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ASSESSING THE IMPACT OF POLY-HOUSE AND OPEN-FIELD CONDITIONS ON WATER USE EFFICIENCY IN DRIP IRRIGATED PEPPER

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ABSTRACT

Water, soil, and environment are vital resources for maximizing crop production in agricultural practice in Nigeria. Sustainable use of these resources is pivotal for ensuring the productivity of vegetables. However, the escalating demand for food resulting from an ever-increasing population has led to a surge in water usage for crop production, thus there is a need to develop a sustainable approach to the use of these resources to facilitate the high productivity of vegetables. Therefore, this study aimed to assess the impact of poly-house and open-field conditions on water use efficiency in drip irrigated green pepper. Green pepper (California wonder), samples used for demonstration in this study were obtained from Dizenghoff W.A. Nigeria Limited, Ibadan, Nigeria. Soil samples were obtained from the Teaching and Research Farm of the Federal Polytechnic, Ado-Ekiti, Nigeria during the 2020/2021 and 2021/2022 growing seasons under irrigation intervals of seven-day (I7), six-day (I6) and five-day (I5). The water use efficiency (WUE) was measured in both environments. The WUE of 18.44 and 13.8 kg/m3 were recorded under poly-house for the 2020/2021 and 2020/2022 seasons, respectively, while corresponding WUE of 12.97 and 9.6 kg/m3 were recorded under open-field for the 2020/2021 and 2021/2022 growing seasons. This study has demonstrated the capability of a poly-house environment to improve water conservation for increased productivity of green peppers. The poly-house environment can be promoted among smallholder vegetable farmers for increased productivity.

KEYWORDS: Water use; efficiency; drip irrigated; green pepper; poly-house; open-field condition

INTRODUCTION

Water is a precious and scarce resource that is vital for all forms of life on Earth. The increasing global population, urbanization, and industrialization have put immense pressure on water resources leading to water scarcity in many regions of the world (Evett et al., 2020). To ensure sustainable use of water resources and meet the increasing water demand, it is essential to improve water use efficiency. Water use efficiency is the ability to achieve maximum benefits from the available resources.

Water use for crop production is on the increase as a result of increasing demands for food and fibres consequent to population increase (Grodde et al., 2018). However, as the water demand is growing, the supply is fixed. The ever-growing population and change in climate patterns are putting water resources under pressure. Therefore, new approaches and techniques to water use planning and management are necessary if the looming crises are to be reduced if not eliminated, and environmental degradation is to be avoided (Hatfied et al., 2019). Good irrigation planning is a means of managing agricultural water use. Therefore, efficient irrigation application is very important in a time like this. One prerequisite for effective and efficient irrigation application is the knowledge of water use efficiency (WUE). Evapotranspiration (ET) is the measure of the amount of water consumed by a soil-plant-atmosphere system (Oluwasemire et al., 2002). Accurate estimation of ET is considered an important part of irrigation system planning and efficient water use in agriculture (Er-Raki et al., 2007). It helps to reduce percolation losses, runoff, and environmental pollution (Orgaz et al., 2005). The demand for water by crops must be met by soil moisture via the root system. The actual rate of water uptake by crops from the soil in relation to its crop evapotranspiration (ETc) is determined by whether the available water in the soil is adequate or whether the crop will suffer from stress induced by water deficit. The effect of water stress on growth and yield depends on the crop species and the variety on the one hand and the magnitude and the time of occurrence of water deficit on the other. The ability to measure, estimate, and predict ET can result in better satisfying the water needs of crops and improving water-use efficiency. For agricultural and environmental sustainability, it is essential to use soil and water resources in a favourable balance that guarantees their future productivity.

Crop water requirement is an important practical consideration for improved water-use efficiency. Crop water requirements vary during the growing period, mainly due to variations in crop canopy and climatic conditions, and are governed by crop evapotranspiration (ETc) (Benli et al., 2006). About 93 % of the total water resources are used by agriculture (Latif, 2002). The gap between water demand and supply has increased manifolds, due to increased agricultural activities and reduced river flows. Availability of adequate good quality water is one of the most important inputs in successful crop production.

