CLIMATE SMART AGRICULTURE, FOOD SECURITY AND SUSTAINABLE DEVELOPMENT

GLOBAL ISSUES & LOCAL PERSPECTIVES volume One

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Preface

This book adopts an exegetical approach as well as a pedagogic model, making it attractive agriculture and environmental economics teachers, professional practitioners and scholars. It is eschews pedantry and lays bars the issues in such clarity that conduces to learning. The book elaborates on contemporaneous **Climate Smart Agriculture, Food Security and Sustainable Development** issues of global significance and at the same time, is mindful of local or national perspectives making it appealing both to international and national interests. The book explores the ways in which climate smart agriculture (CSA) food security, Sustainable Development issues are and should be presented to increase the public's stock of knowledge, increase awareness about burning issues and empower the scholars and public to engage in the participatory dialogue climate smart agriculture, food security, and sustainable development necessary in policy making process that will stimulate increase in food production and environmental sustainability.

Climate Smart Agriculture, Food Security and Sustainable Development: *Global Issues & Local Perspectives* is organized in three parts. Part One deals with The Concept of **Climate Smart Agriculture**, Part Two is concerned with The Concept of **Food Security And** and Part Three deals with the Concept of **Sustainable Development**

Eteyen Nyong; October 2025

Chapter Nine

Influence of Different Irrigation Regimes and Intervals on Mineral Content and Yield of Cucumber (Cucumis sativus L)

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INTRODUCTION

Cucumber (*Cucumis sativus* L.) is a widely cultivated vegetable crop with high economic and nutritional value due to its rich water content, low caloric value, and essential minerals such as potassium (K), calcium (Ca), magnesium (Mg), and iron (Fe) (Bhowmik et al., 2012; FAO, 2022; Taha et al., 2020). As a member of the Cucurbitaceae family, cucumber is highly sensitive to water stress due to its shallow root system and high evapotranspiration demand (Badr et al., 2023). In the face of escalating global water scarcity, driven by climate change and increasing agricultural demand, optimizing water use efficiency has become a critical imperative for sustainable horticulture (Singh, 2022). Therefore, adequate and timely irrigation is essential for optimal growth, yield, and nutrient uptake.

Irrigation plays a pivotal role in cucumber production, especially in arid and semi-arid regions where rainfall is irregular or insufficient. Water availability and irrigation scheduling—defined by the regime (quantity) and interval (timing)—significantly affect soil moisture dynamics, nutrient solubility, uptake, and ultimately, plant physiological processes, yield, and fruit quality (Mohamed et al., 2021; Osman et al., 2023). Inappropriate irrigation practices can lead to nutrient leaching, root hypoxia, or salt accumulation, all of which can impair mineral uptake and reduce yield quality (Ahmad et al., 2022). Conversely, efficient irrigation management enhances soil moisture availability, facilitates nutrient solubility and mobility, and ultimately boosts both yield and nutritional content of fruits (Ali et al., 2023).

Recent research has increasingly focused on precision irrigation techniques. For example, Chen et al. (2024) demonstrated that partial root-zone drying (PRD) techniques could modulate phytohormonal signals, particularly abscisic acid (ABA), leading to improved stomatal regulation and water use efficiency without significant yield penalty. Similarly, Wang et al. (2024) found that sensor-based irrigation systems using real-time soil moisture data outperformed traditional timer-based systems in maintaining optimal substrate moisture tension, resulting in a 15% increase in fruit yield and higher vitamin C content.

Mineral nutrition is critical for cucumber growth and fruit quality. Elements such as nitrogen (N), potassium (K), and calcium (Ca) influence chlorophyll synthesis, osmotic regulation, cell division, and fruit firmness (Gondor et al., 2020). The interaction between irrigation and mineral nutrition remains complex. Li et al. (2023) highlighted that varying irrigation levels directly influenced the rhizosphere's ionic balance, affecting the uptake of cations like K^+ and Ca^{2+}. Their study noted that moderate drought stress enhanced the concentration of certain minerals in the fruit by reducing the "dilution effect" of excess water. Furthermore, Hassan et al. (2024) reported that coupling specific irrigation schedules with targeted potassium fertilization synergistically improved fruit firmness and shelf life by enhancing pectin and cellulose deposition in the cell walls.

