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Assessment of the Performance of Drip-Irrigated Green Pepper (*Capsicum annum* L.) 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

Sweet pepper (*Capsicum annum* L.) is one of an important group of vegetables grown extensively, widely cultivated and used as foods in almost every country of the world. It is a high productivity crop, it has high remunerative and nutritive values. Sweet 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. The experiment was carried out 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 raised, drip irrigation system was installed and fumigation was carried out before transplanting. The experimental design was a randomized

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complete block (RCBD) with nine replications in each environment. The same design was applied to both poly-house and open-field 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. Number of leaves (NL), plant height (PH), stem girth (SG) and weight of fresh fruit (WFF) were recorded. The respective results of performance of green pepper at different irrigation treatments under poly-house and open-field in the 2020/2021 and 2021/2022 growing seasons were: NL-I_5: 180, I_6: 185, I_7: 171 and I_5: 120, I_6: 139, I_7: 122 in 2020/2021 growing season while I_5: 157, I_6: 173, I_7: 160 and I_5: 108.3, I_6: 118.3, I_7: 118 during 2021/2022 growing season. PH-I_5: 128.7, I_6: 139.3, I_7: 125.3 and I_5: 108.3, I_6: 118.3, I_7: 104.7 cm in 2020/2021 growing season while I_5: 117.7, I_6: 129.7, I_7: 120 and I_5: 102, I_6: 115, I_7: 99.3 cm during 2021/2022 growing season. SG-I_5: 30, I_6: 29.7, I_7: 29.6 and I_5: 25.1, I_6: 26, I_7: 25 mm in 2020/2021 growing season while I_5: 20.3, I_6: 23.3, I_7: 21.3 and I_5: 18.5, I_6: 20, I_7: 17.9 mm during 2021/2022 growing season. WFF-I_5: 20.3, I_6: 29.2, I_7: 19.8 and I_5: 13.3.1, I_6: 21, I_7: 14.2 kg/m^2 in 2020/2021 growing season while I_5: 14.6, I_6: 23.5, I_7: 14.7 and I_5: 9.5, I_6: 17.8, I_7: 8.8 kg/m^2 during 2021/2022 growing season.
The controlled conditions provided by the poly-house resulted in best overall performance compared to the open field environment. It is recommended that the assessment of long-term sustainability and economic viability of poly-house cultivation for green pepper production be conducted.

Keywords: Assessment; performance; drip irrigated; green pepper; poly-house and open-field.

1. INTRODUCTION

Sweet pepper (*Capsicum annum* L.) 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]. Sweet 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. Sweet 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.

Green pepper hardly survives during the harsh conditions of the dry season in the southwest region of Nigeria, and this has limited its open-field production during the dry season. The use of poly-house could create a modified environment conducive for the production of green pepper both in the rainy and dry seasons. This in turn increase its productivity and profitability. However, there is likelihood that the natural soil environment could be altered. Despite the great research efforts towards expanding vegetable and species production through the adoption of drip irrigation technologies in every state in Nigeria [3,4,5], there is limited information as regards soil-plant reaction due to irrigation water application. This study therefore becomes expedient, in order to provide adequate scientific information on performance of drip irrigation on green pepper under poly-house and open-field conditions. The deployment of poly-houses in arid and semi-arid regions emerges as a strategic approach to minimize crop water requirements by mitigating evaporation [6]. The plastic and screen coverings alter the local radiation balance, trapping long-wave variations and acting as a barrier to moisture losses [7]. This alteration reduces the water needed for crop production compared to natural conditions. Notably, greenhouses, according to Wiltshire [8], enhance 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 production 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 overall crop production. Therefore, this study aims to performance of drip-irrigated pepper under poly-house and open-field conditions. The southwest region of Nigeria experiences harsh conditions during the dry season, making open-field production of green pepper challenging. The adoption of poly-house technology could

potentially create a controlled environment conducive to green pepper production, irrespective of seasonal variations [9]. However, this shift in the production environment raises concerns about potential alterations to the natural soil conditions.

2. MATERIALS AND METHODS

2.1 Description of the Experimental Site

The study was carried out at the Teaching and Research Farm of the Federal Polytechnic, Ado-Ekiti, Nigeria as shown in Fig. 1. 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^{o}C, respectively. The study area is characterized with highly seasonal rainfall with distinct wet (April – October) and dry (November – March) seasons.

