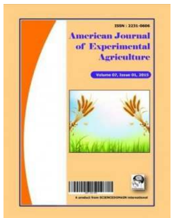

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Density and Cultivar Effects on the Biomass and Crop Growth Rate of Upland Rice in Uyo Southeastern Nigeria

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Author's contribution

The sole author designed, analyzed and interpreted and prepared the manuscript.

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ABSTRACT

Aims: To evaluate population densities and cultivars on the biomass and crop growth rate (CGR) of upland rice and their correlation with grain yield.
Study Design: A Factorial on randomized complete block design.
Place and Duration of Study: The Teaching and Research Farm of the Faculty of Agriculture, University of Uyo, between May 12, 2009 and September 30, 2010.
Methodology: Six sowing densities; 1,600,000, 1,066,666, 800,000, 640,000, 533,333, and 2,054,435 plants ha^{-1} were combined with five cultivars of rice; FAROs 43, 46, 55, 56 and a local cultivar – *Otokongtian*. Treatment combinations were replicated three times. Destructive samples were collected at 3, 6, 9, 12, and 15 weeks after sowing (WAS), oven-dried at 80℃ to constant weight and the biomass and CGR determined. Data were analyzed with Genstat Discovery Edition 4 and means compared by Fisher's protected least significant difference at 5% probability.
Results: Rice biomass for 2,054,435 and 1,600,000 densities increased significantly (8.77-12.55 and 7.08-11.44 g m^{-2}) at 3 WAS in 2009 and 2010 respectively (P=.05). Biomass increase was highest at 15 WAS across densities and cultivars in both years. FARO 46 produced the highest significant biomass in both years during the period but was replaced by *Otokongtian* at 15 WAS. At 3-6 WAS, 2,054,435 produced the highest significant CGR in both years (5.83 and 5.193 g m^{-2}

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day^{-1} for 2009 and 2010 respectively), while FARO 43 had the highest CGR during the period. Higher densities produced higher CGR. The CGR continued to increase across densities and cultivars up to 9-12 WAS and began to decline at 12-15 WAS. There was a positive correlation between rice biomass, CGR and grain yield.

Conclusion: Higher sowing densities produced higher rice biomass and CGR which correlated positively with grain yield.

Keywords: Plant density; crop growth rate; upland rice; biomass.

1. INTRODUCTION

Rice is classified as a food staple for over 60 percent of Nigerian homes [1]. According to [2], Nigeria has continued to experience rapid growth in per capita rice consumption ranging from 5 kg in the 1960s, 11 kg in the 1980s to 25 kg in the 1990s. Nigeria's annual demand for rice is about 5 million tones of milled rice and is far greater than the supply, estimated at 3 million tonnes annually [3] with the result that the rice self-sufficiency ratio is only 0.64 [4].

In Nigeria, rice yield averaged of 1.8 t ha^{-1} [5], is far below that of many countries. For instance, China, Japan, Korea and Egypt have been reported to have average yield of 7.5, 5.9, 7.3 and 7.5 t ha^{-1}, respectively [5]. The current practice of horizontal expansion of rice area in Nigeria is not sustainable due to competition for land resources and high population growth rate. Increase in rice production by vertical expansion through the adoption of good management practices and high yielding varieties would lead to increased productivity per unit area of land. Rice continues to gain prominence among the commodities produced in Nigeria. It occupied the 9th position in 2005, 5th position between 2009 and 2011, and the current 4th position in 2012 [5].

Takai et al. [6] observed cultivar differences in the crop growth rate of rice during the reproductive growth stage in a temperate climate (Japan) and reported that rice genotypes having higher CGR during the late reproductive period produced a greater number of spikelet per unit land area resulting in the highest grain yield. They also observed a positive correlation between the biomass and CGR on the accumulation and rapid translocation of non-structural carbohydrate to panicles in the initial period of grain filling and concluded that improvement of canopy photosynthesis during the late reproductive period may be essential as the first step toward increased yield potential in rice. According to San-oh et al. [7], increasing the biomass productivity of rice is critical for improving the yield potential. They observed greater biomass production and grain yield in plots with high plant density per hectare. Factors responsible for high biomass production were identified to include; vigorous tiller increase at the tillering stage resulting in higher capture of solar radiation. Since most upland varieties have low tiller production (3 – 5 tillers per hill) and constant leaf area [8], it was necessary to evaluate the effect of sowing densities and cultivars on the biomass and crop growth rate of upland rice in the humid rainforest agro-ecology of the southeastern zone of Uyo where no such study has been reported and to determine how these parameters correlate with grain yield.

