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Effect of Light Intensity on Growth and Yield of a Nigerian Local Rice Variety-Ofada

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Abstract Rice is an important staple food in Nigeria but production is low due to single cropping season among other factors. The effect of light regimes on the growth and yield of Ofada rice **(***Oryzasativa* L) was studied. Seeds were collected from Igbemo-Ekiti, Nigeria (lat7° 42'E and long 5° 24'N). They were pre-treated by soaking in water for 24 hours and sown in germinating trays filled with top-soil and watered regularly. A total of four troughs each with dimension of 2.5m x 1m x 0.25m were filled with top soil and flooded. Three seedlings hill^{-1} were transplanted at 20cm x 20cm spacing. Two days later, the troughs were covered with one, two and three layers of green coloured fine mesh net to achieved 75%, 50% and 25% light intensity respectively. The fourth trough (control) with no covering had 100% light intensity. Five hills from each trough were randomly selected and measurements of height and number of tillers were taken at 25 and 45 days after transplanting. Growth and yield parameters such as plant heights (PH), total number of tillers per plant (TNOT), number of effective tillers (EFT), flag leaf length (FLL), panicle length (PANL), panicle weight (PANW), number of grain per panicle (NOG/P), number of spikelet per panicle (NSPP), number of filled and unfilled grain, 1000 grain weight (1000-GW), economic yield (EW), straw weight (SW) and harvest index (HI) were assessed. There were significant differences in PH, TNOT, EFT, number of unfilled grain per panicle, PANW, 1000-GW, HI, EY and BY. Plant height, TNOT, EFT, 1000-GW, EY increased with increasing light intensity while number of unproductive tillers increased with reduced light. Ofada is recommended for planting under full light intensity but there are potentials for breeding for shade tolerance in the variety.

Keywords Ofada, Shade tolerance, Double-cropping, Yield, Tillers

1. Introduction

Rice (*Oryzasativa* L.) is the world's second most important cereal crop, belonging to the family Gramineae. Rice provides 75% calories and 55% proteins to the average daily diet of consumers [1] and contributes tremendously to the economies of many nations. In Nigeria, rice is grown on approximately 3.7 million hectares of land covering 10.6 percent of the 35 million hectares of land under cultivation, out of a total arable land area of 70million hectares [2]. The rice varieties grown in Nigeria shows significant diversity, the common local varieties include: Dias, Santana, Ashawa, Yarsawaba, Ofada, Abakaliki and Yarkuwa; and the enhanced varieties of traditional African rice such as NERICA [3].

Of the large array of staple food crops grown in Nigeria-cereals, legumes, tubers, vegetables and others- made possible by the diversity of agro-ecological production systems, rice has risen to a position of pre-eminence ranking fourth most consumed crop in terms of calories. There is a steady increase in the consumption of rice due to urbanization, changes in employment patterns and life style among other factors. Domestic production has never been able to meet the demand, leading to considerable imports; presently, Nigeria spends US$ 4billion annually on importing rice [4]. There is an urgent need to boost the cultivation of local rice variety so as to reduce the rate of rice importation.

The role of environmental factors in rice production cannot be overemphasized. There are diverse environmental factors that affect rice production; growth and yield, among them are sunlight, drought, and temperature. Growth of autotropic plants is directly and dramatically influenced by light intensity (i.e. quantum flux density) which is the driving force of photosynthesis and provides nearly all of the carbon and chemical energy needed for plant growth [5]. In addition, [6] opined that increased light intensity improved rice yield till plant reaches its light saturation. Furthermore, light intensity is among important requirements for plant growth, development, survival, and crop productivity [7]. Because of the difficulty of controlling light intensity [8], researchers have evaluated the effects of variation in light regimes on morphological characteristics, physiological characteristics, yield, and quality of agricultural crops.

In order to boast the cultivation of rice in Nigeria, it is

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pertinent to determine the appropriate light regimes that favour growth and yield of local varieties. [9] observed 10% lower paddy yield of rice plant in shaded plot with 78% of full solar radiation than un-shaded plot with100% solar radiation. Shade has pronounced effect on the growth of rice. It tends to increase plant height, decrease tiller and panicle number hill^{-1} and grains panicle^{-1} and decrease grain yield. Shade stimulates cellular expansion and rapid cell division resulting in increased leaf length and plant height [10].

