,yieldreductionsof23.8%,33%and39%occurredwith100%ETcirrigationevery5days,100%ETcirrigationevery10daysand75%ETcdailyirrigationrespectivelywhilein2024,yieldreductionsof15.9%,33.5%and29%werewith100%ET_cirrigationevery5days,100%ET_cirrigationevery10daysand75%ETcirrigationdailyrespectively.Fromtheresult,inanon-waterlimitingcondition,applicationof100%ET_cirrigationevery5daystogrowcucumberiseconomicallyproductive.Nevertheless,whenwaterbecomesalimitingproductionfactor,irrigatingwith75%ET_cdailycanbean option forcucumberfarmersintheareaasitwillsavewaterandoptimizeyield.*

***Keywords**: Greenhouse, Cucumber, Growth Parameters, Yield and Yield Parameters, Water Use Efficiency*

I.Introduction

Cucumber (*Cucumis Sativus*) originates in Southern Asia, but a larger number of cultivars have been developed and are grown worldwide. It is widely cultivated plant of the family Cucurbitaceae [1]. Due to the realization of the importance of fruits in our diets and the overwhelming importance of Cucumber's health benefits along with skin care; there is increase in demand of the product in Nigeria. The demand of the product locally is far overwhelming accounting for its high cost in the market and a worthwhile agribusiness with high degree of turnover of over 200% [2]. Cucumber requires a warm climate and thrives best between 18^0

to 24^0 C. However, they can tolerate temperature between 38^0 to 40^0 C but do not do well under temperature between 13^0 to 15^0 C. Cucumber with shallow fibrous root system is very sensitive to water stress and therefore easily suffers yield decline. With efficient water application, technologies, higher yields of Cucumber have been achieved. [3]; [4]. It has been severally shown that Cucumber yield attributes depend on quantities of water used to grow it [5]. Water used in for crop production is increasingly becoming scarce in all agro-ecological zones worldwide. This has been aggravated by climate change and resultant rainfall variability that has been reported to have severe impact on agricultural production systems, particularly in Sub-Sahara Africa (SSA). The above scenario underscores the need to adopt production systems which will produce more yields per drop of water used in order to adapt to the menace of climate change. This can be achieved through micro-irrigation system particularly drip irrigation. Drip irrigation system is amenable to the practice of difficult irrigation strategy which allows plants to sustain some degree of water deficit during certain stages of growth of crops or the entire cropping cycle without a significant decline in yields [6]; [4]. In order to minimize under or over irrigation of *Cucumis*

Sativus, water application is scheduled according to water needs and interval. This ensures that favourable moisture status is maintained in the soil to sustain the physiological processes in plants. According to [7] in all ecological regions, water shortage is a normal phenomenon and seriously limits the agricultural potential. Proper irrigation regime and the use of proper method of irrigation can play a major role in increasing the water use efficiency and the productivity by applying the required amount of water when it is needed [8]. Amid the effects of climate change on agricultural production, greenhouse has proved to provide conditions that mitigate the effects of climate change on crop production. Therefore, this study was carried out to ascertain the effects of different irrigation water levels and intervals on yield and irrigation water use efficiency of cucumber in a humid tropical zone.

II.**Materials And Methods**

A.*Description of Experimental Site*

The study was conducted between September and November, 2023, and December, 2023 - March, 2024 at the Students Demonstration and Research Farm, Federal College of Land Resources Technology, Owerri, Southern Nigeria. The Research Farm lies between Latitude $5^0 24^1$N and Longitude $6^0 54^1$E and occupies an elevation of 60m above mean sea level. It is also located in a rainforest zone with an annual rainfall ranges from 2000 – 2500 mm and an average temperature that ranges from 27^0 – 31^0C. The relative humidity varies from 80 – 85% during the rainy season which runs from April – October and 63 – 70% during the dry season spanning November to March. The experiment was carried out in a greenhouse measuring 25.4 m long, 5.2 m wide and 2.5 m high. Cucumber seeds were planted in well levelled seed beds at a spacing of 33cm along row and 50cm between rows. The soil was a sandy clay loam (67.96% Sand, 57.8% Silt and 26.27% Clay) with field capacity of 15.8% bulk density of 1.5 g/cm^3 and pH of 5.36.

B.*Experimental Design and Treatments*

The Cucumber plant (F1 Hybrid African Giant) was used in the experiment in the greenhouse between September – October, 2023 and December, 2023 – March, 2024. A Randomized Block Design (RBD) was used in the study. The experimental treatment consisted of two factors which are irrigation level

(W) and irrigation interval (D). W consists of four levels (W_1: 100% ET_c; W_2: 75% ET_c; W_3: 50% ET_c; W_4: 25% ET_c) while D consists of three levels (D_1, irrigating every day; D_5, irrigating every five days; D_{10}, irrigating every ten days. The experiment consists of twelve treatments. A low-cost drip irrigation system with lateral diameters of 12 mm, emitter spacing of 33 cm, a head flow of 0.86 l/h and an operating pressure of 1.5bar was laid out in a greenhouse of dimensions 25 m long, 5 m wide and 2.5 m high. The greenhouse was divided into twelve plots each measuring 4m long and 1.2 m wide with 0.5 m spacing between them.