MATERIALS AND METHOD

Description of the experimental site

The study was carried out at the Teaching and Research Farm of the Federal Polytechnic, Ado-Ekiti, Nigeria. The site is located on Longitude 4° 45` to 5° 45` E and Latitude 7° 15` to 8° 51` N. The mean minimum and the maximum temperatures of the study area are 27 and 30 ℃, respectively. The study area is characterized by highly seasonal rainfall with distinct wet (April – October) and dry (November – March) seasons. The geographical details of the study area are illustrated in Figure 1.

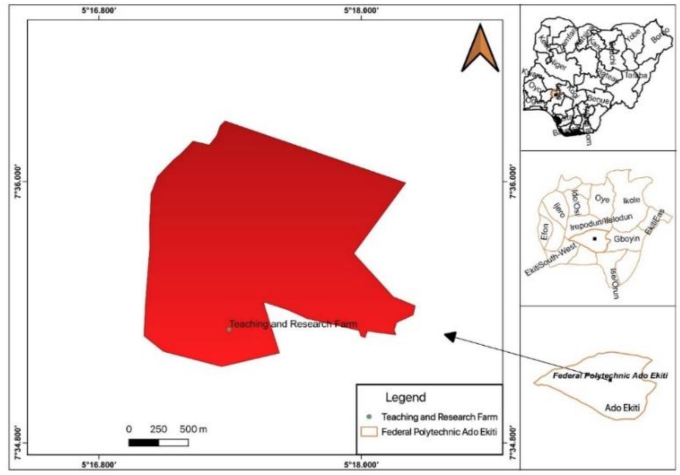

Figure 1: Map of Nigeria and Ekiti State showing the study area

Experimental design and bed preparation

The experiment was conducted during 2020/2021 and 2021/2022. The green pepper crop was grown in the experimental field. The experiment was laid out in a Randomized Complete Block Design (RCBD) with three replications. The experiment was laid out with nine (9) treatment combinations consisting of three irrigation intervals of 5, 6, and 7 (I5, I6, and I7) days under poly-house and open-field conditions.

Land preparation was done manually inside the poly-house and in the open-field using cutlasses, diggers, and hoes. Unburied grasses were properly removed to ensure a clean field. Six (6) raised beds of 24 m length, 1 m width, and 0.40 m height were made both in the poly-house and open-field, respectively for the cultivation of green pepper crops. Three lysimeters were installed on each bed both in the poly-house and open-field conditions. Manure was incorporated into the soil during bed preparation. The size of each block both in the poly-house and open-field was 1 m by 24 m.

Experimental field layout and installation of drip irrigation

The irrigation was laid out with 2 rows in a block. There were six (6) blocks and each block contained three (3) experimental units. The installation of a flow meter was carried out on the delivery pipe to accurately measure the volume of water supplied to the field. The flow meter was validated for confirmation of its accuracy. The laterals were spaced at 40 cm with an emitter spacing of 30 cm shown in Plates 3.5 and 3.6. The spacing of the pepper therefore was 40 cm x 30 cm. A Drip irrigation system was used in irrigating as well as fertigating the green pepper in poly-hose and open-field. The same lateral line which was used in the poly-house was used in the open-field and a control valve was provided for each drip line to regulate the flow of the required quantity of water to each plot.

Planting and field management

The seedlings were ready for transplanting between 28 and 30 days. The plots (poly-house and open-field) were fumigated and irrigated to their field capacity before transplanting to provide favourable moisture conditions for the settlement of seedlings. The field was marked with a spacing of 40 cm × 30 cm in both directions. Seedlings were dipped into a starter solution to facilitate root formation and early establishment. Seedlings were transplanted out simultaneously on the open-field and the poly-house at a planting distance of 30 cm within rows and 40 cm between rows per bed.

Total weight of fresh fruit and water use efficiency

The fresh weight of ten randomly selected mature fruits at the marketable stage was weighed and recorded in kilograms using electronic balance and the average was computed while the water use efficiency (WUE) is the ratio of crop yield and the amount of water applied to the plants. This was estimated as:

$$WUE = \frac{\text{Crop yield kg}}{\text{Total water applied m3}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{Eq. 1}$$

Statistical analysis

Statistical analysis was conducted using Microsoft Excel, and Statistical Package for Social Scientists (SPSS v. 20). Water use efficiency under different irrigation intervals was subjected to statistical analysis. Statistically significant differences in water use efficiency across irrigation interval systems were tested by Analysis of Variance (ANOVA) within the General Linear Model (GLM) procedure. Multiple comparisons were performed using Tukey's HSD post hoc test at 5% levels of significance.