Rice cultivars adapted to various geographical conditions differ in their light requirements. Cultivars that are traditionally being in the tropics are supposed to have greater tolerance for low-light stress than recently introduced cultivars. Thus, identification of such rice cultivar will be essential in developing high-yielding varieties that can survive in low-radiation condition during the wet season; subsequently, enable double cropping per year. Therefore, this present study was carried out in order to examine the effect of light intensity regime on the growth and yield of local Nigerian rice as a prelude to breeding for short rotation variety.

2. Materials and Method

The seeds of Ofada Rice (*Oryzasativa* L) collected from farmers at Igbemo, Ekiti State, Nigeria (lat7° 42' and long 5° 24'N). The open nursery of the Department of Plant Science and Biotechnology, Adekunle Ajasin University, Akungba Akoko, Nigeria was used as the experimental site. The seeds were soaked in cold water at room temperature for 24 hours and thereafter, the soaked seeds were kept in a jute bag for 24 hours after the seeds were allowed to get dried of the imbibed water. The seeds of Ofada rice were sown in germination trays containing top soils, germination of the sprouted seeds was observed for 18 days and the seeds were watered twice daily.

A total of four troughs having the dimension of 2.5m x 1m x 0.25m filled with top soil were used for the experiment. The troughs were flooded for two days to allow the water to soak in at an overlaying excess water height of 10cm above the soil. Three seedlings hill-^{1} were transplanted to each of the troughs at 20cm x 20cm spacing.

Two days after transplanting (DATP), one trough was covered with one layer of green coloured fine mesh net to achieved 75% light intensity, another set of the trough was covered with two layers of net to achieved 50% light intensity, while the third one was covered with three layers of net to obtain 25% illumination. The fourth trough (control) with no covering had 100% light intensity. Urea fertilizer was applied to each of the four troughs once after 8 weeks of transplanting at the rate of 25g per trough. Hand weeding of troughs were carried out fortnightly and watering was done twice (morning and evening) daily. At 3 months after transplanting, a light-meter was used to take the light intensity three times daily at 08.00, 14.00 and 18.00hrs respectively.

2.1. Assessment of Growth and Yield Parameters

Growth parameters such as number of tillers per plant (TNOT), plant heights (PH), length of flag leaf (FLL), number of effective tillers/productive tillers (EFF), panicle length (PANL), panicle weight (PANW), number of grain per panicle, number of spikelet per panicle (NSPP), number of filled and unfilled grain (NFGP/NUFGP), 1000 grain weight, economic yield (EY), straw weight and harvest index were assessed.

Plant height was measured from the base of the plant to the tip of the highest leaf of each seedling by using a meter rule calibrated in centimetres. The number of tillers on each seedling was counted. Length of flag leaf was taken by measuring the last leaf to panicle from the selected plant in each trough using a ruler calibrated in centimetres. Panicle length was measured with centimetre ruler. Panicle weight was measured by using weighing balance. The number of spikelets on each panicle was counted and the numbers recorded. To determine the number of filled and unfilled grain; the grains were separated and the number of filled grain and unfilled grain were counted separately. To obtain 1000 grain weight, 1000 seeds were counted and weighed for each treatment.

The Economic yield was determined by weighing the total number of grains per plant; and the data recorded. To evaluate the straw weight, rice straw was carefully uprooted and placed in a bowl containing water to remove the soil around the roots. The washed root was oven dried for 48 hours at 50°C. Dried straw was then removed to weigh using a weighing balance. The HI was computed the following formula:

$$\text{Harvest index (HI)} = \frac{\text{Economic yield}}{\text{Biological yield}}$$

2.2. Statistical Analysis

The data obtained for the growth parameters were statistically analysed using the analysis of variance (ANOVA) procedure of SAS 9.2 software package and the means of the shoot length, collar diameter and number of leaves were tested using Duncan Multiple Range Test (DMRT).

3. Results

3.1. Plant Height

There were significant ($P \leq 0.05$) differences in plant height among the light treatments (Table 1). At 45days after transplanting (DAT), the highest mean height value of 33.46cm ± 1.66 was obtained in plants under 25% of light intensity, was followed by plant under 50% light intensity with a mean value of 31.06cm ± 0.33, while the lowest mean value of 26.22cm ± 3.10cm was obtained in plant under 100% full light intensity (Table 2).