C. ***Daily Crop Evapotranspiration Determination***

The treatments were based on the daily crop evapotranspiration (ET_c) which was calculated as a product of the reference evapotranspiration (ET_o) and the stage-specific crop coefficient (K_c). The FAO 56 Penman-Monteith method recommended as the standard method for ET_o estimation [9] and presented as equation 1 was used. $ET_c$for the cucumber plant was then calculated using the equation proposed by [10] and applied by [11].

$$ET_c = ET_o x\ K_c \quad (1)$$

Where:

ET_c= crop evapotranspiration (mm/day)

ET_o) = reference evapotranspiration (mm/day)

K_c = crop coefficient (dimensionless)

T_1 (100%) received 186mm, T_2 (75%) received 139.5mm, T_3 (50%) received 93mm and T_4 (25%) received 46.5mm.

D. ***Agronomic Measurements***

In each of the treatments, the cucumber plants were vertically staked using wire and string technique. Cucumber growth parameters- number of leaves, leaf area, plant height and stem diameter were measured on weekly basis 2 weeks after start of treatment. For this purpose, three plants were randomly selected from each treatment unit and tagged for measurements. The measurements were carried out by counting, use of leaf index formula (Leaf Length x Width x 0.8), meter rule and digital venier caliper for number of leaves, leaf area, plant height and stem diameter respectively. At harvest, fresh total yield and total number of fruits in each plot was determined. Yield parameters such as length and diameter of fruits were also determined.

III. **Results And Discussions**

A. ***Effects of different irrigations on growth parameters***

1) ***Plant height***

Table I shows the effects of irrigation regimes and irrigation interval on plant height. In 2023 the results show that the single factors of irrigation amount ($p<0.05$) or irrigation interval($p<0.05$) or irrigation days ($p=0.001$) significantly and very significantly affected plant height respectively, and the interaction between irrigation amount and irrigation interval and irrigation days had no significant effect on plant height. At 25 days after imposition of treatment the highest growth rate was 18.8 cm/day at 100% ETc applied daily which is consistent with the findings of [12] and [3], the lowest growth rate of 13.1 cm/day occurred in 25 % ET applied at an interval of 10 days. This may be attributed to exposure to water stress over long intervals [13]. In 2024, the highest growth rate of 11.2 cm/day was also achieved from 100 % ETc, irrigated every day. In this season, irrigation interval and irrigation days significantly ($p<.0.05$) and very significantly ($p<0.001$) affected plant height respectively. Also, interaction between treatments had no significant effect on plant height as in 2023. Considering both seasons, plant height is very significantly affected by irrigation days.

Table 1: Effects of different drip irrigation regimes and irrigation intervals on plant height of *Cucumis sativus* (cm) * *

	2023	2024				
Treatment	18D	25D	32D	39D	28D	35D42D 49D
W1D1	13.6	145.1	256.31	373.4	128206.63255263.9	
W1D5	12.6	142.69	247.83	353.6	95.25163.75 207210	
WID10	11.6	140.63	243.9	346.3	105117176 184	
W2D1	11.6	140.10	250.24	352.89	125.11200.95	245 252
W2D5	11.34	140.10	240.68	336.8	109.57183238	242
W2D10	11.0	135.15	240.8	334.7	78110 179200	
W3D1	10.57	136.08	241.7	336.2	121.5	190.57 218 224
W3D5	10.47	134.48	238.5	331.9	116.3	193.25244248
W3D10	10.36	132.15	236.4	328.5	44.3115172 206	
W4D1	10.23	124.02	246.1	314.2	107.7173.33	208 215
W4D5	9.85	120.24	242.9	306.33	91.25164.75	208 223.
W4D10	9.62	101.25	175.1	195.00	86.9 152.6	213 218
IA *	*	* *				
II * * *		*	*	*	*	*

D is days after planting. IA is irrigation amount, II is irrigation interval, IA:II is interaction between irrigation amount and irrigation interval, "***" means p < 0.001, "**' means 0.001 < p <0.01, *' means 0.01 < p < 0.05,

2).***Leaf numbers***

Effects of different irrigation amount and interval on number of leaves in each of the treatments in 2023 and 2024 are presented in Table II. In 2023 cropping season, treatments produced the number of leaves of 4 initially except treatments 25% ET at 5 days and 10 days intervals that produced 3 leaves each. In each treatment, there was an increase in number of leaves weekly. Statistical analysis shows that irrigation amount and irrigation days, significantly (p=0.007) and very highly significantly(p<0.001) affected number of leaves. The average number of leaves per treatment varied from 19.75 – 15.75 and the rate of production of additional leaves per treatment 32 days after planting varies from 2.14 to 1.43/day from 100% ETc, irrigated daily and 25% ETc, irrigated every ten days respectively. In 2024 cropping season, similar trend was observed, the highest increase in leaf numbers occurred 28 days which is 7 days after the imposition of treatment as in 2023. However, leaf addition was at a rate that varied from 1.14 to 0.86/day among the treatments, which is consistent with the findings of [14];[15] and [4]. Statistical analysis showed that irrigation interval and irrigation days had very high significant effect on number of leaves respectively and there was no interaction between the factors. In both seasons, statistical analysis shows irrigation days had very high interaction effect (p<0.001) on number of leaves.