2.2 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 and hoes. Six 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. 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.

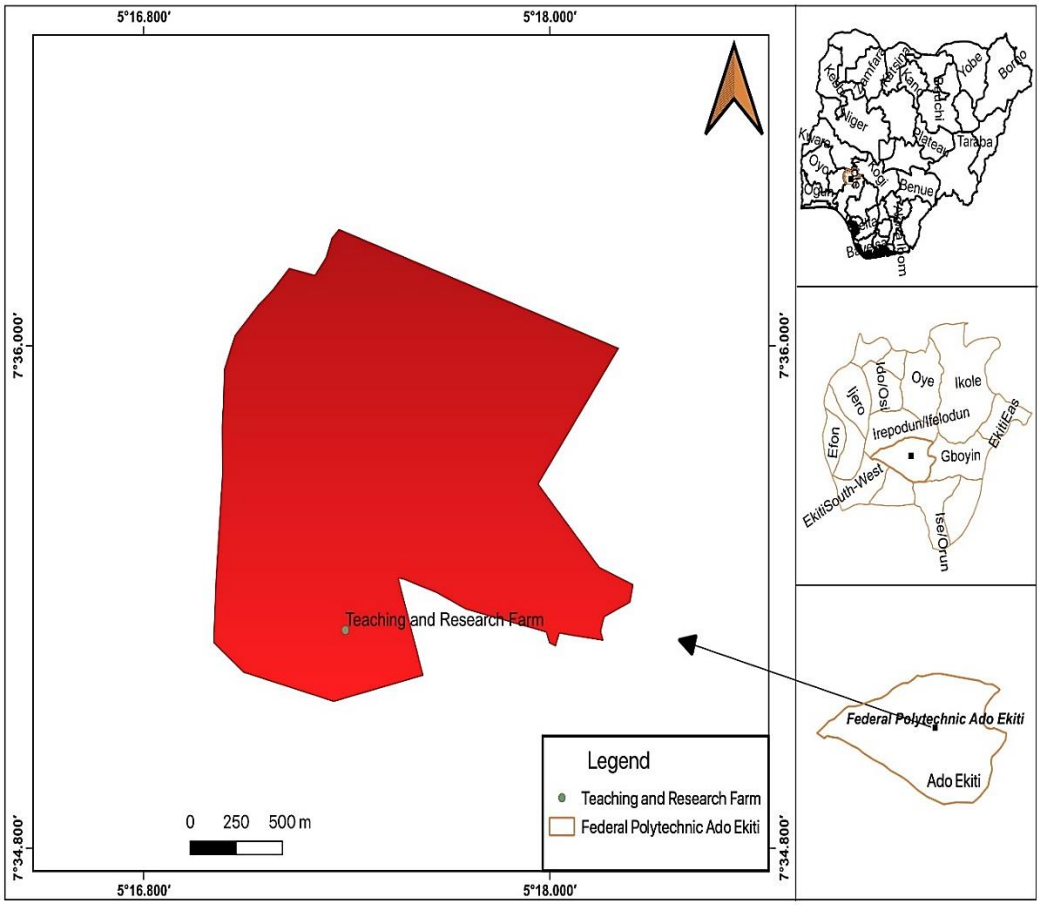

Fig. 1. Map of Nigeria and Ekiti State showing the experimental site

2.3 Experimental Field Layout and Installation of Drip Irrigation

The irrigation was layout with two rows in a block. 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. 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 to each plot.

2.4 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 favorable moisture condition for settlement of seedlings. The field was marked with a spacing of 40 cm × 30 cm in both the directions. 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.

2.5 Measurement of Growth and Yield Agronomic Parameters

The measurements and observations on the growth and yield parameter were conducted and recorded randomly from each plot during the entire period of the experiment. The growth and yield parameters include: Number of leaves, plant heights, girth diameter, number of flowers, number of fruits and weight of fresh fruits. The growth and yield parameters of drip irrigated green pepper under poly-house and open-field conditions were carried out using the procedure described by Abegunrin and Awe [10].

2.6 Statistical Analysis

Statistical analysis was performed using Microsoft Excel, and Statistical Package for Social Scientist (SPSS v. 20). All the agronomic parameters under different irrigation patterns were subjected to statistical analysis. Statistically significant differences in agronomic parameters across irrigation intervals 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.

