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Research Article

Radiation Use Efficiency and Yield Response of Chili Pepper under Rainfed Agriculture in Akure, Nigeria.

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Abstract

Growing pepper extensively under rain-fed conditions is the oldest method of cultivation and widely accepted in most parts of Nigeria, yielding very high returns. However, its progress is hindered by the non-adoption of technology and efficient agricultural management practices, lack of information about soil conditions for cultivation, and inefficient radiation use by the crop. Reliable data specific to southwestern Nigeria for such practices is scarce. This research aims to evaluate the radiation use efficiency (RUE) and yield of chili pepper (*Capsicum Annum*) under rain-fed agriculture. To achieve this, an experiment was conducted on three different chili pepper plants transplanted with varying spacings: 40cm by 40cm on plot A, 35cm by 35cm on plot B, and 30cm by 30cm on plot C. Prior to planting, soil analysis was conducted to determine properties including pH, organic carbon, organic matter, and particle size. Evapotranspiration was determined using the soil and water balance method, considering rainfall, drainage, runoff, and changes in soil moisture. Agronomic and yield parameters such as plant height, stem girth, leaf area index, and photosynthetically active radiation (PAR) were measured using a meter rule, vernier caliper, and Ceptometer (PAR sensor). Radiation use efficiency was calculated based on intercepted photosynthetic active radiation, leaf area index, and yield. Results indicate that the soil pH was measured to be 6.0, classifying the soil as sandy loam, which is suitable for chili pepper cultivation. Evapotranspiration was lowest in the 16th week after transplanting (0.37mm) and highest in the 11th week (41.18mm). In terms of yield and RUE, chili pepper plants on plot A, plot

B, and plot C produced total fresh fruit yields of 2.45 tons/ha, 2.1 tons/ha, and 1.768 tons/ha, respectively. Radiation use efficiency was 1.297b±0.1487 g/MJ for plot A, 1.018ab±0.0316 g/MJ for plot B, and 0.902a ±0.0624 g/MJ for plot C. Significant differences were observed between these values ($p<0.05$). The results demonstrate a positive correlation between increased yield and higher RUE. To enhance chili pepper production, farmers can improve RUE by optimizing management practices such as adjusting plant spacing and plant density.

Keywords: Evapotranspiration, radiation use efficiency, growth variables, yield, chili pepper, rainfed agriculture

1. Introduction

Capsicum annuum L. is the most economically significant pepper and comes in a wide variety of horticultural forms, including sweet and spicy. Due to its economic significance as well as the fruit's mix of flavour, colour, and nutritional content, it is a significant and well-liked produce in agriculture (Al-Snafi, 2015). It is a member of the *Solanaceae* family, specifically the genus *Capsicum*. *Annuum*, *Baccatum*, *Chinense*, *Frutescens* and *Pubescen* are the five domesticated species among the roughly 31 species in the genus Capsicum (Moscone et al., 2007). The fruits are a valuable vegetable crop for both processed goods and the fresh market. There are hundreds of different types and species of peppers. They are consumed as fresh unripe fruits, ripened red or other colors and dried forms. The different species, varieties and consumption forms vary in their nutritional and anti-oxidant contents (Ganguly et al.,2017). While 25–30 °C is the ideal temperature range for seed germination, 18–30 °C is the ideal temperature range for growth and fruit production. According to Campiglia et al. (2010), flower buds are aborted at nighttime temperatures exceeding 32 °C, while delayed flowering occurs if daytime temperatures are less than 25 °C. Temperatures above 30 °C and below 15 °C significantly diminish pollen viability, although nighttime lows around 15 °C promote fruit setting. Despite being day-neutral, capsicum annuum can exhibit photoperiodic reactions in some ways. Long days may cause a slight delay in the first blossoming (Grubben and El Tahir, 2004). Shade can delay flowering, but it can endure up to 45% of sun exposure. In Ethiopia, capsicum annuum can grow up to 3,000 meters, although it can also grow lowland to 2,000 meters. An annual rainfall of at least 600 mm is required in the absence of irrigation. Diseases, rotten fruit, and poor fruit setting are all increased by water logging. According to Gruben and El Tahir (2004), capsicum is quite susceptible to soil salt. Nigeria's favourable soil and climate make it easy for pepper to grow and produce. About half of all pepper produced in Africa comes from Nigeria, which is one of the world's leading producers (Mohammed et al., 2013). 80% of the world's cropland is used for rainfed farming, which also generates over 60% of the world's cereal grains and supports rural communities. Rainfed agriculture produces high yields in temperate regions with rich soils and somewhat consistent rainfall. Yields are further increased by supplemental watering techniques (Molden et al., 2011). The main energy source for life on Earth is solar radiation (Wild, 2009), and PAR, or the fraction of the global radiation with wavelengths between 400 and 700 nm, is essential for vegetation photosynthesis. In hydrological and agricultural research, as well as in the modelling of terrestrial photosynthesis, PAR is crucial (Niu et al., 2018). Even though PAR is a crucial variable in models of terrestrial photosynthesis, a global network for its measurement has not yet been built (Hu and Wang, 2012). The plant's LAI, canopy architecture (which influences how much LAI is successfully exposed to light), and physiological ability to absorb radiation are the primary determinants of an intercepted PAR. Accordingly, the canopy's capacity to absorb incoming PAR and transform it into biomass is the main factor influencing plant growth and production in field settings (Hangs et al., 2011). Radiation use efficiency (RUE) is a crucial component of crop development, along with intercepted photosynthetically active radiation (IPAR). RUE is the relationship between biomass accumulation and the amount of PAR, or the solar energy that the crop absorbs and its biomass production rate. It is frequently used to estimate biomass accumulation in crops like soybeans and maize (Lindquist et al., 2005) and wheat (Zhi-qiang et al., 2018). Given the importance of chili pepper for human consumption and the fact that RUE depends on light intensity, which varies by season, latitude, cloud cover, water application, and plant canopy architecture (leaf position, leaf shape, leaf size, leaf arrangement, LAI, and leaf angle) (Vos et al., 2010), it is imperative to conduct research on the efficiency of radiation and water use for optimal growth. Regarding the aforementioned claim, an effort was made to ascertain the effectiveness of radiation use and evapotranspiration in relation to the development and productivity of chili peppers under rainfed agriculture in Akure, Nigeria.