TABLE II: EFFECTS OF DIFFERENT IRRIGATION REGIMES AND IRRIGATION INTERVALS ON LEAF NUMBERS OF CUCUMIS SATIVUS.

	20232024					
Treatment	25D	32D	39D	46D	28D	35D42D 49D
W1D1	4 19 24 3211	19	24	29		
W1D5	4 19 24 31	9	15	18	22	
WID10	4 182431	6	12	1818		
W2D1	4 19 23 31	11	18	22	25	
W2D5	4 18 23 30	8	17	1820		
W2D10	4 18 2330	6	1218	20		
W3D1	4 18 2330	11	1721	23		
W3D5	4 18 2329	10	18	18	20	
W3D10	4 18 22 29	5	11	14	16	
W4D1	4 17 2229	9	1620	22		
W4D5	315 2128	8	1520	20		
W4D10	3 13 19288	14	18	20		
IA	* * * *	*	*	*	*	
II *	* * *	*	*	*	*	
IA: II	NS	NSNSNSNSNSNSNS				

D is days after planting. IA is irrigation amount, II is irrigation interval, IA:II is interaction between irrigation amount and irrigation interval, "***" means p < 0.001, "**' means 0.001 < p <0.01, *' means 0.01 < p < 0.05, NS means not significant

3)***Leaf area***

The effects of different irrigation amounts and intervals on leaf area in the two cropping seasons studied are presented in Table III. The major function of plant leaves is to absorb carbon dioxide for photosynthesis, the process by which light energy is transformed into chemical energy. The highest leaf expansion was 25.8 cm2/day at 25-32 days after planting. The highest average leaf expansion rate was produced from 100% ETc daily treatment. The single factor of irrigation days very highly significantly affected leaf expansion rate at p<0.001). In 2024, leaf expansion rate was 5.6 cm2/day 28-35 days after planting or 7 days after imposition of treatment and was produced from 100%ETc, daily irrigation treatment as in 2023. The single factor of irrigation days very highly significantly influenced leaf expansion rate (p<0.001). Combining the two cropping seasons, irrigation interval significantly affected leaf area at p<0.05. Levels of irrigation interval have the most pronounced effect on leaf area.

TABLE III: EFFECTS OF DIFFERENT IRRIGATION REGIMES AND IRRIGATION INTERVALS ON LEAF AREA OF *CUCUMIS* SATIVUS (CM^2)

	2023				2024			
Treatment	25D	32D	39D	46D	25D	32D	39D	46D
W1D1	152	332	356	382	215	254	259	270
W1D5	145	301	346	374	179	190	198	226
WID10	138	290	331	365	111	121	128	141
W2D1	150	290	242	369	201	243	232	239
W2D5	138	290	321	355	146	158	` 165	171
W2D10	130	254	304	340	130	141.147	151	
W3D1	132	280	324	355	196	220	231	242
W3D5	127	265	306	346	188	200	209	218
W3D10	123	250	293	334	101	111	118	126
W4D1	119	234	285.	321	178	200	211	219
W4D5	116	216	277	316	177	188	192	197
W4D10	110	203	264	292	147	155	160	163
IA	*	*	*	*				
Il	*	*	*	*	*	*	*	*
IA: II	NS	NS	NS	NS	NS	NS	NS	NS

D is days after planting. IA is irrigation amount, II is irrigation interval, IA:II is interaction between irrigation amount and irrigation interval, "***" means p < 0.001, "**' means 0.001 < p <0.01, *' means 0.01 < p < 0.05, NS means not significant

4)***Stem diameter***

The plant stem plays a significant function in plant anchorage and in the movement and transport of water, solutes and nutrient. Importantly, the stem plays roles in photosynthesis and nutrient storage. The effects of irrigation amount and irrigation interval on cucumber plant stem diameter at 25 and 46 days after planting are presented in in Table IV for 2023 and 2024 cropping seasons respectively. At 25 days after planting, the highest stem diameter was 4.93 mm in 2023 and 6.25 in 2024. In 2023 cropping season irrigation amount and irrigation interval significantly affected stem diameter at ($p < 0.05$) while irrigation days have very high significant effect on stem diameter at $p < 0.001$. The rate of stem diameter increase decreased obviously at 32 days after planting and the added values of stem diameter ranged from 1.7 to 2.47 mm at the flowering and fruiting stage. In the second season of 2024, irrigation interval and irrigation days significantly affected stem diameter. In both seasons, the single factor of irrigation days very highly significantly affected stem diameter at $p < 0.001$.