Table 1. Analysis of variance (ANOVA) for growth and yield traits in Ofada rice grown under different light intensity

Parameter	SV	SS	DF	MS	F value	p-level
TNOT	Treatment	219.200	3	73.067	12.178*	0.000
	Error	96.000	16	6.000		
	Sum	315.200	19			
EFT	Treatment	277.750	3	92.583	18.333*	0.000
	Error	80.800	16	5.050		
	Sum	358.550	19			
TWP	Treatment	5.750	3	1.917	2.738	0.078
	Error	11.200	16	0.700		
	Sum	16.950	19			
PANL	Treatment	31.628	3	10.543	1.887	0.173
	Error	89.408	16	5.588		
	Sum	121.037	19			
PANW	Treatment	29.374	3	9.791	15.512*	0.000
	Error	10.099	16	0.631		
	Sum	39.473	19			
FLL	Treatment	175.522	3	58.507	1.806	0.187
	Error	518.217	16	32.389		
	Sum	693.739	19			
PH	Treatment	146.674	3	48.891	3.020*	0.187
	Error	259.044	16	16.190		
	Sum	405.718	19			
NSPP	Treatment	1078.842	3	359.614	0.880	0.472
	Error	6540.531	16	408.783		
	Sum	7619.374	19			
NFGP	Treatment	799.366	3	266.455	0.317	0.813
	Error	13444.055	16	840.253		
	Sum	14243.421	19			
NUFGP	Treatment	4162.816	3	13877.605	2.845*	0.071
	Error	7804.054	16	487.753		
	Sum	11966.870	19			
1000-GW	Treatment	50.646	3	16.882	6.959*	0.003
	Error	38.812	16	2.426		
	Sum	89.458	19			
EY	Treatment	786.294	3	262.098	125.149*	0.000
	Error	33.509	16	2.094		
	Sum	819.803	19			
BY	Treatment	1714.281	3	571.427	3.187	0.052
	Error	2869.024	16	179.314		
	Sum	4583.306	19			
HI	Treatment	0.082	3	0.027	2.430	0.103
	Error	0.180	16	0.011		
	Sum	0.262	19			

TNOT- Total Number of Tillers; EFT-Number of Effective Tillers; TWP- Tillers Without Panicles; PANL- Panicle Length; PANW- Panicle Weight; FLL- Flag leaf Length; PH-Plant height; NSPP- Number of Spikelet per Panicle; NFGP-Number of Filled Grains per Panicle; NUFGP- Number of Unfilled Grain per Panicle; 1000-GW- Grain Weight of 1000grains; EY-Economic Yield; BY-Biological Yield; HI-Harvest Index.

Table 2. Means values with standard error of growth and yield characters of Ofadarice grown under different light intensities

Parameters	Different light intensity exposures (%)			
	100	75	50	25
PH (cm)	26.2±3.10[a]	28.56±0.71[ab]	31.06±0.33[ab]	33.46±1.66[b]
FLL (cm)	31.55±2.37[a]	31.45±1.36[a]	34.11±2.75[a]	38.75±3.29[a]
TNOT	18.80± 1.88[b]	11.20±0.37[b]	11.20±0.58[a]	10.40±2.07[a]
EFT	17.80±1.74[c]	11.20±0.37[b]	9.60±0.25[ab]	8.00±0.89[a]
TWP	1.00±0.32[a]	1.20±0.20[a]	1.60±0.40[ab]	2.40±0.51[b]
PANL (cm)	24.72±095[a]	24.72±0.93[a]	27.41±0.70[a]	24.54±1.48[a]
PANW (g)	2.65±0.20[a]	3.65±0.40[ab]	5.96±0.35[c]	4.49±0.43[b]
NSPP	8.19±0.19[a]	26.05±17.94[a]	10.84±2.22[a]	8.69±0.44[a]
NFGP	118.43±19.88[a]	101.46±9.69[a]	106.36±3.10[a]	105.64±13.17[a]
NUFGP	39.74±16.49[ab]	60.3±8.80[ab]	31.20±3.02[a]	66.40±5.63[b]
1000-GW	28.14±0.71[b]	27.54±0.91[b]	26.70±0.68[b]	23.98±0.39[a]
EY (t/ha)	33.75±0.66[c]	27.58±1.02[b]	25.75±0.44[b]	16.25±0.01[a]
BY (t/ha)	71.88±9.83[b]	53.08±2.09[ab]	58.80±3.61[a]	46.78±43[a]
HI (%)	0.52±0.08[ab]	0.54±0.02[b]	0.44±0.02[ab]	0.38±0.04[a]

[a,b,c,] = means bearing the same letters in the row are not significantly different at 5% probability level.