1.1 Specific objectives

The specific objectives of this research are to:

i. investigate the fraction of the beam interception and RUE of chili pepper under rainfall water application and different plant spacing;
ii. determine the yield and yield components of chili pepper under rainfall water application and different plant spacing;
iii. investigate the relationship between the RUE and yield of chili pepper.

2. MATERIALS AND METHODS

2.1 Site Description

The study was carried out at the Research and Training Farm of Federal University of Technology, Akure, (FUTA). Akure is located on latitudes $7^0$014'N and $7^0$017´N and within longitudes $5^0$008´E and $5^0$013´E. Akure has a land area of about 2 303 km^2 and is situated in the western upland area within the humid region of Nigeria. The general elevation is 300 - 700 m. Local peaks rise to 1000 m; other hill-like structures which are less prominent rise only a few hundred meters above the general elevations. The average daily temperature is 26 °C with a range between 18 ^oC and 35 ^oC. Mean annual relative humidity of about 80% and relief is about 396 m above sea level (Odubanjo et al., 2011). The pattern of rainfall is bimodal, the first peak occurring in June and July, and the second in September, with a little dry spell in August. The mean annual rainfall ranges from 1300 mm to1500 mm (Fasinmirinet and Oguntuase, 2008). The soils are light textured, fine sandy loam to fine sandy clay loam. The soil is moderately well supplied by organic matter and nutrients. Moisture holding capacity is moderately good (Fasinmirin and Olurunfemi, 2012). The soil generally becomes dry during the dry seasons which fall within November and March.

2.2 Experimental Setup and Layout

An experimental field of 3.14 m by 8 m was cleared, leveled using manual method and was divided into three portions of plot. The soil was sterilized through the direct heat application with firewood in order to eliminate nematode and other harmful microorganism. After, the field was divided into three plots (plot A, B, and C) of size 2 m by 2 m each. Twelve (12) stands of chili pepper plants were transplanted on each plot after being raised in the nursery for 4 weeks with 40cm by 40cm spacing on plot A, 35 cm by 35 cm spacing on plot B, and 30 cm by 30 cm after 4th week of raising the plants in the nursery. Three (3) plants out of the 12 transplanted plants were chosen on each plot as sample (T1, T2 and T3), and measurements were taken on them every week of the growth period. Periodic weeding was also carried out manually and agrochemicals such as pesticides and insecticides (Gly-Net 41) were applied on the farm to keep away insects and pests at regular intervals. The experiment was made on open field to study the leaf area index, RUE, growth and yield response pepper (*Capsicum* sp.) under a Rain fed condition.

2.3 Soil physiochemical properties and bulk density

Samples of sands were randomly taken from each experimental plot. In addition, soil samples were randomly collected within the depths of 0-15 cm using a hand auger from the agricultural engineering experimental farm where the open field farming was carried out. Each sample was separately labeled, air-dried, crushed to pass through a 2 mm sieve, and taken to the laboratory for physical and chemical analysis to determine their physical properties and nutrient level prior to application of inorganic nutrients/solution. The particle size analysis was done with two basic steps namely; the separation of all particles from each other (sieve analysis) and the other is the measurement of the quantities of each size group together (Ibitoye, 2006), The Walkley-Black wet oxidation method was used for determination of organic carbon and organic matter as described by Nelson and Sommers, (1996), total nitrogen content was determined with Kjeldahl method determines (AOAC, 2000). Determination of exchangeable bases such as, calcium (Ca), magnesium (Mg) are carried out by flame atomic absorption spectrophotometer while potassium (K) and sodium (Na) determination is carried out in the laboratory using flame emission spectrophotometer

Also, soil samples each were taken at depths 10cm to 50cm with metal cans, taken to the laboratory to oven dry to determine the soil bulk density base on gravimetric soil core method. The bulk density was determined using the formula below (Agbede and Ojeniyi, 2009)

Bulk density = $\frac{M_5}{\pi r^2 h}$

Mass of dried soil sample = M_5

Radius of core sampler = r

Diameter of core sampler = d

Volume of core sampler = $\pi r^2 h$

2.4 Estimation of Crop Evapotranspiration

Total crop evapotranspiration (ETc) was estimated using the soil water balance equation by (Allen et al., 1998).