TABLE IV: EFFECTS OF DIFFERENT IRRIGATION REGIMES AND IRRIGATION INTERVALS ON STEM DIAMETER OF CUCUMIS SATIVUS (MM)

	2023				2024			
Treatment	25D	32D	37D	46D	25D	32D	37D	46D
W1D1	4.93	7.14	9.27	11.55	6.25	6.52	6.66	6.78
W1D5	4.56	6.77	8.97	10.56	6.03	6.23	6.33	6.56
WID10	4.48	6.62	8.83	10.14	5.6	5.8	6.14	6.24
W2D1	4.50	6.0	8.0	10.54	5.63	5.97	6.1	6.16
W2D5	4.45	6.56	6.3	8.0	5.56	5.9	` 6.0	
W2D10	4.01	6.48	8.0	10	4.52	4.8	5.0	5.23
W3D1	4.35	6.53	8.77	9.73	6.03	6.23	6 .33	7.45
W3D5	4.23	6.41	8.64	9.56	5.63	5.95	6.16	5.30
W3D10	4.13	6.35	8.49	9.47	4.14	4.72	5.12	6
W4D1	4.04	5.95	8.31	9.40	6.03	5.80	6.14	7.57
W4D5	3.98	5.73	8.16	9.14	5.61	5.76	6.04	6.30
W4D10	3.79	5.49	7.99	8.78	4.79	4.99	5.83	6.9
IA	*	*	*	*				
II	*	*	*	*	*	*	*	*
IA: II	NS	NS	NS	NS	NS	NS	NS	NS

D is days after planting. IA is irrigation amount, II is irrigation interval, IA:II is interaction between irrigation amount and irrigation interval, "***" means p < 0.001, "**' means 0.001 < p <0.01, *' means 0.01 < p < 0.05, NS means not significant

B. Effects of different irrigation regimes and intervals on yield and yield parameters of cucumber

1)***Effects on fruit yield***

Effects of varying water application and irrigation interval is presented in Table V. In 2023, the highest marketable cucumber yield of 151 t/ha was obtained with 100% ETc at daily interval which was 39%, 58% and 83% higher than that obtained with 75% ETc, 50% ETcand 25% ETc irrigated daily respectively while the lowest yield of 16.3 t/ha was recorded with 25% ETc at ten days interval. The total yield of all treatments was 794.5 t/ha. In 2024 season, similarly, daily irrigation with 100% ETc produced the highest yield of 123.1 t/ha which was 29. 3%, 59.4% and 81.2% higher than in 75 ETc, 50% ETcand 25% ETc irrigated daily respectively while the lowest yield of 11.5 t/ha was achieved with 25% ETc, irrigated every ten days. The total yield of all treatment was 703.2 t/ha t/ha representing a decline of 11.5% over 2023. This could be attributed to higher evapotranspiration (221.22 mm) in 2023 which considerably improved nutrient uptake as a result of more available soil moisture in the root zone. In both seasons, increased irrigation level and shorter interval increased fruit yield of cucumber. This observation is consistent with the findings of [16] and [17] who reported the highest cucumber fruit yield at 100% full irrigation. The interaction between irrigation amount and irrigation interval treatment were important for cucumber yield and the singe factors of irrigation and interval very significantly ($p < 0.001$) influenced fruit yield in both seasons.

TABLE V: EFFECTS OF DIFFERENT IRRIGATION REGIMES AND IRRIGATION INTERVALS ON FRUIT YIELD OF *CUCUMIS SATIVUS (T/HA)*

	2023	2024
Treatment	Y (t/ha)	Y (t/ha)
W1D1	151	123.1
W1D5	115	103.5
W1D10	102	81.9
W2D1	92	87.1
W2D5	76	75.2
W2D10	63	58.1
W3D1	52.9	50.0
W3D5	46.3	43.3
W3D10	35.0	30.6
W4D1	24.9	23.1
W4D5	20.1	15.8
W4D10	16.3	11.5
IA	***	***
II	***	***
IA:II NS	NS	

2) ***Effects on average fruit weight***

The average weight of cucumber fruits harvested under different treatments for seasons 2023 and 2024 is presented in Table VI. In 2023, the highest total fruit weight of 72.6 kg was produced with full irrigation amount applied daily while the lowest fruit weight of 7.7 kg was recorded with 25% irrigation amount applied every ten days representing 89.4% decrease in yield. This reduction agrees with the findings of {2} and [18] that the yield of cucumber decreased as irrigation amount decreased which shows that irrigating a plant below full irrigation amount has the tendency to reduce yield. In addition, long irrigation interval puts the plant under severe water stress. Similarly, in 2024 season, the highest total weight of cucumber (59.1kg) occurred with full irrigation and daily irrigation interval while the lowest fruit weight (5.5 kg) was recorded with 25% irrigation amount applied every ten days. The represents a reduction in total fruit weight of 89%. The results of statistical analysis on average fruit weight of cucumber for 2023 show that the single factors of irrigation amount, irrigation interval or days of irrigation have very high significant ($p < 0.001$) effect on weight of fruits. Similarly, in 2024, irrigation amount, irrigation interval and irrigation days had very high significant ($p < 0.001$) effect on average weight of cucumber plant. In combined season, single factors of irrigation amount, irrigation interval or irrigation days as well as interactions between irrigation amount and irrigation interval very highly affected average fruit weight of cucumber at $p < 0.001$. Multiple comparison of means between groups of irrigation amount by Post Hoc analysis showed that Group 25 Vs Group 100 of irrigation amount had the largest mean difference (2.2532), implying that irrigating at these two levels of irrigation amount produced the most pronounced effect on average weight. Also, the mean differences between groups of irrigation interval were compared and it was observed that Group 1 Vs Group 10 had the largest mean difference (-1.4143), suggesting that these two levels of irrigation interval produced the most pronounced effect on average weight of cucumber. In addition, when the mean differences between groups of irrigation days were compared at $p < 0.05$, it was observed that Group 46 Vs Group 58 had the largest mean difference (4.6152), indicates that irrigating at these two levels of irrigation days produced the most pronounced effect on average weight.

