Effects of Irrigation Depth and Interval on Reproductive and Yield Components of Cucumber in Ogbomoso

ABSTRACT

Water scarcity is a challenge to agricultural productivity, especially in tropical regions like Nigeria. This study investigated the effects of different irrigation regimes on the reproductive and yield components of cucumber (*Cucumis sativus* L.) in Ogbomoso, Nigeria. The experiment employed a split-plot randomized block design with three deficit irrigation depths: D_1 [100% crop evapotranspiration (ETc)], D_2 (85% ETc), and D_3 (70% ETc) as main plots and three irrigation intervals: I_1 (daily), I_2 (every 2 days), and I_3 (every 3 days) as sub-plots. Irrigation depth had minimal effect on days to first flowering, but three-day intervals significantly delayed flowering to 29 days. Moderate deficit irrigation (D_2) produced longer fruits (13.96 cm) compared to full irrigation (D_1), while daily irrigation (I_1) resulted in significantly longer fruits (14.17 cm) than longer intervals. Unexpectedly, deficit irrigation (D_3) produced fruits with larger diameter (44.50 mm) compared to full irrigation (43.08 mm). Although not statistically significant, full irrigation (D_1) achieved the highest yield (8,738.79 kg/ha). The interaction between irrigation depth and interval revealed that treatment D_1 x I_1 (100% ETc with daily irrigation) produced the highest yield (9,774.54 kg/ha) and earliest flowering (26.92 days), while D_2 x I_3 resulted in the lowest yield (6,812.01 kg/ha). These results offer critical guidance for optimizing water use in cucumber farming, balancing fruit quality and yield in water-scarce environments.

Keywords: Cucumber, irrigation regimes, deficit irrigation, yield, drip irrigation.

1. INTRODUCTION

Increasing water scarcity, driven by climate change and rainfall variability, poses significant challenges to tropical agriculture. In many developing nations, the agricultural sector faces significant challenges in managing water resources efficiently while maintaining crop productivity (Adeyolanu & Okelola, 2024). In Nigeria, where agriculture is predominantly rain-fed and smallholder farming dominates, water scarcity exacerbates food insecurity and limits the economic potential of crops like cucumber. Cucumber (*Cucumis sativus* L.), a vital vegetable crop with significant economic and nutritional value, requires careful water management for optimal growth and yield (Liu *et al*., 2021).

Cucumber production plays a crucial role in both subsistence and commercial agriculture in Nigeria, particularly in regions like Ogbomoso where the tropical climate presents both opportunities and challenges for cultivation. The crop's high water requirement, coupled with irregular rainfall patterns and increasing pressure on water resources, necessitates the development of efficient irrigation strategies that can optimize water use while maintaining acceptable yield levels (Safi *et al*. 2018).
Deficit irrigation has emerged as a promising water management strategy in regions facing water scarcity. This approach deliberately allows crops to sustain some degree of water deficit and yield reduction (Asmamaw *et al*., 2021; Champaneri