$ET_c = I + R \pm \Delta S - D - R$

I = irrigation (mm)

R = precipitation (mm)

ΔS = change in soil water storage (mm)

D = drainage (mm)

R = runoff. (mm)

Throughout the growth weeks, the irrigation was zero due to non-application of water through irrigation. The rainfall/precipitation applied to the field was measured with rain gauge, the soil moisture was determined by the use of soil moisture sensor PR2, the deep drainage measurement was done by the use of lysimeter which was filled with fine sand to the brim and a plastic can place at the water outlet of the lysimeter, while the runoff on the experimental plot was measured with runoff meter The runoff meter was made from metal sheet plate opened at both ends. The device permits the flow of water within the catchments area to a runoff collector (plastic can) after rainfall through a 25.4 mm galvanized steel pipe.

2.5 Agronomic and Yield Measurements

At week three weeks after transplanting, three plants were selected randomly from each plot and tagged for measurement of growth characteristics. As for the agronomic parameters, plant height was measured by meter rule, number of leaves was measured by counting, stem girth was determined using Vernier caliper while the leaf area index, fraction of beam interception, and the PAR were measured with a Ceptometer. For the yield parameters, number of fruits was determined by counting, fruit diameter and length were measured by vernier caliper, and the weight of each fruit was also determined with weighing scale. All this was done after harvest

2.6 Radiation use efficiency

The RUE of the chili pepper plants were obtained based on the intercepted photosynthetic active radiation (IPAR), leaf area index and yield of the chili pepper plants on different planting plots (Plot A, Plot B, and Plot C). RUE can be calculated using the equation (Linderson et al,2007).

$$\mathrm{RUE} = \frac{\mathrm{W_s}}{\mathrm{IPAR}}$$

W_s = total above ground dry mass (AGDM) production (g DM m^{-2})

IPAR = Interception of PAR was evaluated using Lambert-Beer's Law function:

$$\mathrm{IPAR} = \mathrm{PAR_{above}}(1 - e^{-kLAI})$$

PAR_{above} = Cumulated PAR above canopy

K = Constant which ranges from 0.4 – 0.6

The value of K that should be used for chili pepper may vary depending on several factors such as plant age, plant density, leaf angle, and leaf area index. In general, the value of K for chili pepper has been reported to range from 0.45 to 0.65 in various studies. A study by Al-Karaki et al. (2010) reported a value of 0.55 for K in a field experiment with chili pepper. Another study by Kumar et al. (2013) reported a value of 0.50 for K in a greenhouse experiment with chili pepper. For this study, 0.50 was chosen.

2.7 Statistical Analysis

Crop parameters were analyzed using the descriptive statistical approach such as mean, standard deviation and coefficient of variation. Analysis of variance (One-way ANOVA) and post hoc comparison was conducted to test the significant difference among treatments at ($P \leq 0.05$). Homogeneity of means at $P \leq 0.05$) was tested using the Duncan test. Comparison among the treatment was achieved by using Microsoft Excel 16.00 (Microsoft Inc, USA) software package for windows.

3. Results and Discussions

3.1. Soil Analysis

The information soil's physical and chemical properties from the experimental site was as reported in (Table 1). The result showed the percentage proportion of sand, clay and silt to be 64.80%, 23.20% and 12.00% respectively. In comparison to USDA textural classification, the soil could be classified as sandy loam. Pepper performs in sandy loam soils rather than clay soil, although the loam and clay loam soils are also good for chili cultivation but the soil should be well drained and aerated as it gives a better yield (Savvas et al, 2013). The soil pH was 6.0, though acidic, it is the preferred soil range for good growth and optimum yield of pepper. Salako et al. (2007), reported that the best pH range for chili pepper production was 5.0 to 6.0. Organic matter had an average value of 1.58 while the nutrients constituents of nitrogen, phosphorus, potassium, calcium and magnesium were 4903.5 mg/kg, 373852.2 mg/kg, 16392 mg/kg, 52096 mg/kg, 24583.1 mg/kg respectively were in sufficient quantities for optimum production of pepper under standard environmental conditions.