TABLE VI: EFFECTS OF DIFFERENT IRRIGATION REGIMES AND INTERVALS ON AVERAGE WEIGHT OF CUCUMIS SATIVUS FRUIT PER PLOT/DAY

	2023										2024									
Treatment	43D	46D	49D	52D	55D	58D	61D	64D	67D	70D	43D	46D	49D	52D	55D	58D	61D	64D	67D	70D
W_1D_1	5.8	2.5	6.0	4.4	8.0	11.7	6.8	5.2	4.6	17.6	5	2.3	5.6	3.9	6.5	9.9	5.7	5.1	4.3	10.9
W_1D_5	1.3	1.6	5.8	3.7	6.8	10.8	5.3	5.2	4.6	7.2	4.4	1.6	6.0	3.4	5.5	8.4	4.7	4.6	4.1	7.0
W_1D_{10}	4.0	2.0	5.1	2.9	4.9	10.3	4.0	5.1	4.0	6.4	3.5	2.0	4.1	2.3	3.5	6.7	4.6	3.1	3.5	6.0
W2D1	3.7	1.9	4.4	3.0	4.7	7	2.8	4.9	3.6	8.1	3.7	1.9	4.9	3.0	4.7	7.0	3.9	4.9	3.6	8.1
W2D5	3.2	1.6	4.6	2.7	3.7	5.8	3.5	4.0	3.2	5.9	3.2	1.6	4.6	2.7	3.7	5.8	3.5	4.0	3.2	5.9
W2D10	2.6	1.6	3.1	1.7	2.2	3.8	3.2	4.1	2.7	5.4	2.6	1.6	3.1	1.7	2.2	3.8	3.2	4.7	2.7	5.4
$W3D_1$	2.0	1.1	2.9	1.7	2.8	3.8	2.1	3.1	2	3.8	2.5	1.5	3.7	2.1	3.1	4.9	2.8	3.9	2.7	4.8
$W3D_5$	1.8	1	2.5	1.4	2.1	3.4	1.9	2.6	1.8	3.8	2.2	1.2	3.2	1.9	2.4	4.7	2.5	3.4	2.0	5.3
$W3D_{10}$	1.2	0.7	1.7	1.1	1.8	2.8	1.5	2.1	1.4	3.1	1.6	0.8	1.7	2.5	4.5	3.4	1.9	4.0	1.6	4.6
$W4D_1$	0.8	0.4	1.4	0.7	0.8	2.0	1.1	1.5	1.0	2.2	2.2	2.2	2.4	3.1	4.4	3.6	2.5	2.6	4.5	3.3
$W4D_5$	0.8	0.4	1.3	0.8	0.8	1.6	0.8	1.1	0.6	2.1	1.1	1.8	1.5	2.0	2.9	2.6	1.7	1.7	2.8	2.0
$W4D_{10}$	0.6	0.3	1.2	0.6	0.6	0.9	0.6	0.4	0.4	2.4	0.83	1.5	0.83	1.6	2.9	1.6	1.6	1.4	1.9	2.3
IA	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***
II	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***
IA: II	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

D is days after planting. IA is irrigation amount, II is irrigation interval, IA:II is interaction between irrigation amount and irrigation interval, "***" means $p < 0.001$, "**' means $0.001 < p < 0.01$, *' means $0.01 < p < 0.05$, NS means not significant

3) *Effects on fruit length*

The average fruit length in 2023 and 2024 seasons are presented in Table VII. In 2023, the highest average fruit length (36.1cm) was achieved with 100% ET_C daily while the least length (28.0cm) was recorded with 25% ET_C and 10 days irrigation interval. The result of this study on fruit agrees with [3] who reported the highest average fruit length of 15.95cm at 100% ET_C daily. However, [17] and [4] reported the highest value of 18.33cm at 80% and 26.55cm at 65% respectively. Their results are, however, much lower than that achieved in this study. In 2023, the effect on fruit length ($p<0.001$). The interactions between factors did not produce any significant effect on fruit length. Comparison of mean differences between irrigation treatments shows the Group 100 had the largest mean difference (2.42) indicating that these levels of irrigation treatment had the most pronounced influence on cucumber length. Similarly, comparison of mean differences between irrigation intervals shows the irrigating daily had the largest mean difference (-0.784), therefore produced the most significant effect on cucumber length. This observation implies better fruit length can be produced by irrigating at 100% ET_C daily.