et al., 2024). However, the successful implementation of deficit irrigation requires a thorough understanding of crop responses to water stress at different growth stages and under varying irrigation frequencies. This knowledge is particularly crucial for cucumber production, as water stress can significantly impact both reproductive development and fruit quality (Parkash *et al*., 2021; Shani and Musa, 2019).
The reproductive phase of cucumber is especially sensitive to water stress, with flowering time and fruit development being key indicators of plant response to irrigation management (Aparna *et al*., 2023). Previous research has shown that water deficit can affect both the timing of flowering and the quality of fruits produced (Arshad, 2017; Bello et al., 2023; Odhiambo & Aguyoh, 2022). However, the specific responses may vary depending on local environmental conditions, cultivar characteristics, and the timing and severity of water stress application.
In tropical regions like Ogbomoso, the combination of high temperatures and variable rainfall patterns creates unique challenges for irrigation management. The bimodal rainfall pattern, with peaks in June and September, leaves significant periods where supplemental irrigation is necessary for optimal crop production (Ogunbode & Ifabiyi, 2019; Abegunrin *et al.,* 2013). Understanding how different irrigation regimes affect cucumber production under these conditions is essential for developing locally adapted water management strategies (Magdalene *et al*., 2024).
The optimization of irrigation scheduling requires consideration of both the amount of water applied (irrigation depth) and the frequency of application (irrigation interval). While reduced irrigation depth can lead to water savings, the timing of water application can be equally important in determining crop response and resource use efficiency (Taghvaeian *et al*., 2020). The interaction between these factors becomes particularly relevant in systems where water availability is limited or where irrigation infrastructure poses constraints on application frequency (Abebe *et al*., 2020).
Previous studies on cucumber irrigation under tropical field conditions have shown varying results, highlighting the need for location-specific research to develop appropriate irrigation recommendations. The present study was therefore designed to investigate the effects of different irrigation depths and intervals on the reproductive and yield components of cucumber under field conditions in Ogbomoso, Nigeria. The specific objectives were to evaluate the impact of deficit irrigation and varying irrigation frequencies on days to flowering, fruit characteristics (length and diameter), and total yield.

2. MATERIAL AND METHODS

2.1 Study Site Description

The research was conducted at the Teaching and Research Farm of the Department of Agricultural Engineering, Ladoke Akintola University of Technology, Ogbomoso, Oyo State, Nigeria. The experimental site is geographically located at 8°10'06" N latitude and 4°16'12" E longitude. The region is characterized by a tropical climate with distinct wet and dry seasons. The wet season typically extends from April to October, while a relatively brief dry season occurs from November to March. The area receives an average annual rainfall of approximately 1200 mm, with characteristic bimodal peaks observed in June and September. The site experiences a mean annual temperature of 26°C, with variations ranging from 18 to 36°C. The relative humidity averages 74% annually, reaching its peak during the wet season (Abegunrin *et al*., 2013).

2.2 Experimental Design and Treatments

The experiment employed a split-plot randomized complete block design with irrigation depth as the main plot factor and irrigation interval as the subplot factor. The main plot treatments consisted of three deficit irrigation depths based on crop evapotranspiration (ETc): D_1: 100% ETc (Control - full irrigation); D_2: 85% ETc (Moderate deficit irrigation); D_3: 70% ETc (Severe deficit irrigation). The subplot treatments comprised three irrigation intervals: I_1: Daily irrigation (every day); I_2: Two-day interval irrigation (every 2 days); I_3: Three-day interval irrigation (every 3 days).
Each treatment combination was replicated three times, resulting in 27 experimental plots. Individual plot size was 4.2 m × 0.9 m, with 1 m buffer zones between plots to minimize irrigation treatment interference.

2.3 Land Preparation and Crop Establishment

The experimental field was ploughed and harrowed to achieve a fine tilth suitable for cucumber cultivation. Raised beds were prepared with dimensions of 4.2 m length × 0.9 m width × 0.15 m height. Well-decomposed poultry manure was incorporated into the soil at a rate of 10 t/ha during bed preparation to improve soil fertility and water-holding capacity.
Cucumber seeds (variety “DARINA F1”) were sown directly at a spacing of 90 cm between rows and 30 cm within rows. Two seeds were planted per hole at a depth of 2.5 cm, and thinning was performed two weeks after emergence to maintain one healthy seedling per stand.

2.4 Irrigation System Setup and Management

A drip irrigation system with a 1000 l tank and pressure-compensating emitters was used for precise water application.The irrigation system was calibrated before the experiment to ensure uniform water distribution. Drippers were tested for discharge uniformity, achieving a coefficient of uniformity greater than 90%.