Table 1. Result of physical and chemical analysis

S/N	Soil Properties	Value
1	Loam %	64.67
2	Clay %	23.20
3	Sand %	13.19
4	pH	6.0
5	Organic carbon (mg/kg)	165600
6	Organic matter (mg/kg)	284400
7	N^{3-}(mg/kg)	4903.5
8	P^{3-}(mg/kg)	373852.2
9	K^{+}(mg/kg)	16392
10	Na^{+}(mg/kg)	11934.8
11	Ca^{2+}(mg/kg)	52096
12	Mg^{2+}(mg/kg)	24583.1

3. 2. Soil Bulk Density

Based on the data provided in Table 2, it was seen that the bulk density varied between the different plots and depths. The plot A bulk density ranges from 1.93g/cm^3 at a depth of 10 cm to 2.19 g/cm^3 at a depth of 40 cm. Overall, the bulk density for Plot A is relatively high, and it shows an increasing trend with depth until 40 cm, where it reaches the highest value. This is quite similar to study of Awotoye et al. (2013) that, "The bulk density of the topsoil (0-15 cm) varied between 1.65 and 1.93 g/cm^3, and increased significantly ($p < 0.05$) with soil depth from 1.65 to 2.15 g/cm^3 at 15-30 cm depth, and remained relatively constant between 2.05 and 2.19 g/cm^3 at 30-45cm depth". The plot B bulk density ranges from 1.96g/cm^3 at a depth of 10cm to 2.30 g/cm^3 at a depth of 30cm. Overall, the bulk density for Plot B is also relatively high, and it shows an increasing trend with depth until 30 cm, where it reaches the highest value similar to the study of Awotoye et al. (2013). The Plot C, the bulk density ranges from 2.02 g/cm^3 at a depth of 40cm to 2.26 g/cm^3 at a depth of 50 cm. Overall, the bulk density for Plot C is lower compared to the other plots, and it does not show a clear trend with depth. In general, the data suggest that the soil in Plots A and B is more compacted than that in Plot C. This could be due to differences in soil management practices, such as tillage or compaction from heavy equipment. The high bulk density in Plots A and B could limit plant growth and reduce soil fertility, while the lower bulk density in Plot C could indicate better soil structure and a more favorable environment for plant growth. Akinbile and Yussouf (2011) stated that, "The soil bulk density varied from 1.58 g/cm³ to 1.93 g/cm³, indicating moderate compaction at 15-30 cm depth". Therefore, there is moderate compaction at the topsoil of the plot A and B. Compaction increases bulk density and reduces total pore volume, consequently reducing available water holding capacity (Fasinminrin et al., 2018).

3. 3. Evapotranspiration and Climatic Condition

The climatic parameters (rainfall and runoff), change in soil moisture level, soil drainage and irrigation application were collected on the farm, to estimate the evapotranspiration.

Table 2. Bulk density of the soils on each plot at different depths

	Bulk Density (g/cm^3)		
Depths	**Plot A**	**Plot B**	**Plot C**
10cm	1.93	1.96	2.09
20cm	2.15	2.20	2.13
30cm	2.05	2.30	2.05
40cm	2.19	2.05	2.02
50cm	2.07	2.20	2.26

Evapotranspiration of the plants on all the plots were dependent mostly on rainfall water application. Figure 1 shows the graph and trend of the evapotranspiration of the crops. Rise in ET_o was observed from 3rd week after transplanting to week 11 and took a gradual downturn from 11th to the 16th week. The estimated evapotranspiration (ETo) ranges between 0.32 mm recorded at the 16th week after transplanting the crops and 41.18 in week 11th week. It was maximum in the 11th week due to heavy rainfall and must have been caused by high solar radiation which is accompanied by high temperature that often results in quick evaporation of water from soil and water surfaces (Fasinminrin et al., 2009).

