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Comparative Assessment of Crop Water Productivity of Drip Irrigated Green Pepper under Poly-House and Open-Field Conditions

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Authors' contributions

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

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ABSTRACT

Crop water productivity (CWP) is a crucial factor in determining the sustainability of agricultural practices. Drip irrigation is a method that has shown potential in improving CWP in crop production. The study aimed to compare the crop water productivity of green pepper production under poly-house and open-field environments during 2020/2021 and 2021/2022 growing seasons. The experiment was conducted during the dry seasons of 2020.2021 and 2021/2022 at the Teaching and Research Field of Federal Polytechnic, Ado-Ekiti, Nigeria. The beds were prepared, nursery was established, drip irrigation system was installed and fumigation was carried out before transplanting. The experimental design was a randomized complete block (RCBD) with nine replications in each environment. The same design was applied to both poly-house and open-field

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conditions. The factors are environment (poly-house and open-field) and irrigation intervals of 5, 6 and 7 days (I_5, I_6 and I_7). Data obtained were subjected to analysis of variance and Tukey's Honestly Significant Difference (HSD) was used for multiple comparison. Drip irrigation was applied to all plots at different irrigation intervals. The results showed that the crop water productivity under poly-house and open-field environments in 2020/2021 growing season were: I_5: 29.67, I_6: 36.97, I_7: 20.92 and I_5: 17.06, I_6: 21.45, I_7: 12.21 kg/m^3. Similarly, in the 2021/2022 growing season, the CWP values were I_5: 16.90, I_6: 23.27, I_7: 12.95 and I_5: 9.60, I_6: 14.01, I_7: 6.81 kg/m^3 under poly-house and open-field, respectively. The results revealed that water productivity was more efficient at low levels of water supply in the poly-house during the 2020/2021 and 2021/2022 growing seasons. The production of green pepper under poly-house increased water conservation, reduced nutrient leaching, enhanced crop productivity for sustainable agricultural practices and water management.

Keywords: Comparative assessment; crop water productivity; drip irrigated pepper; poly-house and open-field conditions.

1. INTRODUCTION

Green pepper (*Capsicum annuum*) belongs to the family Solanaceae is one of an important group of vegetables grown extensively, widely cultivated and used as foods in almost every country of the world [1]. Green pepper is the world's second most important vegetable after tomato [2]. It is a high productivity crop; it has high remunerative and nutritive values. It is one of the most popular and highly priced annual herbaceous vegetable crops in Nigeria. Green pepper consumption in Nigeria is growing recently because of increasing demand by rural and urban consumers as a result of rapid population growth and water scarcity calls for an alternative means of production system for sustenance of the human race.

Scarcity of water is becoming the most severe constraint for development of agriculture in the developing nation, especially Nigeria. Under these conditions, the need to use the available water economically and efficiently is unquestionable. Based on the actual crop need, the irrigation management has to be improved so that the water supply to the crop can be reduced while still achieving high yield. Water use for crop production via irrigation is on the increase as a result of increasing demands for food and fibres consequent upon population increase. However, as the demand for water 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 eliminated, and environmental degradation is to be avoided. 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 crop water productivity.

Accurate measurements of crop water play a crucial role in optimizing production and utilizing crop water productivity efficiently under irrigation. Information on crop water productivity attributes is indispensable for irrigation management, guiding water allocation, system design, and on-farm scheduling practices. However, the pressure exerted on suitable water availability by geometric population growth and erratic climate change requires attention. Understanding crop water productivity is crucial as it directly impacts crop growth and yield.