3. RESULTS AND DISCUSSION

The performance of drip irrigated green pepper was estimated at different irrigation frequencies under poly-house and open-field conditions during 2020/2021 and 2021/2022 growing seasons. The results are presented and discussed as follows:

3.1 Number of Leaves

The effect of drip irrigation frequency on the number of leaves of green pepper crops cultivated in both poly-house and open-field conditions during the 2020/2021 and 2021/2022 growing seasons is presented in Table 1 and Plate 1. Except for 8 WAT (2020/2021) and 4 WAT (2021/2022) in the poly-house, significant differences ($p < 0.05$) were observed in the number of leaves due to drip irrigation frequency in the cropping environments and growing seasons, with treatment I_6 having the highest number of leaves. The poly-house had significantly higher ($p < 0.05$) green pepper plant leaves compared to the open-field in both growing seasons.

3.2 Plant Height

The effect of different drip irrigation frequency on the plant height of green pepper crop cultivated in both poly-house and open-field conditions during the 2020/2021 and 2021/2022 growing seasons is presented in Table 2 and Plate 2. In 2020/2021 growing season, plant height differed significantly ($p < 0.05$) among the drip irrigation frequency only at 4 and 19 WAT in the poly-house while it differed throughout in the open-field. In 2021/2022 growing season, green pepper plant height differed significantly among the drip irrigation frequencies in the two cropping environments. In both growing seasons, treatment I_6 had the consistent tallest green pepper plant.

The poly-house had taller green pepper plant compared to the open-field although the differences were significant ($p < 0.05$) from 12 WAT to harvest in 2020/2021 growing season and from 8 WAT to harvest in 2021/2022 growing season.

Table 1. Effects of drip irrigation frequency on the number of leaves of green pepper grown in poly-house and open-field conditions

		2020\2021					2021\2022				
		Weeks after transplanting (WAT)					Weeks after transplanting (WAT)				
Env.	Irri.	4	8	12	16	19	4	8	12	16	19
	I5	45b	89a	130b	159b	180a	30a	75b	115b	140b	157b
Poly-house	I6	51a	97a	143a	170a	185a	32a	80a	130a	158a	173a
	I7	43b	86a	127b	156b	171b	28a	69b	116b	145b	160ab
	SEM	1.04	3.17	2.47	2.21	1.96	0.92	1.11	2.70	2.64	3.07
	I5	26b	48b	66b	105b	120b	25b	54b	80ab	110b	122b
Open	I6	31a	54a	79a	125a	139a	29a	63a	88a	120a	133a
	I7	25b	47b	67b	102b	122b	24b	53b	76b	106b	118b
	SEM	0.82	0.58	2.08	6.17	6.14	0.43	1.66	2.21	2.30	2.35
Poly x	PH	46A	91A	133A	162A	179A	30A	75A	121A	148A	163A
Open	OF	27B	50B	71B	111B	127B	26A	56B	81B	112B	124B
	SEM	1.14	1.78	2.47	3.74	3.48	0.78	1.73	2.47	2.68	2.73

Env: environment; Irri.: irrigation frequency; I_5: five irrigations per week; I_6: six irrigations per week; I_7: seven irrigations per week; PH: poly-house; OF: open-field; SEM: standard error of the mean.
Irrigation frequency with different lowercase letters differed significantly at 5% level of probability by Tukey test.
Cropping environment with different uppercase letters differed significantly at 5% level of probability by t-test.

Table 2. Effect of drip irrigation frequency on plant height (cm) of green pepper grown in poly-house and open-field conditions.