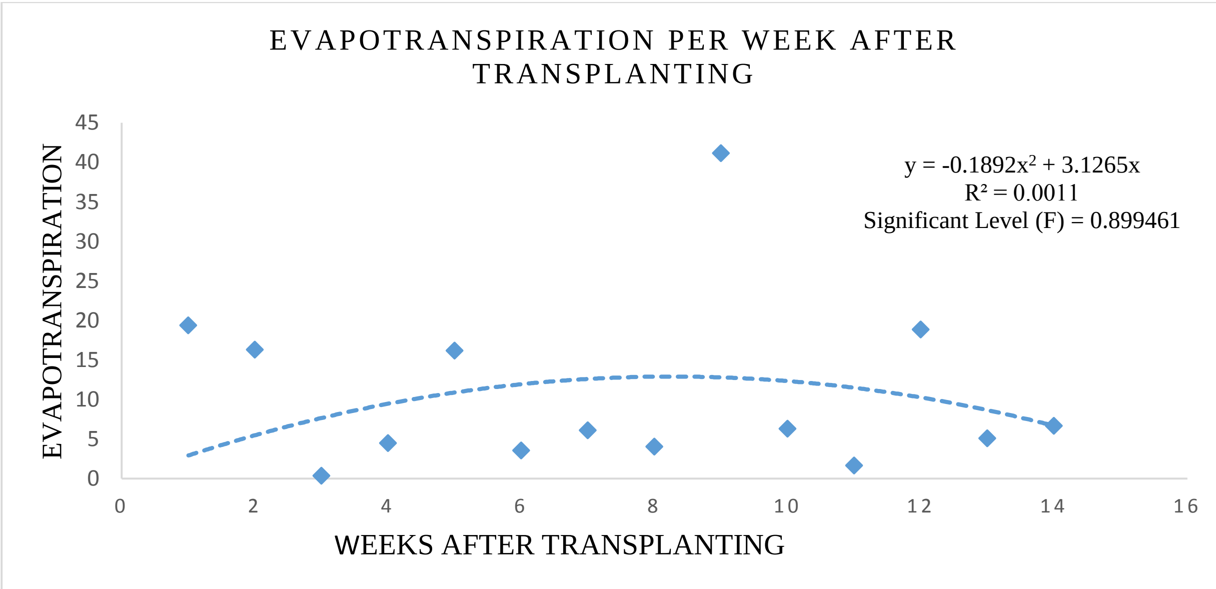

Figure 1. Evapotranspiration throughout the planting weeks

Table 3. Evapotranspiration of plants weeks after transplanting

weeks	Rainfall (mm)	Runoff (mm)	Drainage (mm)	Change in soil moisture storage (mm)	Irrigation (mm)	Evapotranspiration (mm)
3	70	24	26	0	0	19.41
4	53	16	21	-1.35	0	16.34
5	14	6	6	-0.37	0	0.37
6	18	8	6	-0.52	0	4.52
7	61	20	21	3.79	0	16.21
8	23	14	10	-4.57	0	3.57
9	18	6	8	-2.11	0	6.11
10	25	6	10	4.93	0	4.07
11	142	44	52	4.82	0	41.18
12	69	31	31	0.66	0	6.34
13	23	7	14	0.33	0	1.67
14	71	33	20	-1.86	0	18.86
15	63	21	29	5.89	0	5.11
16	69	28	34	0.32	0	6.68

3. 4. Agronomic Parameter

The result of measured average plant heights in all the treatments with the corresponding Weeks After Planting (WAT) is as shown in Figure 2. Although the plant growth pattern shows an initial slow growth and then accelerated as observed in Figure 1, after the normal slow establishment of the plant. This result agreed with the findings of other researchers (Olaniyi et al., 2010) who found that the plant showed growth in height at the beginning rather slowly, increasing to a maximum then slow down again. The maximum mean plant heights in Plot A, B, and C were approximately 70, 79, and 61 cm, respectively which showed that planting the pepper on different farming plot with different spacing under rainfall did not really affect the plant heights. There are possibilities that, the soil on the plots has same properties or same quantity of rainfall was applied on all the plots. The means number of leaves of the plots were highest at week 13 before the number of leaves started reducing, and this can mean the average number of leaves has direct relationship with the amount of rainfall applied on the plots. At week 11 of the growth period, there was much rainfall, poor percolation, and this affected the plant growth. Akinbile and Yussouf (2011) noted that, under well-watered conditions, photosynthesis with chlorophyll brings out the lush green and radiant colorations of leaves and its width is also a function of nutrients and water availability for uptake from the root zones.. Therefore, for ideal growth of crops, water application must be optimum. There was also a significant but gradual increase in average stem diameters in all the three farming plots during the growth period of the plants. The mean stem girth value for plot B was the highest ranging from 1.97 to 17.27 mm, followed by plot A with mean stem girth ranging from 1.81 to 13.83 mm, and the lowest mean stem girth value of 1.49 to 12.69mm which was found to be for plot C as shown in figure 1. This result is similar to Akinbile and Yussouf (2011), in their study of the “Growth, Yield and water use pattern of chili pepper under different irrigation scheduling and management”, where it was noted that average stem diameter ranged from 0.7 to 1.7cm which is equivalent to 7 to 17 mm. This shows that there was a direct relationship between plant height and stem diameter when compared with the quantity of rainfall or water used. According to figure 1, the highest average leaf area index mean value (1.2567) was obtained for peppers on farming plot B in week 13 after transplanting, at this week the Leaf area index of the pepper on plot B was 23.6% greater than the pepper on plot A (0.9600), and 24.6% greater than the pepper on plot C (0.9167) which was the lowest average mean value among the plots. Oyewole et al. (2020) reported the LAI values to ranging from 0.9 to 1.3 for chili pepper under rainfed conditions with mulching. The leaf area index peak value for all plants on all the plots was recorded in week 13 of the growth week before it started decreasing gradually till week 16. this was due to loss of plant leaves and poor growth during the period due to much water in the soil. Also, water stress can affect plant's LAI as reported by Karam et al. (2009), that water stress reduces the IPAR and RUE of the crop. Plot B has the peak average FB (1.900) among the farming plots as shown in Figure 6 and this was attributed to the plot B having the highest leaf area index (LAI), Jonckheere et al. (2004), reported that leaf area has a significant impact on photosynthesis and PAR interception. Figure 1, the graph of above PAR against weeks after transplanting of the peppers on each plot, shows that above PAR for all the plots were at peak in week 8 with over 1350 μmol $m^{-2}s^{-1}$, while the lowest value was recorded in week 3 of the growth period. The above PAR increase haphazardly from week 3 to 8 before it became stable and decrease. This goes against the findings of Shrarifi et al. (2020), they found that a PAR level of 1000 μmol $m^{-2}s^{-1}$ was optimum for chili pepper plant growth and photosynthesis. However, Du et al. (2021), found out that the PAR can range from 500 - 1600μmol $m^{-2}s^{-1}$, but 1600 μmol $m^{-2}s^{-1}$ is excessive light intensity which can cause photoinhibition and reduced plant growth and yield.