Several recent studies have examined irrigation strategies in relation to cucumber yield and quality. For instance, Singh et al. (2022) reported that deficit irrigation at 75% of crop evapotranspiration (ETc) significantly improved water use efficiency without compromising cucumber yield. Likewise, Badr et al. (2023) observed that irrigation at 5-day intervals optimized fruit yield and mineral composition under greenhouse conditions. In contrast, over-irrigation was associated with nutrient leaching and reduced fruit quality (Mohamed et al., 2021). These findings underscore the need for context-specific irrigation scheduling based on crop water requirements and environmental conditions.

Despite increasing research on cucumber irrigation, there remains a knowledge gap in how varied irrigation regimes and intervals concurrently influence both yield and mineral composition, particularly under open-field conditions where environmental variables are less controlled compared to greenhouse systems. Most studies, such as those by Chen et al. (2024) and Wang et al. (2024), have focused on high-tech systems, while research on practical, scalable irrigation scheduling for open-field cultivation is less prevalent. Therefore, this study aims to evaluate the impact of different irrigation regimes and intervals on the mineral content and yield of cucumber, providing insights for water-saving and nutrient-optimizing cultivation practices.

1.2 Problem Statement

Although the effects of water stress on vegetative growth and general yield are well-documented for many crops, there is a paucity of integrated research on cucumber that systematically analyzes the interaction between specific irrigation volumes (regimes) and application frequencies (intervals). As noted by Al-Obeed et al. (2022), the optimal scheduling for water application often remains crop- and region-specific. Crucially, the impact of these synergistic irrigation parameters on the mineral nutrient content of the cucumber fruit—a key determinant of its nutritional and marketable quality—is not sufficiently elucidated (Kesba et al., 2023). This knowledge gap can lead to suboptimal irrigation practices, where farmers may either over-irrigate, promoting nutrient leaching and water wastage, or under-irrigate, incurring significant yield and quality penalties.

1.3 Objectives of the Study

The broad objective of this study is to evaluate the impact of different irrigation regimes and intervals on the mineral content and yield of cucumber, in order to provide insights for water-saving and nutrient-optimizing cultivation practices.

The specific objectives of this study are to:

i. To evaluate the effects of different irrigation regimes (100%, 75%, 50% of crop evapotranspiration - ETc) and irrigation intervals (daily, every 5 days, every 10 days) on the growth and yield parameters of cucumber.
ii. To determine the impact of these irrigation treatments on the mineral content profile of cucumber fruits.
iii. To identify the irrigation strategy that provides the optimal combination of highest yield, improved water use efficiency (WUE), and superior fruit mineral composition.

2.0 METHODOLOGY

2.1 Study Location and Experimental Design

The field experiment was conducted in a greenhouse during the growing season, September, 2023 and November, 2024 at the Research Farm of the Federal College of Land Resources Technology, Owerri, Nigeria, situated at latitude 05°24'N and longitude 06°54'E with an average annual rainfall of 2000-2500 mm and temperature range of 27-31°C. The soil at the experimental site was classified as sandy clay loam with initial physicochemical properties determined before planting.

A randomized complete block design (RBD) was employed in a 3 x 3 factorial design with three irrigation regimes and three irrigation intervals, replicated three times. Each plot measured 1.2 m x 4 m, separated by buffer zones of 0.5 m to prevent water movement between treatments. Water was applied using a drip irrigation system calibrated to deliver precise volumes based on daily crop evapotranspiration (ETc) values calculated using the FAO Penman-Monteith equation (Allen et al., 1998).