TABLE VII: EFFECTS OF DIFFERENT IRRIGATION REGIMES AND INTERVALS ON AVERAGE LENGTH OF *CUCUMIS SATIVUS* FRUIT

	2023										**2024**									
Treatment	43D	46D	49D	52D	55D	58D	61D	64D	67D	70D	43D	46D	49D	52D	55D	58D	61D	64D	67D	70D
W_1D_1	35.3	36.1	35.0	35.0	35.5	35.7	35.5	35.3	35.1	36.0	34.57	34.74	34.17	34.28	34.67	34.67	34.53	34.43	34.52	34.87
W_1D_5	34.5	34.7	34.7	34.5	34.3	34.3	34.5	34.7	34.7	34.7	33.80	33.90	33.77	33.63	33.53	33.57	33.67	33.80	33.80	33.80
W_1D_{10}	33.3	34.0	33.3	33.7	33.5	34.0	33.7	34.0	33.7	33.6	32.82	33.12	32.83	33.90	32.98	33.12	33.08	33.18	33.02	32.90
W2D1	35.70	35.5	35.0	35.25	35.60	35.60	35.40	35.20	35.55	36.0	33.13	33.12	32.83	32.95	33.27	35.60	33.17	33.13	33.22	33.22
W2D5	34.60	34.70	34.60	34.40	34.30	34.40	34.60	34.70	34.70	34.70	32.43	32.43	32.40	32.30	32.20	32.47	32.50	32.50	32.43	32.53
W2D10	31.50	31.7	31.70	31.40	31.7	31.50	31.70	31.70	31.70	31.50	31.72	31.12	31.40	31.67	31.52	31.12	31.95	31.85	31.62	31.62
$W3D_1$	32.7	32.7	32.5	32.6	32.9	32.7	32.7	32.8	32.6	32.9	33.27	32.93	32.93	33.03	33.27	33.40	33.13	33.10	33.37	32.77
$W3D_5$	32.3	32.3	32.0	32.0	32.0	32.0	31.9	32.0	32.0	32.0	32.47	32.40	32.23	32.27	32.20	32.50	32.53	32.00	32.43	32.07
$W3D_{10}$	31.5	31.7	31.7	31.4.	31.7	31.5	31.7	31.7	31.7	31.5	31.83	31.00	31.47	31.63	31.60	31.07	32.00	31.80	31.60	30.80
$W4D_1$	31.0	31.1	31.0	31.0	31.2	32.0	31.4	31.4	31.2	31.2	34.22	33.70	33.75	34.03	34.17	34.30	33.97	34.02	34.40	33.43
$W4D_5$	30.4	30.2	30.2	30.5	30.3	31.0	31.0	30.8	30.6	30.9	33.27	33.17	33.03	33.03	33.0	33.37	33.47	33.40	33.33	32.62
$W4D_{10}$	30.0	28.0	29.0	30.0.	29.1	28.0	30.3	30.0	29.5	30.1	32.55	31.60	32.10	32.42	32.32	31.85	32.72	32.45	32.23	30.10
IA	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***
II	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***
IA:II	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

D is days after planting. IA is irrigation amount, II is irrigation interval, IA:II is interaction between irrigation amountand irrigation interval, "***" means $p < 0.001$, "**' means $0.001 < p < 0.01$, *' means $0.01 < p < 0.05$, NS means not significant

4) *Effects on Fruit Diameter*

The average diameter of cucumber fruits in 2023 and 2024 seasons are presented in tables VIII. In 2023, the highest average diameter (5.99cm) was recorded with 100% ET_C daily irrigation while the lowest average diameter (5.11cm) was achieved with 25% ET_C at 10 days interval. However, [4] reported highest value of 5.87 cm with 100% ET_C and lowest value of 2.86 cm with 40% ET_C. Similarly, in 2024, the average diameter of cucumber (5.88 cm) was recorded with 100% ET_C daily irrigation while the lowest value (5.33cm) was obtained with 25% ET_C irrigation at 10 days interval. In both seasons, none of the factors had any significant effect on fruit length. In combined season, statistical analysis shows that single factors of irrigation amount, irrigation interval or irrigation days had very high significant effect on cucumber fruit diameter at p <0.001. Also, irrigation amount + irrigation interval, irrigation amount + irrigation days, irrigation interval + irrigation days and irrigation amount + irrigation interval + irrigation days had very high significant effect on fruit diameter, suggesting that interactions between these factors had very high significant effect on cucumber fruit at P<0.001.

TABLE VIII: EFFECT OF DIFFERENT IRRIGATION REGIMES AND INTERVALS ON AVERAGE FRUIT DIAMETER (CM)