3. 5. Yield Parameters

The size of the chili pepper fruit was obtained based on the fruit diameter and the fruit length on weekly basis under different plots (A, B and C) are presented in Figure 2. it shows that the fruit length ranges from 9.433 cm - 10.543 cm, 9.023 cm - 10.700 cm, 6.017 cm - 10.477 cm on plot A, plot B, and plot C respectively, this clearly shows that the pepper fruits obtained on plot A has the biggest length compared to other plots. Those values are close to what some other researchers reported on fruit lengths of chili pepper. Yang et al. (2018), reported the fruit length of hot pepper under rainfed agriculture ranges from 8.78 to 10.44cm, and Canan et al. (2019), reported that it ranges from 8.28 to 10.15cm Also, Figure 3 shows that the fruit diameter ranges from 0.627 cm – 2.427 cm, 0.573 cm – 2.380 cm, 1.110 cm – 2.043 cm on plot A, plot B, and plot C respectively, this clearly shows that the pepper fruits obtained on plot A has the biggest diameter compared to other plots. The range of fruit diameter gotten was the almost the same to that of some researchers. Yang et al. (2018), reported the fruit length of hot pepper under rainfed agriculture ranges from 1.46 to 1.68cm, and Canan et al. (2019), reported that it ranges from 1.49 to 1.76cm. The total weight of the harvested fruits on each plot was recorded and presented in figure 13. It can be seen that plot A has the highest harvested fruit weight of 983.0g, followed by plot B with 840.4g average fruit weight, while plot C has the lowest average harvested fruits weight of 707.3g. The yield of the pepper was also presented on figure 13, the plot A was seen to have the highest yield of 2450 kg/ha which is equivalent to 2.45ton/ha, followed by plot B with yield of 2100 kg/ha equivalent to 2.1ton/ha, and plot C with the lowest yield of 1768 kg/ha equivalent to 1.768 ton/ha. Similar results were obtained by Akinbile and Yussouf (2011) in their study of growth, yield and water use pattern of chili pepper under different irrigation scheduling and management, with pepper yield ranging from 1.28 to 2.64 ton/ha. Difference in the yield is due to the planting space between the pepper on the plots. Plot C has the smallest planting space and the lowest yield, and this may be due to competition for nutrient between the plants.