		2020\2021					2021\2022				
		Weeks after transplanting (WAT)					Weeks after transplanting (WAT)				
		4	**8**	**12**	**16**	**19**	**4**	**8**	**12**	**16**	**19**
Poly House	I5	23.7b	56.0a	87.3a	117.0a	128.7ab	26.0b	53.7b	77.7b	106.3b	117.7b
	I6	26.0a	59.3a	95.0a	123.3a	139.3a	29.3a	59.7a	87.7a	118.0a	129.7a
	I7	23.3b	57.3a	89.0a	113.0a	125.3b	26.3b	52.3b	78.3b	109.3b	120.0ab
	SEM	0.43	1.32	3.10	2.91	2.91	0.54	0.67	0.67	1.82	2.49
Open Field	I5	24.3ab	50.7ab	75.0b	90.3b	108.3b	24.0ab	47.0b	69.3b	91.0b	102.0b
	I6	29.3a	60.7a	86.0a	103.0a	118.3a	28.3a	54.3a	79.7a	103.7a	115.0a
	I7	19.0b	46.3b	70.7b	90.0b	104.7b	19.0b	42.7b	66.3b	89.3b	99.3b
	SEM	1.52	2.36	2.50	2.41	2.00	1.58	1.52	1.56	1.69	2.12
Poly x	PH	24.3A	57.6A	90.4A	117.8A	131.1A	27.2A	55.2A	81.2A	111.2A	122.4A
Open	OF	24.2A	52.6A	77.2B	94.4B	110.4B	23.8A	48.0B	71.8B	94.7B	105.4B
	SEM	1.23	1.81	2.29	2.28	2.42	1.18	1.56	1.92	2.20	2.44

Env: environment; Irri.: irrigation frequency; I_5: five irrigations per week; I_6: six irrigations per week; I_7: seven irrigations per week; PH: poly-house; OF: open-field SEM: standard error of the mean.
Irrigation frequency with different lowercase letters differed significantly at 5% level of probability by Tukey test.
Cropping environment with different uppercase letters differed significantly at 5% level of probability by t-test.

Plate 1. Number of leaves of green pepper under poly-house

Plate 2. Plant height of green pepper

3.3 Stem Girth

Table 3 and Plate 3 show the effect of drip irrigation frequency on the stem girth of green pepper crop cultivated in both poly-house and open-field conditions during the 2020/2021 and 2021/2022 growing seasons. Stem girth did not differ significantly ($p > 0.05$) due to drip irrigation frequency except in the open-field during the second growing season. Irrespective of the cropping environment and growing season, treatment I_6 had green pepper plants with the widest stem. Although the poly-house had wider green pepper plants compared to the open-field but the difference was only significant ($p < 0.05$) during the second growing season. Furthermore, higher stem girths were observed in 2020/2021 growing season compared to 2021/2022 growing season, suggesting that factors beyond irrigation frequency, such as differences in temperature, precipitation, and overall weather conditions, and soil nutrient conditions.

3.4 Yield and Yield Components

The results of the impact of drip irrigation frequency on the yield and yield components of the green pepper crop cultivated in both poly-house and open-field conditions during the 2020/2021 and 2021/2022 growing seasons is presented in Table 4 and Plates 4 & 5. In 2020/2021 growing season, the total number of fruits was significantly ($p < 0.05$) higher in I_6 treatment compared to I_5 and I_7 treatments by about 23% in the poly-house and 28% in the open-field. Similarly, fruit weight was higher ($p < 0.05$) in I_6 treatment than from I_5 and I_7 treatments by about 31% in the poly-house and 37% in the open-field. In the second growing season, similar trend was observed however the fruit weight increased further in I_6 treatment by 7% (poly-house) and 13% (open-field) compared to I_5 and I_7 treatments.

The poly-house had total number of fruits and fruit weight significantly higher ($p < 0.05$) by about 27% and 30%, respectively than the open-field in the 2020/2021 growing season. In 2021/2022 growing season, the difference in the total number of fruits between the two cropping environments decreased by about 2% while the difference in fruit weight increased by about 2% in comparison to the previous growing season.

Table 3. Effect of drip irrigation frequency on stem girth (cm) of green pepper grown in poly-house and open-field conditions