RESULTS AND DISCUSSION

The water use efficiency of drip irrigated green pepper was estimated at different irrigation frequencies under poly-house and open-field conditions during the 2020/2021 and 2021/2022 growing seasons. The findings are presented and discussed below.

The effect of cropping environment and irrigation intervals on irrigation water use efficiency (WUE) (kg/m^3) of green pepper during the 2020/2021 and 2021/2022 cropping seasons is presented in Table 1.

Table 1: Effect of cropping environment and irrigation intervals on irrigation water use efficiency (IWUE) (kg/m^3) of green pepper in 2020/2021 and 2021/2022 cropping seasons

Year (Y)	Cropping Environments	Significance of the difference between irrigation intervals			
		I_5	I_6	I_7	Average
2020/2021	Poly-House	18.65b	23.18a	13.49c	18.44A
	Open-Field	12.73b	16.53a	9.66c	12.97B
	Average	15.69b	19.85a	11.57c	
2021/2022	Poly-House	12.74b	18.67a	9.99c	13.80A
	Open-Field	8.69b	14.07a	6.04c	9.60B
	Average	10.72b	16.37a	8.02c	

During the 2020/2021 growing season, there was no significant difference ($p > 0.05$) in water use efficiency (WUE) of green pepper in both poly-house and open-field conditions under irrigation interval I_5. Similar results were observed under irrigation intervals I_6 and I_7. However, WUE significantly varied among different irrigation intervals, with the order of efficiency being $I_6 > I_5 > I_7$. A similar trend was observed during the 2021/2022 growing season under both poly-house and open-field cropping environments. Numerically, the WUE in the open-field during the two growing seasons was lower than in the poly-house environment.

The water use efficiency (WUE) of the green pepper crop under irrigation frequency and cropping environment for the 2020/2021 and 2021/2022 growing seasons is presented in Figure 2.

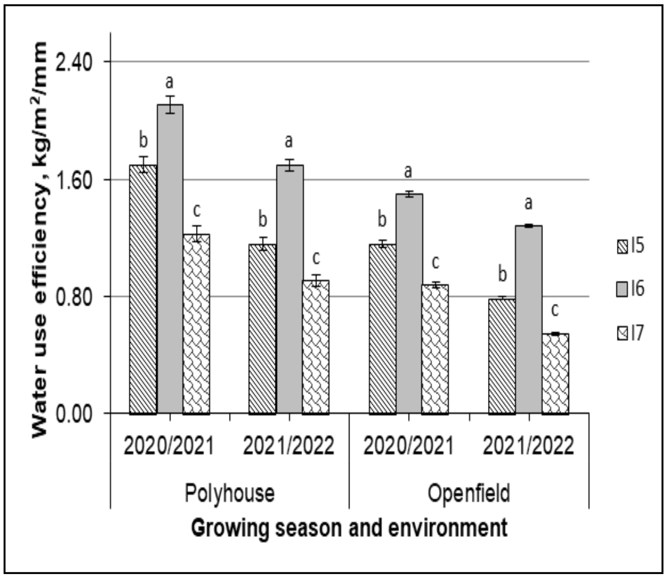

Figure 2: Water use efficiency at different intervals under a growing environment

I_5: five irrigations per week; I_6: six irrigations per week; I_7: seven irrigations per week, Bars with different letters differed significantly at a 5% level of probability by Tukey test, capped vertical lines are the standard error of the mean.

Treatment I_6 gave the significantly ($p < 0.05$) highest WUE while treatment I_7 gave the lowest WUE in both cropping environments and growing seasons.

Irrespective of the cropping environment, I_6 had the highest (23.18 kg/m^3) WUE compared to I_5 (18.65 kg/m^3) and I_7 (13.49 kg/m^3) in the 2020/2021 growing season while the same trend $I_6 > I_5 > I_7$ was observed in 2021/2022 growing season. A comparison of the two cropping environments showed that the poly-house consistently had a higher ($p < 0.05$) WUE compared to the open-field in both growing seasons (Figure 3).