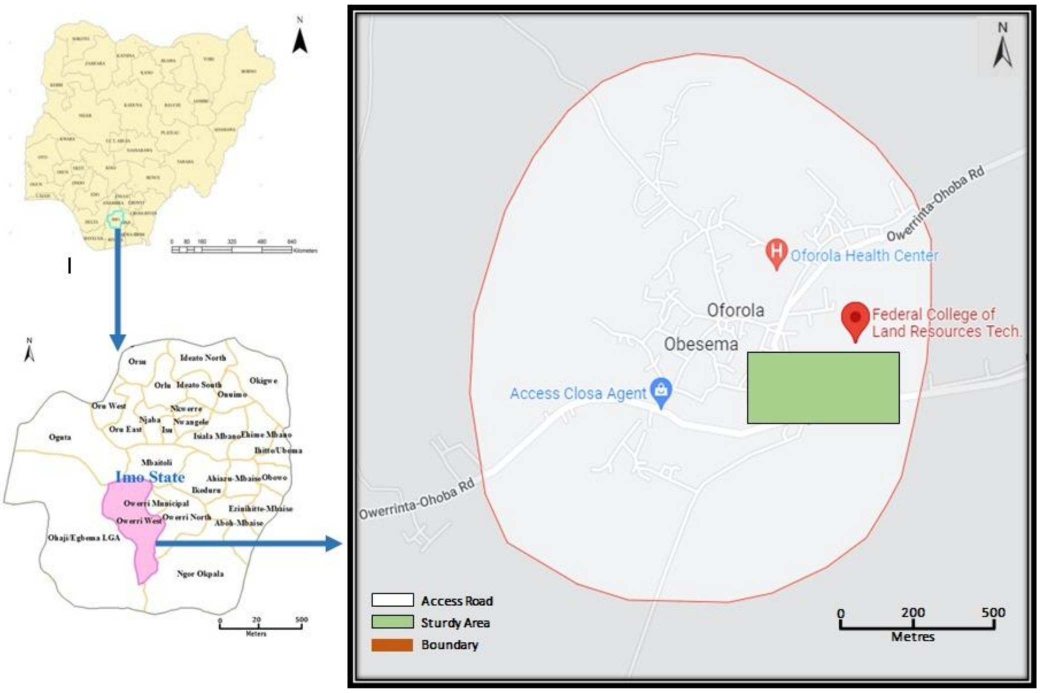

Figure 1: Map of Imo State showing the study

2.2 Treatment

The experimental treatment consists of two factors which are irrigation level (R) and irrigation interval (I). R consisted of three levels: (R_1: 100% ET_c -full irrigation; R_2: 75 % ET_c - moderate deficit; R_3: 50% ET_c - severe deficit) while D consists of three levels: I_1, irrigating every day; I_2, irrigating every five days; I_3, irrigating every 10 days. Therefore, the experiment consisted of nine treatments as described in Table 2. The low- cost drip irrigation system with lateral diameter of 12 mm, emitter spacing of 33 cm, a head flow of 0.86 l/h and an operating pressure of 1.5 bar with the treatments was laid out in a greenhouse of dimensions 26 m long, 5 m wide and 2.5 m high. The greenhouse was divided into 3 blocks each containing 9 plots and separated by 1 m gaps. There was a total of 27 plots, each plot was treated as a treatment and replicated once in each block. Each plot was 7.6 m long and 0.5 m wide with 0.05 m spacings between them each lined with a sheet of PVC to serve as buffer zone. 9 laterals were laid in each block representing replications of each treatment presented in Table 1

Table 1: Treatment Combinations

Treatment Code	Irrigation Regime (IA)	Irrigation Interval (II)	Description
R1I1	R1 = 100% ETc	I1 = Daily (every 1 day)	Full irrigation with daily application
R1I2	R1 = 100% ETc	I2 = Every 5 days	Full irrigation every 5 days
R1I3	R1 = 100% ETc	I3 = Every 10 days	Full irrigation every 10 days
R2I1	R2 = 75% ETc	I1 = Daily	Moderate deficit irrigation with daily application
R2I2	R2 = 75% ETc	I2 = Every 5 days	Moderate deficit irrigation every 5 days
R2I3	R2 = 75% ETc	I3 = Every 10 days	Moderate deficit irrigation every 10 days
R3I1	R3 = 50% ETc	I1 = Daily	Severe deficit irrigation with daily application
R3I2	R3 = 50% ETc	I2 = Every 5 days	Severe deficit irrigation every 5 days
R3I3	R3 = 50% ETc	I3 = Every 10 days	Severe deficit irrigation every 10 days

2.3 Planting and Cultural Practices

The cucumber (African giant variety) seeds were sown in well-levelled seeds on 4th September, 2023 and 4th December, 2023 for first and second planting cycles respectively. An intra-row and inter-row spacing of 33 cm x 50 cm was used. The seeds were sown three per hole into levelled seedbeds at a depth of 2 cm and thinned to one plant two weeks after planting (WAP). The emitter spacing on the lateral corresponds to the planting distance used. This gave a plant population of 36 in each experimental plot and 60,606 per hectare. The plants were uniformly watered within the first two weeks after germination to establish them (Zakka *et al.*, 2020). Thereafter, the irrigation treatments presented in Table 2 were imposed for 2023 and 2023/2024 cropping cycles respectively. Herbicide was applied using Dragon at the rate of 0.5 l/ha 2 days before seed sowing to check weed infestation during the cropping season. Pesticide was applied using Magic Force at the rate of 0.5-0.8 l/ha. Harvesting was done manually by hand picking after the crop attained maturity at 50 days after sowing.