2.5 Determination of Irrigation Requirements

Crop water requirements were calculated using the FAO Penman-Monteith method to estimate reference evapotranspiration (ETo). The daily minimum and maximum temperature were gotten using a minimum and maximum thermometer while the daily relative humidity data for Ogbomoso was gotten from web-based source (Google Weather).
Crop evapotranspiration (ETc) was calculated using the Equation 1:

$$ETc = Kc \times ETo \quad (1)$$

where:

ETc is crop evapotranspiration (mm/day)
Kc is the crop coefficient for cucumber at different growth stages
ETo is reference evapotranspiration (mm/day)

The crop coefficients used were: Initial stage: Kc = 0.45; Development stage: Kc = 0.7; Mid-season stage: Kc = 0.9; and Late season stage: Kc = 0.75 (Allen et al., 1998)
Irrigation water was applied based on the calculated ETc values and adjusted according to the treatment depths (100%, 85%, and 70% ETc).

2.6 Crop Management

Standard agricultural practices were followed throughout the growing season. Weeds were controlled through regular hand weeding to minimize competition for water and nutrients. Pest and disease management was implemented with minimal chemical interventions when necessary.

2.7 Data Collection and Measurements

The following parameters were measured throughout the growing period:

2.7.1 Days to first flowering

The number of days from sowing to the appearance of the first flower on each plant was recorded as days to first flowering. Ten tagged plants per plot were monitored, and the average days to flowering were calculated for each treatment.

2.7.2 Fruit length

Fruit length was measured using a digital caliper, with measurements taken from the base to the tip of the fruit. An average of 10 randomly selected fruits per plot at each harvest was recorded to determine the mean fruit length for each treatment.

2.7.3 Fruit diameter

Fruit diameter was measured at the middle portion of the fruit using a digital caliper, with an average of 10 randomly selected fruits per plot used to calculate the mean fruit diameter for each treatment.

2.7.4 Yield

Total yield was determined by weighing all marketable fruits harvested from each plot. The yield was converted to kilograms per hectare (kg/ha) based on the plot size. Harvesting was conducted at three-day intervals when the fruits reached commercial maturity, ensuring accurate yield assessment across all treatments.

2.8 Statistical Analysis

The collected data were subjected to analysis of variance (ANOVA) using statistical software SPSS V20. The significance of treatment effects was determined at $p \leq 0.05$. Treatment means were separated using Duncan's Multiple Range Test. This test was chosen because it is well-suited for agricultural studies, allowing clear comparison of multiple treatments and their interactions, such as irrigation depth and interval.

3. RESULTS AND DISCUSSION

3.1 Days to flowering

The timing of flowering in cucumber showed varying responses to irrigation treatments (Table 1). While irrigation depth did not demonstrate statistically significant effects on days to first flowering, a clear trend emerged showing delayed flowering under deficit irrigation conditions. Plants under D_3 took 29 days to flower compared to 28 days under D_1. This delay can be attributed to the plant's physiological response to water stress, where limited water availability typically reduces cell expansion and delays developmental processes (Cantuário *et al*., 2021).

Irrigation intervals showed more pronounced effects on flowering time, with statistical significance observed between different intervals. The longest interval (I_3) resulted in delayed flowering (29 days) compared to daily irrigation (I_1, 28 days). This finding aligns with research by Zakka *et al*. (2020), who reported that extended intervals between irrigation events can disrupt the normal progression of reproductive development in cucurbits.

The interaction between irrigation depth and interval revealed interesting patterns, with treatment $D_1 \times I_1$ resulting in the earliest flowering at 27 days, while $D_3 \times I_3$ delayed flowering to 30 days. These results suggest that both water availability and timing of application play crucial roles in determining the onset of reproductive development. The observed delay under water stress conditions can be explained by the plant's adaptive responses, where limited resources are initially directed toward vegetative survival rather than reproductive development.

3.2 Fruit length

Fruit length demonstrated significant responses to both irrigation depth and interval treatments. Interestingly, D_2 produced longer fruits (13.96 cm) compared to both D_1 (13.41 cm) and D_3 (13.50 cm) (Table 1). This response suggests that mild water stress might trigger compensatory mechanisms in fruit development, possibly through enhanced resource allocation to fewer developing fruits.