The use of poly-house in arid regions decreases crop water requirements by reducing evapotranspiration. The plastic cover utilized on these structures changes locally the radiation balance by entrapping long-wave radiation and creates a barrier to moisture losses [3]. As a result ETo is reduced by 60 to 85% compared to outside the poly-house [4]. This leads to clear reduction in water demand when compared to field agriculture. Thus, poly-house agriculture provides a way of increasing crop water use efficiency. This has been highlighted by Mears, [5] who stated that a poly-house is generally regarded as necessary to provide a warm environment in cold climates, it has also been shown that with properly designed cooling system. It is possible to improve plant growing conditions under extensively hot conditions [6]. Adaptation of modern technologies to arid conditions will undoubtedly lead to increased opportunities for production of high value plants and materials in areas where the environment is extremely harsh [7]. Protected cultivation also has the potential benefit of substantially increasing plant productivity per unit water consumption which is important in many areas where water sources are severely limited" Poly-house cultivation reduces evapotranspiration (ET) to about 70% of open field, therefore improving the water use, relative to unprotected cropping [8]. It obviously does not rain in the greenhouse, and water has to be provided by an irrigation system. In general, irrigation system is controlled to provide enough easily available water to plants, and thus transpiration is close to its potential value [9]. The poly-house environment reduces the water needed for crop production compared to natural conditions. Notably, poly-house, enhances crop yields significantly compared to open field conditions, improving both the quality and quantity of produce while reducing dependency on chemicals. Despite these advantages, limited studies have investigated the crop water productivity of drip-irrigated green pepper under poly-house and open-field conditions in the study area. Addressing this gap is critical, given the urgent need for strategies focusing on improving crop water productivity and overall crop production. Therefore, this study aims to estimate crop water productivity of drip-irrigated pepper under poly-house and open-field conditions.

2. MATERIALS AND METHODS

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^o 45^1 to 5^o 45^1 E and Latitude 7^o 15^1 to 8^o 5^1 N. The mean minimum and the maximum temperatures of the study area are 27 and 30^oC, respectively. The study area is characterized with highly seasonal rainfall with distinct wet (April – October) and dry (November – March) seasons.

Experimental design and bed preparation: The experiment was conducted during the dry seasons of 2020/2021 and 2021/2022. The green pepper crop was planted in the experimental field. The experiment was laid out in a Randomized Complete Block Design (RCBD) with three replications and nine (9) treatment combinations consisting of three irrigation intervals of 5, 6, and 7 (I_5, I_6 and I_7) 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, hoes and unburied grasses was 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 cultivation of green pepper crop. 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.

Crop details: Green pepper is a popular crop with a sweet taste and abundant health benefits. The variety California wonder, used for this research is one of the commonly grown because of its large size, thick walls, and broad three to four-lobed shape [10]. The recommended spacing for planting California wonder green pepper is 30 x 40 cm. The seed rate is one per hole. The crop details and its variety are presented in Table 1.

Table 1. Crop details

Crop	Details
Common name	Green pepper
Scientific name	*Capsicum annuum*
Variety	California wonder
Seed rate	1 seed/hole
Spacing	30 cm x 40 cm

Source: Kim et al., [10]

Experimental field layout and installation of drip irrigation: The irrigation was layout with two rows in a block. There was six (6) blocks and each block contained three (3) experimental units. The installation of 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 was spaced at 40 cm with an emitter spacing of 30 cm shown in Plates 1 and 2. The spacing of the pepper therefore was 40 cm x 30 cm. Drip irrigation system was used in irrigating as well as fertigating the green pepper in poly-hose and open-field. Same lateral line which was used in the poly-house was used in the open-field and control valve was provided for each drip line to regulate the flow of required quantity of water supplied to each plot.

Plate 1. Experimental site showing the ridges and the drip lines: in the open-field

Plate 2. Experimental site showing the ridges and the drip lines: in the open-field

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

Measurement of total weight of fresh fruit and crop water productivity: Fresh weight of ten randomly selected mature fruits at marketable stage was weighed and recorded in kilograms using electronic balance and the average was computed while the crop water productivity (CWP) is the ratio of crop yield and the amount of water consumed by the plants. This was estimated as:

$$CWP = \frac{Crop\ yield\ kg}{Consumptive\ use\ m3}$$

Statistical analysis: Statistical analysis was performed using Microsoft Excel, and Statistical Packages for Social Scientist (SPSS v. 20). All the irrigation patterns were subjected to statistical analysis to determine the mean, standard deviation and coefficient of variation. Statistical significant differences in CWP under poly-house and open-field conditions during 2020/2021 and 2021/2022 growing seasons across irrigation intervals systems were tested by one-way Analysis of Variance (ANOVA) within the General Linear Model (GLM) procedure. Multiple comparisons were performed using Tukey's test using Honestly Significant Difference (HSD) post hoc test at 5% levels of significance.