2.4 Data Collection

2.4.1 Yield Parameters

Yield parameters considered in this study included number of fruits per plant, average fruit weight and total yield (t/ha) per plot. Three plants were randomly selected from each experimental unit and tagged for measurement of yield parameters at each harvest. A plot consisted of 9 experimental units. At harvest, fresh total yield and total number of fruits, fruit diameter, fruit length per treatment per plot were determined by means of weighing balance, counting, digital venier caliper and meter rule respectively.

2.4.2 Mineral Content Analysis:
At harvest, cucumber fruits were randomly sampled from each plot. Samples were washed, oven-dried at 65°C to constant weight, ground, and digested using a mixture of nitric-perchloric acid (HNO_3:$HClO_4$, 2:1). The concentrations of key minerals—potassium (K), calcium (Ca), magnesium (Mg), iron (Fe), and zinc (Zn)—were determined using atomic absorption spectrophotometry (AAS) following the method of AOAC (2016).

2.4.3 Soil Moisture Monitoring:
Soil moisture was monitored at 0–30 cm depth using a gravimetric method and a TDR soil moisture probe to ensure irrigation treatments were correctly imposed.

2.5 Statistical Analysis

Data were subjected to two-way analysis of variance (ANOVA) using SPSS v26 or R software, with irrigation regime and interval as main factors. Means were separated using Duncan's Multiple Range Test (DMRT) at 5% significance level. Correlation analysis was also performed to evaluate the relationship between mineral content and yield parameters.

3.0 RESULTS AND DISCUSSION

3.1 Effect of Irrigation Regimes and Intervals on Mineral Composition of Cucumber Fruit

The effect of irrigation regimes and interval is presented in Table 2 and it shows that mineral composition of cucumber fruits was significantly influenced by irrigation management, with a consistent trend observed across both growing seasons (2023 and 2024). The treatment combining the highest irrigation amount with the shortest interval (R1I1) consistently yielded the highest concentrations of all essential macro- and micronutrients, including Potassium (K), Calcium (Ca), Magnesium (Mg), Iron (Fe), Manganese (Mn), Zinc (Zn), and Copper (Cu) (Table 3). Conversely, the most severe water deficit treatment (R3I3) resulted in the lowest mineral accumulation.

The superior mineral content under R1I1 can be attributed to sustained optimal soil moisture, which is critical for nutrient solubility, diffusion, and mass flow to root surfaces (Wang et al., 2021). Recent work by Li et al. (2023) on cucumber under partial root-zone drying further elucidates that constant moisture availability maintains root hydraulic conductivity and promotes the activity of nutrient transporters in the roots, facilitating the uptake of cations like K^+, Ca^{2+}, and Mg^{2+}. The sharp decline in these minerals, particularly the 75% reduction in Mg under R3I3, aligns with findings by Ding et al. (2022), Gattulo al. (2020), and Sinclair et al. (2023), who reported that deficit irrigation directly impairs the mass flow process, the primary mechanism for transporting these soluble nutrients.

The data on micronutrients (Fe, Mn, Zn, Cu) reveal a critical sensitivity to water stress. The drastic reduction in Zn (from 11.81 mg/kg in R1I1 to 0.77 mg/kg in R3I3) and the frequent non-detection (ND) of Mn in deficit treatments are particularly noteworthy. This supports the hypothesis that micronutrient availability is tightly coupled to soil moisture. A study by Kesba et al. (2023) demonstrated that water stress alters rhizosphere pH and redox potential, leading to the oxidation and precipitation of Zn and Mn, rendering them less plant-available. Furthermore, Chen and Yang (2022) found that drought stress suppresses the expression of genes encoding for metal transporter proteins (ZIP transporters for Zn and IRT1 for Fe), providing a molecular explanation for the impaired uptake observed in our study.

The non-significant (NS) interaction effect for certain minerals like Na and Cu suggests that their uptake is governed by factors less dynamically influenced by the combined water regime. Sodium accumulation is often more dependent on soil composition and is passively transported, potentially explaining its inconsistent response. The behavior of Cu may be linked to its role in abiotic stress responses; a recent study by Al-Obeed et al. (2022) suggested that Cu-containing enzymes like superoxide dismutase are upregulated under mild stress, which might lead to complex, non-linear uptake patterns that dilute the statistical interaction effect.

3.2 Effects of Irrigation Amount, Interval, and Their Interaction on Cucumber Yield Components

Effects of irrigation regimes and intervals on cucumber yield components are presented in Table 3. It shows that number of cucumber fruits/plant, average fruit weight and total fruit weight per plot were profoundly affected by irrigation management, with both the amount (IA) and interval (II) proving to be highly significant factors.