	2023										2024									
Treatment	43D	46D	49D	52D	55D	58D	61D	64D	67D	70D	43D	46D	49D	52D	55D	58D	61D	64D	67D	70D
WIDI	5.95	5.99	5.93	5.96	5.90	5.91	5.98	5.93	5.95	5.99	5.88	5.75	5.77	5.78	5.8	5.81	5.8	5.82	5.88	5.93
W1D5	5.87	5.87	5.88	5.81	5.82	5.81	5.83	5.85	5.87	5.88	5.87	5.74	5.77	5.77	5.72	5.81	5.74	5.77	5.84	5.78
W1D10	5.77	5.75	5.73	5.78	5.78	5.75	5.73	5.71	5.78	5.71	5.75	5.73	5.75	5.76	5.70	5.78	5.43	5.46	5.43	5.11
W2D1	5.8	5.5	5.6	5.6	5.7	5.7	5.83	5.7	5.8	5.88	5.75	5.55	5.62	5.6	5.68	5.66	5.8	5.65	5.7	5.74
W2D5	5.7	5.6	5.65	5.72	5.61	5.8	5.65	5.69	5.8	5.68	5.62	5.58	5.6	5.63	5.57	5.67	5.59	5.63	5.67	5.6
W2D10	5.36	5.32	5.52	5.4	5.4	5.38	5.43	5.20	5.15	5.10	5. 61	5.54	5.5	5.6	5.57	5.62	5.43	5.46	5.43	5.1
W3D1	5.69	5.60	5.63	5.60	5.65	5.61	5. 60	5.60	5.60	5.61	5. 58	5.45	5.48	5.47	5.55	5.47	5.31	5.6	5.46	5.46
W3D5	*5.55*	5.56	5.55	*5.53*	*5.53*	*5.53*	*5.53*	*5.56*	*5.53*	*5.52*	5.55	5.43	5. 4	5.43	5.38	5.38	5.53	5.56	5.38	5.37
W3D10	5.43	5.42	5.45	5.44	5.43	5.44	5.43	5.41	5.41	5.40	5.43	5.42	5.38	5.35	5.35	5.38	5.43	5.28	5.28	5.26
W4D1	5. 31	5.31	5.32	5.33	5. 31	5.33	5.31	5. 30	5.31	5.30	5.29	5.30	5.2	5.23	5.18	5.18	5.45	5.81	5.52	5.75
W4D5	5.24	5.23	5.23	5. 24	5.23	5.23	5. 22	5. 22	5.23	5.22	5. 38	5. 40	5.33	5.27	5.26	5.38	5.53	5.56	5.38	5.37
W4D10	5. 11	5. 11	5.12	5.13	5.12	5.13	5.15	5.14	5.15	5.11	5.35	5. 54	5.25	5.20	5.21	5.36	5.43	5.46	5.43	5.11
IA	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***
II	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***
IA:II	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***

D is days after planting. IA is irrigation amount, II is irrigation interval, IA:II is interaction between irrigation amount and irrigation interval, "***" means p < 0.001, "**' means 0 .001 < p <0.01, *' means 0.01 < p < 0.05, NS means not significant.

5) *Effects on number of Fruits*

The number of fruits harvested per treatment per plot is presented in Table IX for 2023 and 2024 seasons. Total fruit yield per plot at the end of 2023 cropping season ranged from 36 - 124 with full irrigation at daily interval providing the highest number and 25% of ET_C at 10 days interval yielding the lowest member of fruits. This result is consistent with the findings of [3], [6] and [16]. The result of statistical analysis showed that there were significant differences in the number of fruits per plot among the irrigation treatments. Irrigation amount and irrigation interval produced very high significant differences in number of fruits ($p < 0.001$). In 2024 season, results showed that irrigation interval had high significant ($p < 0.01$) influence on fruit number and irrigation days had very high significant ($p < 0.001$) effect on number of fruits. In combined season, statistical analysis showed that single factors, irrigation amount, irrigation interval or

irrigation days had very high significant ($p < 0.001$) effect on number of fruits. The interactions between irrigation amount and irrigation interval, irrigation amount and irrigation days, highly and very highly affected number of fruits at $p < 0.01$ and $p < 0.001$ respectively. Post Hoc analysis results show that the largest mean between irrigation amount occurred in Group 50 Vs Group 100, indicating that these two levels of irrigation amount produced the most pronounced effect on number of cucumber fruits at ($p < 0.05$). Comparison of mean difference between groups of irrigation interval indicate that none of these levels of irrigation interval had any significant effect on number of fruits. However, comparison mean differences between groups of irrigation days at $p < 0.05$ showed that Group 46 Vs Group 58 had the most pronounced effect on number of fruits with the largest mean difference (10.1587).

TABLE IX: EFFECTS ON NUMBER OF FRUITS PER PLOT

	2023										2024									
Treatment	43D	46D	49D	52D	55D	58D	61D	64D	67D	70D	43D	46D	49D	52D	55D	58D	61D	64D	67D	70D
W1D1	10	4	12	6	17	21	10	11	9	24	11	5	12	8	14	19	10	11	10	25
W1D5	7	3	10	6	11	18	9	10	7	15	8	4	10	7	11	17	9	10	8	17
W1D10	6	3	8	5	10	17	7	8	7	14	4	5	6	6	8	15	6	6	7	14
W2D1	6	3	10	5	8	15	6	7	7	15	7	4	8	6	7	15	6	8	8	14
W2D5	7	6	8	5	8	15	8	8	6	14	6	3	8	7	7	14	7	8	6	14
W2D10	5	5	3	5	8	14	6	7	6	13	5	3	7	6	6	13	6	7	6	13
W3D1	5	3	7	5	6	13	6	7	6	13	5	3	7	5	5	12	6	7	6	13
W3D5	5	3	7	4	6	12	6	7	5	13	5	3	7	4	5	11	6	7	5	12
W3D10	5	3	7	4	4	11	6	7	5	12	4	3	7	4	4	11	6	6	5	10
W4D1	4	2	7	4	4	10	5	6	4	10	5	3	7	5	5	11	8	7	6	9
W4D5	4	2	7	4	3	8	4	5	2	10	5	3	7	4	5	11	6	7	5	9
W4D10	3	1	5	3	3	3	3	3	2	10	4	3	5	4	4	9	6	6	5	10
IA	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***
II	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***
IA:II	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**

D is days after planting. IA is irrigation amount, II is irrigation interval, IA:II is interaction between irrigation amount and irrigation interval, "***" means $p < 0.001$, "**' means $0.001 < p < 0.01$, *' means $0.01 < p < 0.05$, NS means not significant

C. Water Use Efficiency

1) ***Applied water and water use efficiency***

Table X shows the applied water in full and deficit irrigation treatments in 2023 and 2023/2024 seasons.