3. RESULTS AND DISCUSSION

The effect of cropping environment and irrigation intervals on crop water productivity (CWP) (kg/m^3) of green pepper in 2020/2021 and 2021/2022 cropping seasons is presented in Table 1. During 2020/2021 growing season, there was no significant difference (p < 0.05) in crop water productivity (CWP) of green pepper in both poly-house and open-field under I_5. Similar results are observed under I_6 and I_7. However, the CWP is significantly varied under their irrigation intervals in the order $I_6 > I_5 > I_7$. Similar trends were observed for 2021/2022 growing season under poly-house and open-field cropping environment. Numerically, the CWP in open-field during the two growing seasons were lower than under poly-house environment. The highest CWP was recorded at I_6 under poly-house in 2020/2021 while lowest CWP was obtained at I_7 under and open-field in 2021/2022 growing seasons, respectively.

The results of the effect of drip irrigation frequency and cropping environment on crop water productivity (CWP) of the green pepper crop during the 2020/2021 and 2021/2022 growing seasons is presented in Fig. 1. The significantly (p < 0.05) highest CWP was obtained from treatment I_6 while treatment I_7 gave the lowest CWP in both cropping environments and growing seasons. Regardless of cropping environment, I_6 had the highest (36.97 kg/m^3) CWP compared to I_5 (29.67 kg/m^3) and I_7 (20.97 kg/m^3) in the 2020/2021 growing season while same trend $I_6 > I_5 > I_7$ was observed in the 2021/2022 growing season.

A comparison of the two cropping environments showed that higher (p < 0.05) CWP was observed in the poly-house compared to the open-field in both growing seasons (Fig. 2). The 2020/2021 growing season had higher CWP than that of 2021/2022 growing season.

Table 2. Effect of cropping environment and irrigation intervals on crop water productivity (CWP) (kg/m^3) of green pepper in 2020/2021 and 2021/2022 cropping seasons

Year (Y)	Cropping Environments (CE)	Significance of the difference between irrigation intervals (II) and cropping environments (CE)			
		I_5	I_6	I_7	Average
2020/2021	Poly-House	29.67b	36.97a	20.92c	29.91A
	Open-Field	17.06b	21.45a	12.21c	16.91B
	Average	23.36b	29.21a	16.57c	
2021/2022	Poly-House	16.90b	23.27a	12.95c	17.71A
	Open-Field	9.60b	14.01a	6.81c	10.14B
	Average	13.25b	18.64a	9.88c	

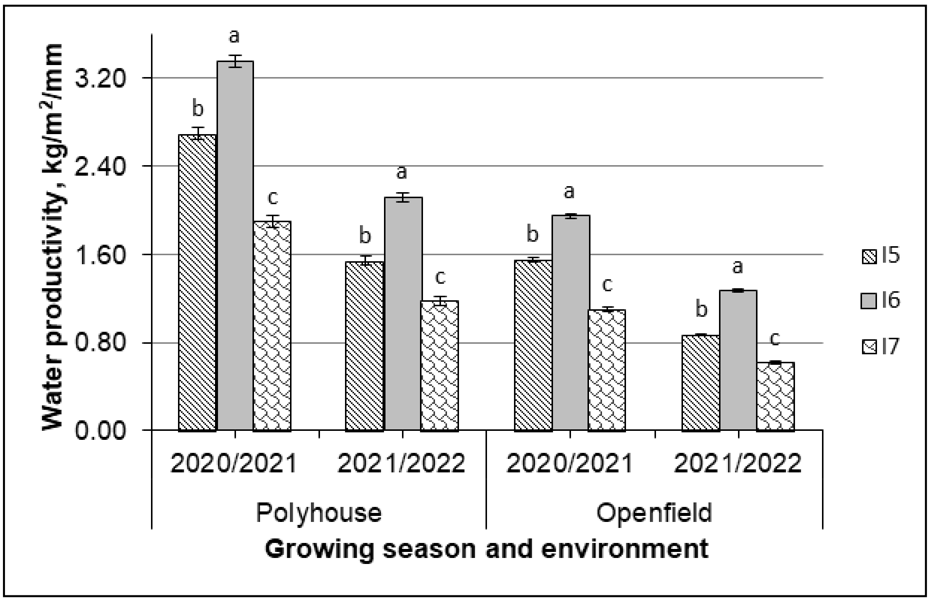

Fig. 1. Crop water productivity at different intervals under growing environment

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 5% level of probability by Tukey test Capped vertical lines are the standard error of mean.