3.2. Total Number of Tillers

There were significant (P≤ 0.05) differences in total number of tillers (TNOT) among the light treatments (Table 1). The highest mean TNOT value of 18.80 ± 1.88 was recorded in plants under 100% full light intensity. This was followed by plants under 75% light intensity with a mean tiller value of 12.40 ± 0.25 while the lowest mean TNOT value of 10.4 ± 22.07 was obtained in plants under 25% light intensity. The mean TNOT of plants under 100% full light intensity was significantly different from those under 75%, 50%, and 25% light intensities (Table 2).

3.3. Number of Effective Tillers

Highly significant (P≤0.05) differences were observed in the number of effective tillers (EFT) per hill among plants under different light regimes (Table 1). The highest mean EFT of 17.80 ± 1.74 was observed in plants under 100% full light intensity, this was followed by plant under 75% light intensity with a mean value of 11.20 ± 0.37, while the lowest mean EFT of 8.00 ± 0.89 was obtained under 25% light intensity. The mean EFT of plant under 100% full light intensity was significantly (P≤0.05) different from those under other light regimes (Table 2).

3.4. Tillers without Panicle/Unproductive Tillers

There were no significant (P≥0.05) differences in number of tillers without panicle (TWP) under the different light regimes (Table 1). Table 2 showed that tillers without panicle plants under 25% light intensity had the highest mean number of unproductive tillers (2.40 ± 0.51), this was followed by plants under 50% light treatment with a mean TWP value of 1.60 ± 0.40, while the lowest mean TWP of 1.00 ± 0.32 was recorded under 100% full light intensity (Table 2). The mean TWP under 25% light regime was significantly (P≤ 0.05) different from those under 75% and 100% light intensities.

3.5. Flag Leaf Length

There were no significant differences in flag leaf length (FLL) in plants under the different light regimes (Table 1). The highest mean FLL value of 38.75cm±3.29 was recorded in plants under 25% light intensity, this was followed by plant under 50% light intensity of 34.11cm ± 2.75, while the lowest mean FLL value of 31.45 ± 1.36 was obtained under plants grown under 75% light intensity. There were no significant (P≤ 0.05) differences in mean FLL among the plants under different treatments (Table 2).

3.6. Panicle Length (cm)

Panicle length (PANL) was not significantly (P≥ 0.05) affected by different light regimes (Table 1). The highest mean PANL value of 27.41cm ± 0.70 was recorded in plants under 50% light intensity, 24.72 ± 0.95cm was obtained under 100% light intensity while the lowest mean value of 24.31cm ± 0.93 was recorded in plants under 75% light intensity. The mean PANL of rice were not significantly different under the light regimes (Table 2).

3.7. Number of Spikelet per Panicle

The number of spikelet per panicle (NSPP) was not significantly (P≤ 0.05) affected by light regimes (Table 1). The highest mean NSPP value of 26.05 ± 17.94 was recorded in plants under 75% light intensity followed by plants under 50% light intensity with a mean value of 10.84 ± 2.22, while the lowest mean NSPP value of 8.19 ± 0.19 was recorded for plant under 100% light. There were no significant (P≤ 0.05) differences in mean NSPP among the treatments (Table 2).

3.8. Number of Filled Grains per Panicle

Effect of shading was not significant (P≤ 0.05) on the number of filled grain per panicle (NFGP) in rice (Table 1). The highest mean NFGP (118.43 ± 19.88) was obtained in plants under full light, this was followed by plants under 50% light with a mean value of 106.36 ± 3.10. The lowest value of 101.46 ± 9.69 was recorded in plants under 75% light intensity. There were no significant (P≤ 0.05) differences in mean NFGP under different light intensities (Table 2).

3.9. Number of Unfilled Grain per Panicle

The effect of different light intensities were significant (P≤ 0.05) on the number of unfilled grain per panicle (NUFGP) (Table 1). Plants under 25% light had the highest mean NUFGP of 66.40±5.63, those under 75% light had a mean NUFGP of 60.31 ± 8.80 while the lowest mean NUFGP value of 31.20 ± 3.02 was obtained in plants under 50% light intensity. The mean NUFGP for plant under 50% light was significantly (P≤ 0.05) different from those under 25% light regime (Table 2).