Daily irrigation (I_1) consistently resulted in longer fruits (14.17 cm) compared to I_2 (13.38 cm) and I_3 (13.24 cm). This finding supports the importance of maintaining consistent soil moisture during fruit development, as reported by Coussement et al. (2021), who demonstrated the critical role of sustained cell turgor pressure in fruit elongation.

The interaction effects were particularly noteworthy, with treatments $D_1 \times I_1$ and $D_2 \times I_1$ producing the longest fruits (14.50 cm and 14.47 cm respectively). These results corroborate with findings by Bello *et al*. (2023) and Çebi *et al*. (2018), who reported highest fruit length in cucumber under well-watered conditions with frequent irrigation. The reduced fruit length under extended irrigation intervals (Table 1) can be attributed to periods of water deficit affecting cell expansion during critical fruit development stages (Coussement*et al*., 2021).

3.3 Fruit diameter

Deficit irrigation (D_3) produced significantly larger fruit diameter (44.50 mm) compared to full irrigation (43.08 mm) (Table 1). This response might be due to resource reallocation under water stress. Similar compensatory responses have been documented in other cucurbit species under moderate water stress.

Irrigation intervals showed on significant effect on fruit diameter, with values ranging from 43.93 mm to 44.04 mm across different intervals. This suggests that fruit radial expansion might be less sensitive to irrigation frequency compared to fruit elongation. The interaction analysis revealed that treatments D_2 x I_2 and D_3 x I_3 produced fruits with the largest diameter (45.11 mm), while D_1 x I_2 resulted in the smallest (41.76 mm).

These findings challenge conventional expectations about the relationship between water availability and fruit size. The enhanced fruit diameter under deficit irrigation might be explained through several physiological mechanisms, such as increased concentration of osmolytes under water stress conditions, modified source-sink relationships favoring fewer but larger fruits, and altered hormonal balance affecting fruit cell expansion patterns.

3.4 Yield

Total yield responses provided important insights into the practical implications of different irrigation regimes. Although not statistically significant (Table 1), full irrigation (D_1) produced the highest yield (8,738.79 kg/ha) compared to deficit irrigation treatments. This trend aligns with the general understanding that optimal water availability supports maximum productive potential in cucumber.

The relationship between irrigation interval and yield was less pronounced, with yields ranging from 8,043.20 kg/ha to 8,281.18 kg/ha across different intervals. This suggests that cucumber plants can adapt to different irrigation frequencies when total water volume is maintained, possibly through adjustments in root water uptake patterns and physiological adaptation mechanisms.

Table 1: Effect of Irrigation Depth and Interval on Reproductive and yield components of cucumber

Treatments	**Days to First Flowering**	**Fruit length (cm)**	**Fruit Diameter (mm)**	**Yield (kg/ha)**
Depth (D)				
D_1 (100% ET_C)	27.75 a	13.41 a	43.08 a	8738.79 a
D_2 (85% ET_C)	28.22 a	13.96 b	44.23 ab	7801.37 a
D_3 (70% ET_C)	29.08 a	13.50 ab	44.50 b	8025.20 a
Interval (I)				
I_1 (1 day)	28.14 a	14.17 b	44.04 a	8043.20 a
I_2 (2 days)	28.22 a	13.38 a	43.94 a	8281.18 a
I_3 (3 days)	28.69 b	13.24 a	43.93 a	8147.86 a
Treatment (D × I)				
$D_1 \times I_1$	26.92 a	14.50 a	44.48 ab	9774.54 a
$D_1 \times I_2$	27.75 ab	12.54 c	41.76 c	7051.68 b
$D_1 \times I_3$	28.58 ab	12.87 bc	42.64 bc	9258.81 ab
$D_2 \times I_1$	28.00 ab	14.47 a	43.74 abc	7144.88 b
$D_2 \times I_2$	28.75 abc	13.88 ab	45.11 a	9232.36 ab
$D_2 \times I_3$	27.92 bc	13.18 bc	43.75 abc	6812.01 b
$D_3 \times I_1$	29.50 bc	13.42 bc	43.99 abc	7464.05 ab
$D_3 \times I_2$	28.17 c	13.51 abc	44.43 ab	8228.14 ab
$D_3 \times I_3$	29.58 c	13.57 ab	45.11 a	8403.08 ab

Note: Means followed by the same letter(s) within columns are not significantly different at $p \leq 0.05$.