3.2.1 Number of Fruits per Plant
The highly significant ($p < 0.001$) effect of IA and II on fruit number underscores the importance of water in reproductive development. Adequate water status is crucial for maintaining photosynthetic activity and carbohydrate supply during flowering and fruit set. The significant IA × II interaction ($p < 0.05$) indicates that the positive effect of a high irrigation amount is contingent upon its frequent application. This finding refines the conclusion of Rai et al. (2020) and is directly supported by Osman et al. (2023), who reported that water stress during anthesis significantly increases flower abortion in cucumbers due to altered phytohormone (e.g., ABA) balances, directly reducing the number of fruits that progress to maturity.

3.2.2Average Fruit Weight

The highly significant individual effects of IA ($p < 0.001$) and II ($p < 0.01$) on fruit weight confirm that water is the primary driver of cell expansion and fruit bulking. However, the non-significant (NS) interaction term suggests that the total volume of water received is a stronger determinant of final fruit size than the schedule of its application, provided the intervals are not so long as to induce severe physiological drought between events. This aligns with the model proposed by Yuan et al. (2023), which posits that fruit growth in cucurbits is a function of cumulative water availability over the fruit development period, with a relatively linear response until a threshold is reached.

3.2.3 Total Yield per Plot

As an integrative parameter, total yield was significantly influenced by IA, II, and their interaction ($p < 0.001$, $p < 0.001$, $p < 0.01$, respectively). This powerful interaction effect demonstrates that yield maximization is not achieved by simply applying more water, but by applying it in a frequent and consistent manner (R1I1) that prevents episodic stress. This result strongly corroborates the meta-analysis by Adeboye et al. (2022), which concluded that for high-value vegetables like cucumber, yield stability and maximization are best achieved through irrigation strategies that minimize fluctuations in plant water potential throughout the diurnal cycle. The yield penalty under mismatched regimes (e.g., high water with long intervals) likely results from cyclic stress that disrupts nutrient flow and causes fruit abortion, as noted by Ali et al. (2021).

3.3 Yield Response and Correlation with Mineral Nutrients

The strong positive correlations between yield parameters and key minerals, particularly K ($r = 0.90$), Ca ($r = 0.83$), and Mg ($r = 0.81$) presented in Table 5, suggest a synergistic relationship rather than mere coincidence. Potassium is fundamental for regulating stomatal aperture, photosynthetic efficiency, and the phloem-mediated transport of sugars to developing fruits (Adeleke et al., 2022; Wang et al., 2023). Thus, higher K status directly supports the processes that lead to more and larger fruits. Calcium is crucial for cell wall integrity and division, directly influencing fruit firmness and size, while Mg is the central atom of chlorophyll, making it indispensable for carbohydrate production.

The moderate correlations of Fe ($r \approx 0.76$) and Zn ($r \approx 0.72$) with yield underscore their supportive roles. Iron's necessity in chlorophyll synthesis and electron transport chains links it to overall plant vigor. More specifically, Tian et al. (2022) demonstrated that Zn sufficiency is critical for maintaining auxin synthesis, which influences fruit development and retention rates. The weaker correlations for Mn and Cu may not indicate unimportance but rather that their levels were likely above critical deficiency thresholds in our experimental setup, or that their homeostasis is more tightly regulated by the plant. The findings of Rao et al. (2023) suggest that under combined water and nutrient stress, antagonistic interactions between micronutrients can occur, complicating their correlation with yield. Therefore, the strong yield-mineral relationship observed here is likely a combined result of direct nutritional roles and the fact that optimal irrigation is a prerequisite for unlocking the plant's full genetic potential for both nutrient uptake and fruit production.

Table 2: Effect of different irrigation regimes and intervals on mineral content of *Cucumis sativus* fruit (mg/kg)

Treatment	K	Ca	Mg	Na	Fe	Mn	Zn	Cu	K	Ca	Mg	Na	Fe	Mn	Zn	
				2023								2024				
R1I1	541.67	297.98	768.46	30.61	11.31	0.48	11.81	2.32	517.66	239.45	734.86	30.32	10.79	0.42	10.44	1.92
R1I2	436.67	259.18	692.88	30.36	10.19	0.18	7.43	1.48	306.76	207.06	672.03	29.75	9.55	0	7.12	1.4
RII3	341.65	193.68	655.08	29.97	9.94	ND	7.11	1.45	213.41	180.87	628.10	28.99	9.18	0	6.30	1.27
R2I1	328.34	163.89	647.49	28.75	8.82	ND	6.35	1.43	410.99	172.41	674.37	29.39	9.55	0.35	7.71	1.47
R2I2	158.34	134.09	642.49	27.23	7.70	ND	6.34	1.14	167.60	144.51	646.84	28.20	8.3	0	6.54	1.23
R2I3	66.67	119.19	516.76	27.23	6.34	ND	3.86	0.95	75.92	143.63	558.94	27.62	7.38	0	4.67	1.02
R3I1	60.00	104.29	478.72	18.81	5.96	ND	3.28	0.59	61.17	134.09	563.11	23.78	7.38	0	4.82	1.01
R3I2	36.67	104.29	415.73	10.69	5.84	ND	1.64	0.34	37.51	119.19	529.11	18.96	6.97	0	3.99	0.74