3.10. Panicle Weight (g)

There were significant differences (P≤0.05) in panicle weight (PANW) under different light intensities (Table 1). The highest mean PANW value of 5.96g ± 0.35 was recorded in plants under 50% light intensity, plants under 25% light had a mean value of 4.49g ± 0.43 while the lowest mean PANW value of 2.65g± 0.20 was recorded in plants under 100% light intensity. The mean PANW of plants under 50% shading was significantly (P≤0.05) different from those under other light regimes (Table 2).

3.11. Harvest Index (%)

There were significant (P≤ 0.05) differences in harvest index (HI) of rice under different light regimes (Table 1). Harvest index was highest in plants under 75% light with a mean value of 0.54 ± 0.02, plants under full light had a mean value of 0.52 ± 0.08 while the lowest value of 0.38 ± 0.04 was obtained in plants under 25% light intensity. The mean HI of plants under 75% light was different from those under 25% light regime (Table 2).

3.12. Grain Weight (1000)

The weight of 1000 grains of rice were significantly (P≤0.05) different under different light regimes (Table 1). Plants under full light had the highest mean value of 28.14g ± 0.71, plants under 75% light regime had a mean value of 27.58g ± 1.20. The lowest mean value of 23.98 ± 0.01 was obtained in plants under 25% light. The mean weight of 1000grains of rice grown under 25% light regime was significantly different from those grown under other regimes of light (Table 2).

3.13. Economic Yield (t/ha)

The effect of light regime was significant (P≤0.05) on the economic yield (EY) of rice (Table 1). Rice grown under full light had the highest mean EY value of 33.75 ± 0.66; this was followed by plants grown under 75% light intensity with a mean value of 27.58 ± 2.09 while the lowest value of 16.25 ± 0.01 was obtained in plants grown under 25% light. The mean EY of plants grown under full light was significantly (P≤0.05) different from those under 25%, 50% and 75% light regimes (Table 2).

3.14. Biological Yield (t/ha)

Biological yield (BY) of rice were significantly (P≤0.05) affected by different light regimes (Table 1). Biological yield was highest in plants grown under full light (71.88g ± 9.83), this was followed by plants grown in 50% light with a mean value of 58.80g ± 3.61 while the lowest value was obtained plants grown under 25% light. The mean BY of plants grown under full light was significantly different from that of plants grown under 25% light intensity (Table 2).

4. Discussion and Conclusions

The result of this study indicated there are several indices in the cultivation and management of the local rice variety-Ofada that could be improved. Plant height decreased with increasing light intensity; this is encouraging because tall rice stems make them susceptible to lodging consequently heavy harvest losses. Also, plants grown in the dark or in very weak light have delicate, soft and slender stem since they continue in rapid growth and elongate, looking for light untill they reach their maximum dimension and bend toward light direction. A condition generally referred to as etiolation. Short erect plant type is also an impetus for direct seeding which is often cheaper than transplanting using machines.

Rice productivity comes under some influencing indices which are often interdependent. The present study revealed that total number of tillers; and more importantly, number of effective tillers incresed with increasing light intensity; this agreed with the findings of [11] who reported that the numbers of tiller increased in parallel with increases in the level of light intensity.In the same vein, the quantity of harvest is directly related to the number of tillers that produced panicles provided there were no disease or pest incidence. As a corollary to this, number of tillers without panicles increased under reduced light intensity, this is line with the submission of [12] that apart from genotype and hormonal balance, available light to the plant may affect the number of tillers.

Rice is cultivated mainly for its edible grains of which size and weight are crucial; the presently study revealed that both the grain weight and the economic yield increased under increasing light intensity. This agreed with the findings of several authors that low irradiance treatment significantly diminish grain yield ([13-16]).

Rice is an international crop which global production and consumption affects the economy and food security status of many countries; there is therefore the need to stimulate production is areas with potentials for high productivity. Meanwhile, farming in sub-Saharan Africa is mostly rain-fed; the period of heavy rainfall with its attendant low irradiance usually coincides with the crucial time of booting and grain filling in rice. It is therefore recommended that appropriate irrigation facilities should be developed especially in Nigeria to enable double-cropping in a year, thus, enhancing the yield of local variety like Ofada which performs better under high light intensity prevalent during the dry weather conditions.

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