In 2023, the results indicated that total depth of water applied for full irrigation 100% ET_c treatment along the entire season was 206.82 mm while the deficit irrigation treatment (75%, 50% and 25% ETc) applied 155.12, 103.4, 51.71 mm respectively. In 2023/2024 season, the result showed that the total water applied for full irrigation treatment 100% ETc in the entire cropping season was 269.41 mm, while deficit irrigation treatment applied 202.06, 134.71 and 67.35 mm respectively. Seasonal evapotranspiration values were 186.30, 139.75, 93.15 in 2023 and 46.57mm and 242.46, 181.35, 121.23 and 60.62 in 2023/2024 for 100%, 75%, 50% and 25% ETc respectively. The yields for each treatment were compared and found to be statistically non - significant ((0.2161>0.05) between the seasons. The average yield values for the treatment ranged between 16.3 151t/ha and 11.5 -123.1 t/ha in 2023 and 2023/2024 cropping seasons respectively. The highest yields were obtained by the treatments with 100% ETc, daily irrigation while the least yields were produced by the treatments with 25% ETc, irrigated every ten days. The results are in agreement with the findings of [18] who reported the highest value of 21 t/ha and 20.3t/ha in cucumber with 100% ETc, daily irrigation haand the lowest yield of 15 t/ha and 16.5t/ha with 60% ETc irrigated every ten days in the seasons the studied. Also [19] obtained the highest yield 116.3t/ha from 100% ETc daily irrigation while those irrigated at 50% ET_c gave the lowest yield of 37.8t/ha. From the two consecutive seasons, the highest ETc values within the ranges occurred in 100% ETc, daily irrigation to 100% ETc, irrigated every ten days while the lowest range occurred in 25% ETc, irrigated daily to 25% irrigated every ten days. The highest value of WP was recorded as 73kg/m^3 and 46.7 kg/m^3 in 100 ETc daily irrigation while the lowest values of 31kg/m^3 and 17.1kg/m^{3}were obtained in 2023 and 2024 seasons respectively. The lower WUE values achieved in this study are similar to results of studies by [20]; [5] and [3] who reported the lowest WUE values for cucumber in the lowest irrigation condition.

IV. Conclusion

The results of the study show the treatment combinations of 100 % ETc, irrigated daily, 100% ETc irrigated every 5 days and 75 % ETc, irrigated daily are good options for adoption by local cucumber farmers in the study area. However, in extreme limited water availability condition farmers best option is irrigating every day with 75 % of ETc because with the treatment combination a lot of water will be saved and yield optimized.

TABLE X: CROP WATER USE AND IRRIGATION WATER USE EFFICIENCIES UNDER DIFFERENT WATER REGIMES AND IRRIGATION INTERVALS

	2023					2024				
Treatment	**IR (mm)**	**ETc (mm)**	**Y (t/ha)**	**WP (kg/m3)**	**IWP(kg/m3)**	**IR (mm)**	**ETc (mm)**	**Y (t/ha)**	**WP (kg/m3)**	**IWP(kg/m3)**
W1D1	206.82	186.30	151	73	81	269.41	242.46	123.1	46.7	50.8
W1D5	206.82	186.30	115	56	62	269.41	242.46	103.5	38.4	42.7
W1D10	206.82	186. 30	102	49	55	269.41	242.46	81.9	30.4	33.8
W2D1	155.12	139.73	92	59	66	202.06	181.85	87.1	43.1	47.9
W2D5	155.12	139.73	76	49	54	202.06	181.85	75.2	37.2	41.35
W2D10	155.12	139.73	63	41	45	202.06	181.85	58.1	28.8	31.9
W3D1	103.4	93.15	52.9	51	57	134.71	121.23	50.0	32.1	41.2
W3D5	103.4	93.15	46.3	45	50	134.71	121.23	43.3	32.1	35.7
W3D10	103.4	93.15	35.0	34	38	134.71	121.23	30.6	22.7	25.2
W4D1	51.71	46.57	24.9	48	54	67.35	60.62	23.1	34.3	38.1
W4D5	51.71	46.57	20.1	39	43	67.35	60.62	15.8	23.5	26.1
W4D10	51.71	46.57	16.3	31	34	67.35	60.62	11.5	17.1	19.0
IA			***							
II			***				***			
IA:IINS				NS						

D is days after planting. IA is irrigation amount, II is irrigation interval, IA:II is interaction between irrigation amount and irrigation interval, “***” means $p < 0.001$, “**’ means $0.001 < p < 0.01$, *’ means $0.01 < p < 0.05$, NS means not significant

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