2. MATERIALS AND METHODS

2.1 Location of Experiment

Field experiments were conducted during the cropping seasons of 2009 and 2010 at the Teaching and Research Farm of the Faculty of Agriculture, University of Uyo, located at Use Offot, Uyo, Akwa Ibom State. The experimental sites were located between latitude 05°, 01^{1}, 56.2" N and 05°, 01^{1} 56.6" N and longitude 07°, 58^{1} 20.2" E and 07°, 58^{1} 20.6" E and 55 – 57 m above sea level. Slus [9] reported that this humid rain forest zone received an annual rainfall of about 2,500 mm and a mean relative humidity of 87%. The mean annual temperature varies between 22 and 32℃ and sunshine hours of 3 – 8 hours. The soil is acidic and belongs to broad soil classification group, ultisol, formed from acid plain sand [10]. Treatments consisted of six sowing densities fitted in a factorial arrangement with five cultivars of upland rice. The sowing densities were obtained by the following inter- and intrarow spacing with four seedlings per hill:

Spacing		Density ha^{-1}
25 cm x 10 cm	=	1,600,000
25 cm x 15 cm	=	1,600,666
25 cm x 20 cm	=	800,000
25 cm x 25 cm	=	640,000
25 cm x 30 cm	=	533,333
25 cm x drill (mean)	=	2,054,435

The rice cultivars were:

1. FARO 43, 2. FARO 46, 3. FARO 55, 4. FARO 56, 5. A local check – *Otokongtian*.

The treatment combinations were laid out on a randomized complete block design and replicated three times.

In both years, each experimental unit measured 3 m x 4 m and treatments were assigned randomly to each plot within a block. Seeds were sown by dibbling (except 25 cm x drill), using six seeds hill $^{-1}$. At two weeks after sowing (WAS), seedlings were thinned to four per hill. Weeds were controlled using *paraquat* at the rate of 1.0 kg active ingredient ha^{-1} pre-emergence and by hand hoeing at 3, 6, 9 and 12 WAS.

2.2 Fertilizer Application

NPK 15-15-15 fertilizer was applied at 400 kg ha^{-1} to supply 60 kg N, 60 kg $P_2$05 and 60 kg K_2O in split doses at 2, 6 and 9 WAS by side placement. Human bird scarers were employed to chase birds.

2.3 Data Collection

The biomass of rice was determined by sampling four hills per plot at 3, 6, 9, 12, and 15 WAS into four bags after separating them into leaves and stems. They were dried in thermostatic ventilated oven model DHG 9202 at 80℃ [11] for 48 hours. They were then weighed using Mettler Toledo (AB 204) and a mean of the four samples was recorded as the mean biomass hill^{-1}. Crop growth rate (CGR) was estimated with the equation given by Radford [12]:

$$CGR = \frac{W_2 - W_1}{SA(t_2 - t_1)} \; gm^{-2}d^{-1}$$

Where,

W_1 and W_2 = Dry weight of plant at the beginning and end of the sampling interval
t_1 and t_2 = Sampling times 1 and 2
SA = The soil area occupied by the plant at each sampling.

Data collected were analyzed using Genstat Discovery Edition 4 and significant means were compared with Fishers Least Significant Difference.

3. RESULTS

3.1 Rice Biomass

At 3 WAS in 2009 and 2010, the biomass of rice increased significantly with increase in density with the highest biomass obtained from 2,054,435 followed by 1,600,000. The least biomass was obtained from 533,333 density in both years (Table 1).

FARO 46 produced the highest significant biomass, followed by *Otokongtian* compared with FARO 55 which produced the lowest biomass during the period in both years. The interaction effect showed that cultivars produced higher biomass at higher densities than at lower densities.

At 6 WAS in 2009 and 2010, 1,600,000 density produced the highest significant biomass followed by 1,066,666 density (Table 2). The lowest biomass was produced by 533,333 density in both years.