The interaction effects revealed that D_1I_1 produced the highest yield (9,774.54 kg/ha), while D_2I_3 resulted in the lowest (6,812.01 kg/ha). This substantial yield difference (approximately 30%) demonstrates the cumulative impact of both water availability and timing on overall productivity. For instance, a 30% yield reduction could translate to significant economic losses for farmers, especially in commercial cucumber production where profit margins are closely tied to yield. In practical terms, a farmer cultivating one hectare of cucumber could lose approximately 2,962.53 kg of produce under $D_2 \times I_3$ compared to $D_1 \times I_1$.These findings align with research by Zakka *et al.* (2020), who reported optimal cucumber yields under well-watered, frequent irrigation regimes.
The yield reduction under extended intervals and deficit irrigation can be attributed to several factors including reduced photosynthetic efficiency during periods of water stress decreased fruit set and increased abortion under water-limited conditions. Farmers in water-limited regions might benefit from adopting moderate deficit irrigation with shorter intervals to conserve water while maintaining quality.

3.5 Integration of Findings and Practical Implications

The interactions observed between irrigation depth and interval provide valuable insights for irrigation management in cucumber production (Table1). While some quality parameters (fruit diameter) showed positive responses to deficit irrigation, the overall yield data suggests that maintaining adequate soil moisture through full irrigation with frequent application ($D_1 \times I_1$) optimizes productive potential.
These findings have important implications for irrigation management in regions with limited water resources. Where water conservation is necessary, moderate deficit irrigation (D_2) with daily application (I_1) might offer an acceptable compromise, as it maintained relatively good fruit quality parameters while reducing water use by 15%. However, the significant yield reduction under severe deficit irrigation (D_3) suggests that this level of water stress might not be economically viable for commercial production.
The varying responses of different parameters to irrigation treatments highlight the complexity of plant-water relationships in cucumber. While reproductive timing (flowering) and fruit elongation showed sensitivity to both water availability and timing, fruit diameter demonstrated unexpected resilience and even positive responses to water stress. These differential responses suggest the possibility of targeting specific quality parameters through carefully managed irrigation regimes.
The results also emphasize the importance of considering local environmental conditions in irrigation management. The tropical climate of Ogbomoso, with its high evaporative demand and variable rainfall patterns, likely influenced the crop's responses to different irrigation treatments. The findings therefore provide particularly relevant guidance for cucumber production in similar tropical environments.

4. CONCLUSION

The findings revealed complex relationships between irrigation depth and interval in determining crop performance. While full irrigation (100% ETc) with daily application produced the highest yield (9,774.54 kg/ha) and earliest flowering (27 days), some quality parameters showed unexpected positive responses to deficit irrigation. Notably, moderate deficit irrigation (85% ETc) produced longer fruits, and severe deficit irrigation (70% ETc) resulted in larger fruit diameter, suggesting potential physiological adaptations under water stress conditions. However, the substantial yield reduction under severe deficit irrigation (D_3) and extended irrigation intervals (I_3) indicates that these water conservation strategies may not be economically viable for commercial production. The research demonstrates that while cucumber can maintain certain quality parameters under water stress, optimal productivity requires adequate and frequent irrigation. This study recommends full irrigation with daily intervals for maximizing cucumber yield in tropical climates. Where water conservation is critical, moderate deficit irrigation (85% ETc) offers a viable alternative with minimal quality trade-offs.

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