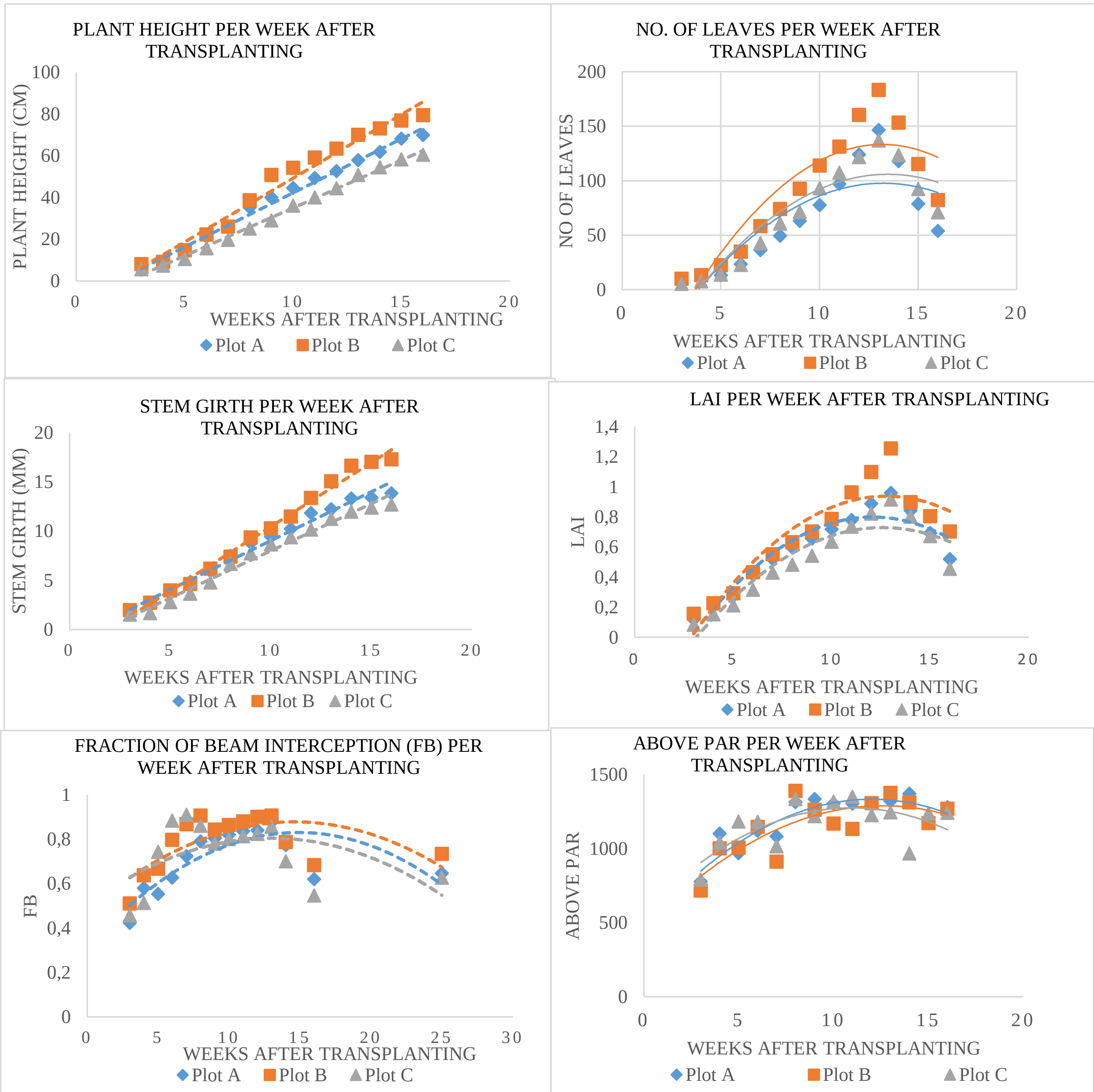

Figure 2. Graphics of agronomic parameter (plant height, stem girth, number of leaves, LAI, FB, and above PAR) against weeks after transplanting

This shows that plant spacing and density affect yield of chili pepper plants. Liu et al. (2008), concluded that pepper yield varied significantly from one region to the other and several factors such as topography, soil type, water quality, soil tillage and fertilizer application. For the yield of chili pepper on sandy loam soil, average 2.45ton/ha is desirable but a much higher yield could be obtained under similar soil conditions with fertilizer application as stated by Liu et al. (2008).