		2020\2021					2021\2022				
		Weeks after transplanting (WAT)					Weeks after transplanting (WAT)				
Env.	**Irri.**	**4**	**8**	**12**	**16**	**19**	**4**	**8**	**12**	**16**	**19**
Poly House	I5	6.6	12.4	19.0	27.3	30.0	5.0	8.5	15.7	21.8	25.1
	I6	7.0	12.5	19.2	27.3	29.7	5.7	10.5	16.7	23.0	26.0
	I7	7.1	12.6	19.3	27.2	29.6	5.1	9.6	15.6	22.0	25.0
	SEM	0.41	0.32	0.31	0.64	0.80	0.16	0.80	0.48	0.48	0.48
Open Field	I5	5.7	9.6	14.8	19.0	20.3	4.3ab	7.3b	12.8b	16.7b	18.5b
	I6	7.1	11.8	16.9	21.2	23.3	4.7a	8.5a	14.6a	18.5a	20.0a
	I7	5.8	10.5	15.5	19.6	21.3	3.9b	7.3b	12.7b	16.7b	17.9b
	SEM	0.50	0.68	0.76	0.80	0.93	0.15	0.15	0.29	0.37	0.24
Poly x	PH	6.9	12.5	19.2	27.3	29.8	5.3A	9.5A	16.0A	22.3A	25.4A
Open-field	OF	6.2	10.6	15.7	19.9	21.6	4.3B	7.7B	13.4B	17.3B	18.8B
	SEM	0.28	0.35	0.37	0.43	0.54	0.14	0.38	0.31	0.33	0.32

Env: environment; Irri.: irrigation frequency; I_5: five irrigations per week; I_6: six irrigations per week; I_7: seven irrigations per week; PH: polyhouse; OF: open-field; SEM: standard error of the mean.
Irrigation frequency with different lowercase letters differed significantly at 5% level of probability by Tukey test.
Cropping environment with different uppercase letters differed significantly at 5% level of probability by t-test.

Table 4. Effect of drip irrigation frequency on yield traits of green pepper grown in poly-house and open-field conditions

		2020/2021		2021/2022	
		Total No of Fruit -	**Fruit Weight, kg/m^2**	**Total No of Fruit-**	**Fruit Weight kg/m^2/mm**
Poly-house	I5	226.3b	20.3b	166.7b	14.6b
	I6	296.7a	29.2a	212.7a	23.5a
	I7	227.7b	19.8b	160.0b	14.7b
	SEM	3.45	0.66	2.70	0.46
Open-field	I5	160.0b	13.3b	126.3b	9.5b
	I6	224.3a	21.0a	155.3a	17.8a
	I7	163.0b	14.2b	120.0b	8.8b
	SEM	3.41	0.33	3.57	0.21
Poly x	PH	250.2A	23.1A	179.8A	17.6A
Open-field	OF	182.4B	16.2B	133.9B	12.0B
	SEM	11.19	1.40	7.18	1.47

I_5: five irrigations per week; I_6: six irrigations per week; I_7: seven irrigations per week; PH: poly-house; OF: open-field~; SEM: standard error of the mean.
Values in a column followed by different letters differed significantly at 5% level of probability by Tukey test.

Plate 3. Stem girth of green pepper

Plate 4. Pictorial view of the number of fruits under poly-house

Plate 5. Harvested fresh fruits of green pepper

The differences observed between poly-house and open-field conditions can be attributed to various factors. Poly-house environments offer controlled climate conditions, contributing to enhanced plant growth compared to the open-field, where plants are subject to more variable weather conditions. The higher crop performance observed in the poly-house condition shows the potential advantages of controlled environments for promoting plant growth. These findings align closely with the research of Ali and Kelly [11], Polowick and Sawlaney [12], Kumari [13], and Beese et al. [14]. There were fewer number of leaves, reduced plant height, stem girth, and number of flowers in 2021/2022 growing season compared to the 2020/2021 growing season, suggesting that factors beyond irrigation frequency, such as climatic variations (temperature fluctuations, precipitation, and overall weather conditions) and potential differences in crop management, may have influenced plant growth. These findings align with the results of Rameshi and Arunugam [15], Patil et al. [16] and Shende et al. [17] on capsicum, sweet pepper, tomato, cucumber and other vegetables grown under poly-house and open-field conditions.

4. CONCLUSION AND RECOMMENDATION

The green pepper plants grown in the poly-house environment showed better overall performance compared to those planted in the open-field condition. The poly-house condition provided a favourable micro-climate, reduced exposure to pests and diseases. This resulted in higher yield, better fruit quality and reduced crop losses. Yields were found to be significantly higher in the poly-house condition compared to the open-field environment during the two growing seasons. The production of green pepper should be carried out under poly-house condition for optimum productivity and sustainability of soil. Research on performance of green pepper under poly-house and open-field conditions will provide valuable insights into the effect of environmental factors, such as temperature, humidity, and light intensity on plant growth and yields. This research will help farmers make informed decisions on which cultivation method to use, based on their specific environment.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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