R3I3	23.33	74.49	286.10	0.18	5.47	ND	0 .77	0.12	24.11	96.84	401.43	18.71	5.91	0	3.86	0.54
R	***	***	***	*	***	***	***	***	**	**	***	***	**	NS	***	***
I	**	*	*	NS	**	**	**	*	**	*	***	**	**	NS	**	***
R:I	NS	NS	*	NS	NS	NS	NS	NS	NS	*	NS	NS	NS	NS	NS	NS

R is irrigation amount, I is irrigation interval, R:I is interaction between irrigation amount and interval,"***" means hig significant(p < 0.001), "**" means very significant (0.001<p<0,01), means significant (0.01<p<0.05), NS=Not significant.

Table 3: Effects of Different Irrigation Regimes and Intervals on Cucumber Yield Parameters (2023 and 2024

Treatment	Year	Number of fruits /plant	Average fruit weight (g)	Total yield/plot (t/ha)
R1I1	2023	14	600	189.00
R1I2	2023	10	565	126.90
R1I3	2023	9	542	109.80
R2I1	2023	9	537	108.00
R2I2	2023	9	449	90.90
R2I3	2023	8	427	76.86
R3I1	2023	8	356	64.08
R3I2	2023	7	328	51.66
R3I3	2023	7	292	42.84

Treatment	Year	Number of fruits /plant	Average fruit weight (g)	Total yield/plot (t/ha)
R1I1	2024	13	516	150.93
R1I2	2024	11	514	126.90
R1I3	2024	10	495	111.42
R2I1	2024	9	485	98.28
R2I2	2024	9	432	87.48
R2I3	2024	8	347	62.46
R3I1	2024	7	343	54.00
R3I2	2024	6	320	43.20
R3I3	2024	6	246	33.21

Table 4: Statistical Significance of Irrigation Level, Interval and Interactions

Effect	Variable	2023	2024
R	Number of fruits/plant	***	***
	Average fruit weight	***	***
	Total yield/plot	***	***
I	Number of fruits/plant	**	**
	Average fruit weight	**	**

Effect	Variable	2023	2024
	Total yield/plot	***	***
R:I	Number of fruits/plant	*	*
	Average fruit weight	NS	NS
	Total yield/plot	* *	**

R: Irrigation level; I: irrigation interval; R:I: Interaction effect,*** means highly significant ($p<0.001$); ** means very significant ($p<0.01$); * means significant ($p<0.01$); NS means not significant ($p\geq0.05$)

Table 5: Correlation (r) between mineral content and yield parameters

Mineral	Number of Fruits	Avg. Fruit Weight	Total Yield
Potassium (K)	0.88***	0.85***	0.90***
Calcium (Ca)	0.81***	0.78**	0.83***
Magnesium (Mg)	0.79**	0.75**	0.81**
Iron (Fe)	0.74**	0.70*	0.76**
Zinc (Zn)	0.69*	0.68*	0.72*
Copper (Cu)	0.52	0.50	0.55
Manganese (Mn)	0.47	0.43	0.48
Sodium (Na)	0.38	0.31	0.30

(Note: ***$p < 0.001$ (highly statistically significant), **$p < 0.01$(very statistically significant), (* $p < 0.05$ (statistically significant)

4.0 CONCLUSION

The results of this study demonstrate a clear and statistically significant relationship between irrigation practices, mineral nutrient accumulation, and yield performance in cucumber production. High irrigation amounts combined with short intervals (R_1I_1) significantly enhanced the uptake of essential macronutrients—particularly potassium, calcium, and magnesium—leading to higher fruit number, increased average fruit weight, and improved total yield per plot.

Macronutrients had the strongest positive associations with yield components, validating their central roles in physiological processes such as photosynthesis, carbohydrate translocation, and cell wall development. Micronutrients, iron and zinc, also contributed positively to yield formation, albeit to a lesser degree. On the other hand, manganese, copper, and sodium displayed weaker correlations, indicating either non-limiting levels or diminished roles under the prevailing soil and water conditions.