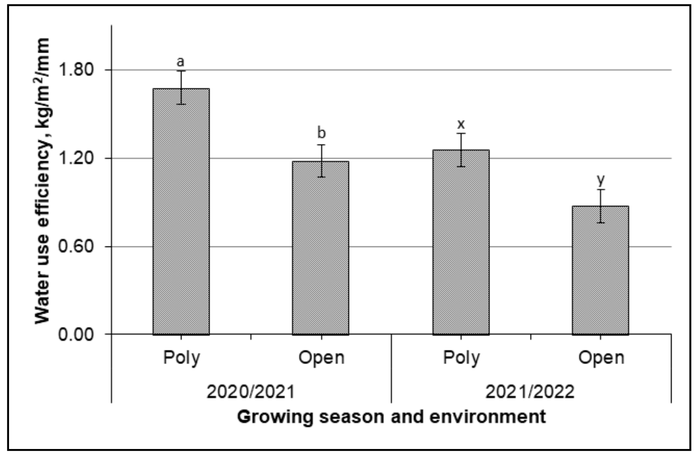

Figure 3: Water use efficiency growing environment

It was also observed that the WUE in the 2021/2022 growing season was lower than that of the 2020/2021 growing season.

The maximum value of the water use efficiency (WUE) of green pepper was obtained in the poly-house cropping environment during the two seasons. On average, the WUE of green pepper was higher in the poly house environment compared to the open-field environment in both growing seasons. The highest WUE values were consistently obtained at an irrigation interval of 6 days per week for both cropping environments, while the lowest values were observed at an irrigation interval of 7 days per week. Statistical analysis showed that both cropping environments and irrigation intervals had significant effects on the WUE of green pepper in both seasons. However, the interaction between the cropping system and irrigation interval was only significant in the 2020/2021 season, indicating that the combined influence of these factors had a greater impact on WUE during that particular season.

The slight variability in WUE observed between the poly-house and open-field environments at different irrigation intervals could be attributed to several factors. The controlled environment provided by the poly-house may have contributed to better water management and reduced water losses compared to the open-field. Additionally, the difference in microclimatic conditions, such as temperature and humidity, between the two environments could have influenced plant water requirements and water use efficiency. Other factors that may have affected WUE include differences in soil properties, crop management practices, and plant physiological responses to varying environmental conditions. The specific reasons for the higher WUE at an irrigation interval of 6 days per week compared to 5 or 7 days per week could be related to optimized soil moisture levels, balanced plant water uptake, and reduced water stress. The choice of cropping environment and irrigation interval significantly impact the WUE of green pepper. Understanding these effects can help in optimizing water management strategies for green pepper cultivation, leading to improved water use efficiency and potentially reduced water consumption in agricultural practices. The results obtained are similar to the findings of Kumar et al., (2022), Sharma et al. (2022), Rathore et al. (2021), Yadav et al. (2021), Gangwar et al. (2021), Martinez-Cob et al. (2020), Li et al. (2020) and Singh et al. (2020) who reported that the water use efficiency of tomato, cucumber, cauliflower, vegetable production, and capsicum are lower under open-field conditions than in the poly-house environments.

CONCLUSIONS AND RECOMMENDATIONS

The water use efficiency was found to be significantly higher in the poly-house condition compared to the open-field environment. The highest and lowest water use efficiency of 23.18 and 9.66 kg/m^3 was recorded under poly-house and open-field environments in the 2020/2021 growing season, while the maximum and minimum water use efficiency of 18.67 and 9.04 kg/m^3 was obtained under poly-house and open-field conditions in 2021/2022 growing seasons, respectively.

The water use efficiency of green pepper is significantly higher under poly-house compared to water use efficiency under open-field in both cropping seasons. The controlled environment provided by the poly house may have contributed to better water management and reduced water losses compared to the open field. The water use efficiency helps in optimizing water management strategies for green pepper cultivation which potentially reduces water consumption in the production of green pepper. Achieving higher water use efficiency in pepper production is crucial to sustainable water management practices. The production of green pepper under a poly-house environment is therefore recommended for the development of effective and efficient crop management strategies for sustainable green pepper production in the current and future.

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