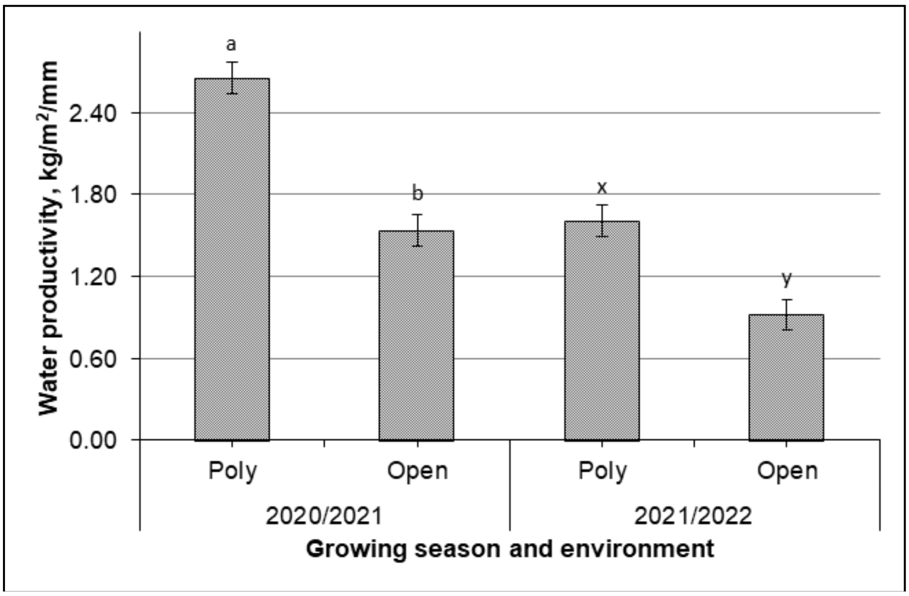

Fig. 2. Crop water productivity during growing season and environment

Bars with different letters differed significantly for each growing season at 5% level of probability by T-test Capped vertical lines are the standard error of mean.

Poly-house cultivation consistently yielded the maximum crop water productivity (CWP) throughout both seasons. Furthermore, the highest CWP values were obtained at an irrigation interval of 6 days per week, while the lowest values were observed at an interval of 7 days per week for both cropping environments and across both seasons. Statistical analysis indicated that both the cropping environment and irrigation interval significantly influenced the CWP of green pepper in both growing seasons.

The use of different cropping environments and irrigation intervals resulted in slight variations in the CWP of green pepper.

The probable reasons for the obtained results on CWP of green pepper under poly-house could be attributed to several factors. Poly-house cultivation provides a controlled environment, allowing for better regulation of temperature, humidity, and light, which can enhance crop productivity. The protective structure of the poly-house may also shield the plants from adverse weather conditions, pests, and diseases. Additionally, the irrigation interval of 6 days per week may have facilitated optimal water availability for the plants, promoting higher CWP. Conversely, an interval of 7 days per week may have resulted to over-irrigation while an irrigation of 5 days per week may have led to under-irrigation and reduced productivity. The differences observed between the two growing seasons could be attributed to variations in climatic conditions, management practices, or other factors not explicitly mentioned in the provided information. The results are in conformity with findings of Zhang *et al.* [11]; Huang *et al.* [12]; Wang *et al.* [13]; Li *et al.* [14] and Wu *et al.* [15] who reported that the crop water productivity of tomato, maize, vegetable production, cabbage and lettuce, respectively are higher under poly-house conditions than in the open-field environments.

4. CONCLUSION AND RECOMMENDATIONS

The maximum and minimum crop water productivity of 39.97 and 12.21 kg/m^3 was obtained under poly-house and open-field condition in 2020/2021 growing season, while the greatest and lowest crop water productivity of 23.27 and 6.81 kg/m^3 was recorded under poly-house and open-field conditions in 2021/2022 growing seasons, respectively. The crop water productivity of green pepper is significantly higher under poly-house environment compared to CWP under open-field in both cropping seasons. The confined environment created by the poly house may have contributed to better water management and reduced water losses compared to the open field. The CWP contributed to optimization of water management strategies for green pepper cultivation which potentially minimizes water consumption in the production of green pepper. Achieving higher crop water productivity in pepper production is essential for sustainable water management practices. The cultivation of green pepper under poly-house environment is recommended for the development of effective and efficient crop management strategies for sustainability of green pepper production in the current and future. Further studies should be conducted on the economic analysis of green pepper under poly-house and open-field conditions.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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