The interaction between irrigation amount and frequency significantly influenced both nutrient composition and yield outcomes, underscoring the need for integrated water-nutrient management strategies in cucumber cultivation.

REFERENCES

Adeboye, A. O., Adebayo, O. S., and Ajayi, A. E. (2020). Response of cucumber (*Cucumis sativus* L.) yield to irrigation interval and nitrogen fertilization. *Agricultural Water Management, 232*, 106041. https://doi.org/10.1016/j.agwat.2020.106041

Adeleke, A. O., Akinyemi, O. A., and Ogundipe, O. M. (2022). Influence of irrigation management on nutrient uptake and quality of cucumbers grown under tropical conditions. *International Journal of Agricultural Research, 17*(1), 45–56.

Adeoye, M. O., Agbaje, G. O., and Olaniyi, J. O. (2021). Irrigation interval effects on growth, yield, and water productivity of cucumber in tropical agro-ecology. *Nigerian Agricultural Journal, 52*(1), 99–107.

Ahmad, S., Khan, A. A., and Rehman, A. (2022). Optimizing irrigation and fertilization strategies to improve vegetable crop yield and nutrient uptake. *Agricultural Water Management, 260*, 107318. https://doi.org/10.1016/j.agwat.2021.107318

Ahmed, M., Hassan, F. U., Aslam, M. T., and Iqbal, Z. (2018). Soil moisture impacts on mineral nutrient uptake in vegetable crops: A mechanistic approach. *Plant and Soil Environment, 64*(5), 209–216.

Akanbi, W. B., Adeboye, A. O., and Olatunji, S. O. (2021). Effects of irrigation intervals and water quantity on growth and yield of cucumber in Nigeria. *Nigerian Journal of Horticultural Science, 26*(2), 105–113.

Al-Obeed, R. S., Al-Saif, A. M., Al-Saif, A. M., & Al-Qahtani, S. M. (2022). Improving yield and water use efficiency of cucumber under heat stress conditions in arid regions. *Journal of Saudi Society of Agricultural Sciences, 21*(5), 325-331.

Ali, M. M., Ahmed, S., and Hossain, M. A. (2021). Impact of climate variability on cucumber productivity under different irrigation practices. *International Journal of Agricultural Sciences, 11*(3), 233–240.

Ali, M. M., Ghoneim, A. M., and Ibrahim, A. H. (2023). Influence of irrigation scheduling on growth, yield, and quality of cucumber under greenhouse conditions. *Horticulturae, 9*(2), 112. https://doi.org/10.3390/horticulturae9020112

Allen, R. G., Pereira, L. S., Raes, D., and Smith, M. (1998). *Crop evapotranspiration: Guidelines for computing crop water requirements*. FAO Irrigation and Drainage Paper 56. FAO, Rome.

Badr, M. A., El-Tohamy, W. A., and Abou-Hussein, S. D. (2023). Impact of different irrigation intervals on cucumber yield and water productivity. *Agricultural Sciences, 14*(1), 20–30.

Bhowmik, D., Kumar, K. P. S., Paswan, S., and Srivastava, S. (2012). Cucumber: A potential medicinal plant. *International Journal of Chemical and Analytical Science, 3*(12), 1–4.

Chen, L., Wang, Y., & Li, S. (2024). Partial root-zone drying irrigation modulates abscisic acid signaling and enhances water use efficiency in cucumber (*Cucumis sativus* L.). *Agricultural Water Management*, 291, 108602. https://doi.org/10.1016/j.agwat.2023.108602

Ding, Y., Li, F., Hao, Y., & Qin, J. (2022). Deficit irrigation impacts on nutrient uptake, biological nitrogen fixation, and isotopic nitrogen fractionation in field-grown legumes. *Field Crops Research, 288*, 108697.

FAO. (2022). *The State of Food and Agriculture 2022: Leveraging automation in agriculture for transforming agrifood systems*. Rome: Food and Agriculture Organization of the United Nations.

Fatma, M., Ali, H. M., and Asgher, M. (2021). Regulation of nutrient uptake and stress tolerance in cucumber plants through irrigation and mineral nutrition. *Plants, 10*(8), 1640. https://doi.org/10.3390/plants10081640

Gattullo, C. E., Allegretta, I., Medici, L., Fretto, S., & Terzano, R. (2020). Nutrient mobility and availability in the rhizosphere of zucchini (Cucurbita pepo L.) under different irrigation regimes. *Plant and Soil, 447*, 347–364.