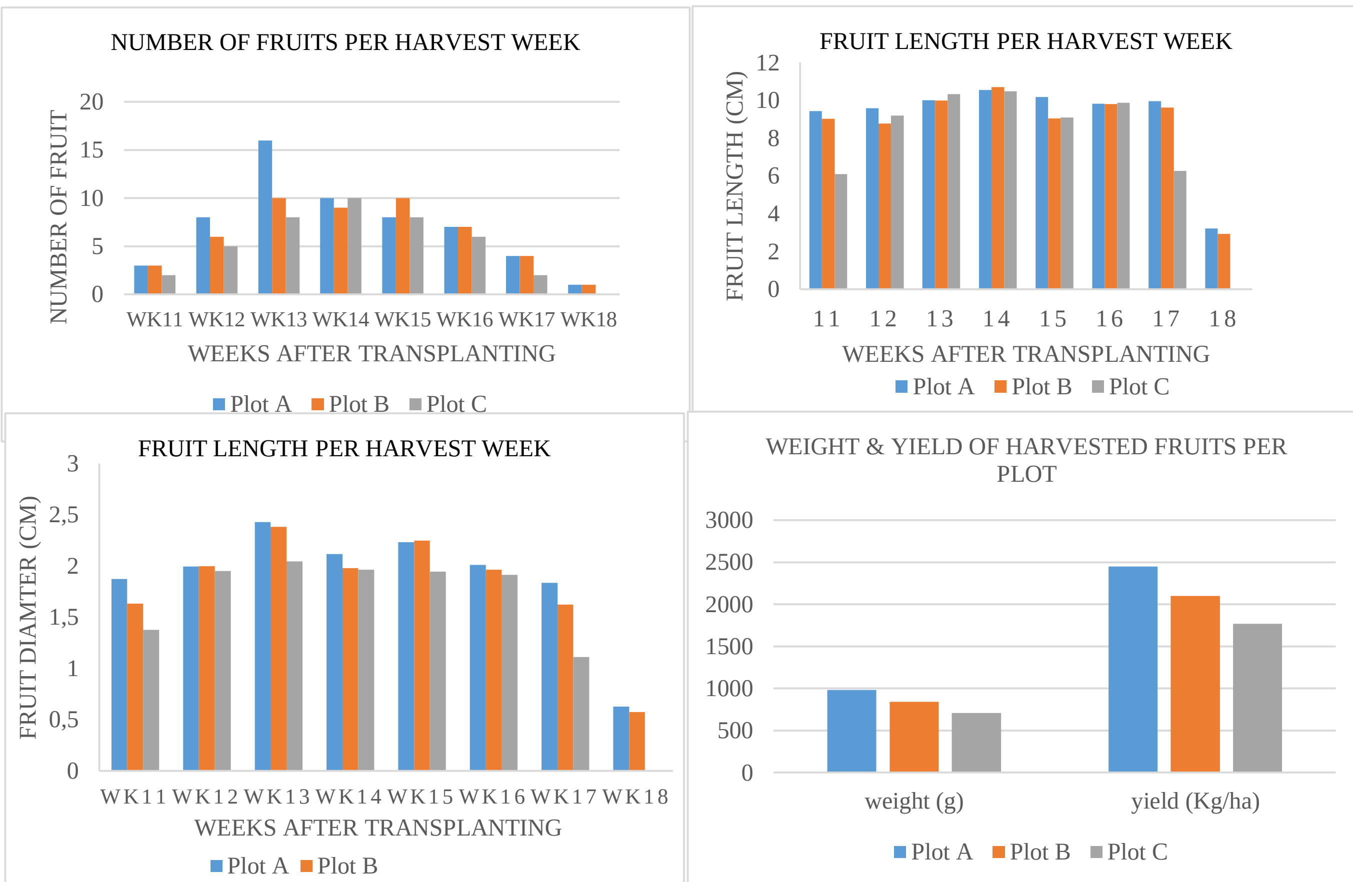

Figure 3. Graphics of yield parameters (number of harvested fruit, fruit length and diameter, fruit weight and yield) against weeks after transplanting.

3. 6. Radiation Use Efficiency (RUE)

The RUE of the chili pepper plants were obtained based on the intercepted photosynthetic active radiation (IPAR), leaf area index and yield of the chili pepper plants on different planting plots (Plot A, Plot B, and Plot C). From Table 4., the average RUE value of 1.297g/MJ, 1.018g/MJ, and 0.902g/MJ, were recorded for the chili pepper plant grown on plot A, plot B, and plot C respectively, the obtained result clearly shows that the plants with spacing of 40 cm by 40 cm on plot A has the highest RUE compared to other plots, also it was seen that the same plot has highest yield compared to the other plots. This shows that there is linear relationship between the plant spacing, yield of the pepper, and the RUE. The result is nearly similar to the study of Santos et al. (2014), that found that the RUE of chili pepper in open-field production can range from 0.92 to 1.67 g/MJ, depending on the cultivar and growing conditions. However, it is quite different from Lee et al. (2018), in their finding that, that the average RUE of chili pepper in greenhouse production can range from 1.24 to 1.76 g/MJ, with higher RUE observed in plants grown under high light intensity and supplemental LED lighting.

Table 4. Average RUE of plants on the plots

Plots	**RUE (g/MJm^{-2})**
Plot A	$0.997^{b} \pm 0.1487$
Plot B	$0.898^{ab} \pm 0.0316$
Plot C	$0.682^{a} \pm 0.0624$

3. 7. Test of Significance of the Parameters (ANOVA)

The significance level of the parameters tested by using one-way ANOVA is as shown in Table 5. Out of the parameters that were tested, 4 had significant differences between the plots. The average plant height, Number of leaves, stem girth, fraction of beam interception, below PAR, fruit length, and fruit diameter of the plants of the plots were found to be insignificantly different because the P-value is greater than 0.05 alpha level ($p>0.05$) considering 95% confidence level. However, the LAI, Above PAR, number of fruits, and the RUE of the plants of between the plots were found to be significantly different considering 95% confidence level, ($p<0.05$).

Table 5. Test of Significance of the Parameters (ANOVA)

Parameters	**P-value**
Plant height	0.311
Number of leaves	0.499
Stem girth	0.743
Leaf area index	0.043
Fraction of beam interception	0.051
Above PAR	0.042
Below PAR	0.123
Number of fruits	0.049
Fruit length	0.566
Fruit diameter	0.713
RUE	0.017

4. Conclusion

In this study, RUE and yield response of chili pepper under rainfed agriculture in Akure, Nigeria was investigated. The ability to capture PAR by a canopy has a positive impact on biomass accumulation and crop production. The results show that RUE and yield response of chili pepper was significantly affected by the growth stage of the plant. The differences in RUE and yield of the farming plots can be attributed to plant stress, plant density, water stress, temperature, canopy structure, etc. within the growing season, hence, it showed that RUE can be applicable under growth-limiting conditions.

The research indicates that there is significant relationship between RUE, evapotranspiration, plant spacing, and yield response of chili pepper under rainfed agriculture. In addition, the RUE and yield recorded in this research is constituent with previous studies under any planting condition. Thus, chili pepper cultivation is good under rainfed condition.

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