Gondor, O. K., Nagy, R., and Szalai, G. (2020). Mineral nutrition and fruit development in cucumber: Effects of calcium and potassium supplementation. *Acta Horticulturae, 1294*, 293–300.

Hassan, M. U., Ullah, A., & Liu, Q. (2024). Synergistic effects of irrigation scheduling and potassium fertilization on fruit firmness, mineral content, and postharvest life of cucumber. *Frontiers in Plant Science*, 15, 1347890. https://doi.org/10.3389/fpls.2024.1347890

Kesba, M. H., Mazrou, Y. S., & El-Zohri, M. (2023). Foliar application of zinc and boron enhances fruit yield and nutritional quality of cucumber under deficit irrigation. *Journal of Plant Nutrition, 46*(5), 891-905.

Li, X., Zhang, K., Sun, Y., & Wang, Z. (2023). Rhizosphere ionic balance and mineral nutrient acquisition in cucumber (*Cucumis sativus* L.) under different irrigation regimes. *Journal of Plant Nutrition and Soil Science*, 186(4), 456-467. https://doi.org/10.1002/jpln.202200348

Mohamed, M. A., Ahmed, A. M., and Soliman, H. I. (2021). Effect of irrigation levels and potassium fertilization on cucumber yield and quality. *Egyptian Journal of Agronomy, 43*(3), 219–229.

Omid, A., Ahmad, S., and Dehdari, M. (2019). Interactive effects of irrigation and fertigation on cucumber productivity and fruit quality in arid climates. *Irrigation Science, 37*, 281–291. https://doi.org/10.1007/s00271-019-00630-w

Osman, M. M., El-Sayed, S. F., & Hassan, H. S. A. (2023). Response of cucumber plants to different irrigation water sources and potassium fertilization under drought stress. *Journal of Soil Science and Plant Nutrition, 23*(1), 1082-1096.

Rahimi, A., Ebrahimian, E., and Taghizadeh-Mehrjardi, R. (2019). Effects of water deficit on micronutrient accumulation in cucurbit crops under drip irrigation systems. *Horticultural Plant Journal, 5*(3), 139–148.

Rai, R. K., Verma, A. K., and Sharma, A. K. (2020). Response of cucumber (*Cucumis sativus* L.) to irrigation scheduling under drip system. *Indian Journal of Agricultural Sciences, 90*(6), 1150–1154.

Shah, S. N., Khan, M. F., and Abbas, A. (2022). Irrigation scheduling enhances nutrient uptake and cucumber productivity in arid soils. *Journal of Horticultural Research, 30*(4), 355–367.

Sinclair, T. R., & Rufty, T. W. (2023). Mass flow to roots and the challenges of modeling nutrient uptake in water-limited environments. *Annals of Botany, 132*(3), 453-460.

Singh, A. (2022). Soil salinization management for sustainable development: A review. *Journal of Environmental Management, 277*, 111383.

Singh, J., Sharma, P., and Meena, M. L. (2022). Deficit irrigation strategies for improving cucumber productivity and water use efficiency. *Irrigation Science, 40*(4), 401–412. https://doi.org/10.1007/s00271-022-00782-0

Taha, R. S., Omar, A. F., & El-Nagar, G. R. (2020). Influence of water deficit on fruit quality and antioxidant levels of cucumber. *Egyptian Journal of Horticulture*, 47(2), 295–306. https://doi.org/10.21608/ejoh.2020.149637

Wang, F., Zhang, H., & AbdElgawad, H. (2024). Sensor-based irrigation management improves yield and quality of greenhouse cucumber by optimizing root-zone moisture tension. *Scientia Horticulturae*, 325, 112649. https://doi.org/10.1016/j.scienta.2023.112649

Wang, Y., Zhang, X., & Li, D. (2021). Soil moisture regimes and mineral uptake in drip-irrigated cucumber: A two-year field study. *Agricultural Water Management*, 248, 106752. https://doi.org/10.1016/j.agwat.2021.106752

Zakka, E.J., Onwuegbuchunam, N.E., Dare A., Onwuegbuchulam, D.O., and Emeghara U.U. (2020). Yield, Water Use and Water Productivity of Drip-Irrigated Cucumber in Response to Irrigation Depths and Intervals in Kaduna, Nigeria. *Nigerian Journal of Technology (NIJOTECH)*, vol. 39 (2), pp. 613 – 620. doi:10.4314/njt.v39i2.33