Table 1. Effects of plant density and cultivars on biomass of rice (g m^{-2}) at 3 WAS in 2009 and 2010 in Uyo, Nigeria

Density plant/ha	Rice cultivars					
	FARO 43	**FARO 46**	**FARO 55**	**FARO 56**	***Otokongtian***	**Mean**
			2009			
1,600,000	5.64	7.80	5.84	4.68	11.44	**7.08**
1,066,666	5.05	4.94	4.24	4.54	3.51	**4.46**
800,000	3.22	4.62	2.88	2.82	2.88	**3.28**
640,000	2.69	2.00	1.65	2.67	2.14	**2.24**
533,333	1.43	1.79	1.76	2.11	1.50	**1.72**
25cm x drill ($\bar{x}$ = 2,054,435)	7.34	10.15	7.24	9.44	9.74	**8.77**
Mean	**4.23**	**5.22**	**3.94**	**4.38**	**5.20**	**4.59**

			2010			
1,600,000	10.20	13.52	6.92	9.88	16.68	**11.44**
1,066,666	7.02	7.02	3.81	5.70	5.51	**5.81**
800,000	5.00	4.18	3.02	3.96	3.84	**4.00**
640,000	2.51	3.74	2.45	2.90	4.19	**3.15**
533,333	1.63	3.09	1.74	1.85	2.17	**2.09**
25cm x drill ($\overline{x}$ = 2,054,435)	12.55	15.66	13.97	10.56	9.89	**12.55**
Mean	**6.49**	**7.87**	**5.32**	**5.81**	**7.05**	**6.51**

Year	**2009**	**2010**
LSD (*P*=.05) for population density means (P)	0.36	0.64
LSD (*P*=.05) for cultivar means (C)	0.34	0.63
LSD (*P*=.05) for P x C means	0.84	1.55

Table 2. Effects of plant density and cultivars on biomass of rice (g m^{-2}) at 6 WAS in 2009 and 2010 in Uyo, Nigeria

Density plant/ha	**Rice cultivars**					
	FARO 43	**FARO 46**	**FARO 55**	**FARO 56**	***Otokongtian***	**Mean**
			2009			
1,600,000	75.72	81.24	52.44	61.12	33.92	**60.89**
1,066,666	42.20	50.95	36.72	49.82	42.31	**44.40**
800,000	35.48	34.96	26.34	35.40	30.94	**32.62**
640,000	30.03	30.78	20.18	21.36	27.70	**26.01**
533,333	18.46	21.78	15.26	20.33	21.01	**19.37**
25cm x drill ($\overline{x}$ = 2,054,435)	49.06	41.57	35.65	34.43	41.87	**40.52**
Mean	**41.83**	**43.55**	**31.10**	**37.08**	**32.96**	**37.30**
			2010			
1,600,000	72.12	90.28	37.60	62.80	62.84	**65.13**
1,066,666	53.89	58.21	30.54	37.40	39.37	**43.88**
800,000	33.60	37.24	26.16	21.82	32.10	**30.18**
640,000	19.60	34.69	12.22	22.93	23.92	**22.67**
533,333	19.45	19.81	12.04	16.59	15.89	**16.76**
25cm x drill (X = 2,054,435)	41.46	39.68	35.60	40.09	40.09	**39.38**
Mean	**40.02**	**46.65**	**25.69**	**33.61**	**35.70**	**36.33**

Year	**2009**	**2010**
LSD (*P*=.05) for population density means (P)	2.85	3.17
LSD (*P*=.05) for cultivar means (C)	2.49	2.76
LSD (*P*=.05) for P x C means	6.08	6.72

In 2009 FAROs 43 and 46 produced similar biomass that was significantly higher than other cultivars, followed by FARO 56 while the lowest biomass was produced by FARO 55 In 2010, FARO 46 produced the highest biomass followed by FARO 43. The lowest biomass was also obtained from FARO 55. Apart from the 2,054,435 density, cultivars always produced higher biomass at higher densities.

Biomass production at 9 WAS in 2009 and 2010 increased significantly with increase in density except the 2,054,435 density which produced similar biomass with 800,000 density. The 533,333 density produced the lowest biomass in both years (Table 3).

FARO 46 produced the highest significant biomass, followed by *Otokongtian*. With the exception of 2,054,435 density, higher densities produced significantly higher biomass during the period. However, in 2010 while FARO 46 produced the highest significant biomass, similar biomass was produced by FARO 56 and

Otokongtian. In general, biomass production was greater at higher than at lower densities during this period of growth.

The 1,600,000 density continued to produce the highest significant biomass at 12 WAS in 2009 and 2010, followed by 1,066,666, while 533,333 produced the lowest biomass (Table 4).

FAROs 43, 46 and *Otokongtian* produced similar biomass in 2009 that was significantly higher than the biomass for FAROs 55 and 56. The lowest biomass was obtained from FARO 55 in 2009. In 2010, FARO 43 was similar to *Otokongtian* in the biomass they produced per m^2. They were followed by FAROs 46 and 56 while FARO 55 produced the lowest biomass. In both years higher densities produced greater biomass than lower densities at 12 WAS.

Higher densities produced higher biomass at 15 WAS in 2009 and 2010 with the exception of 2,054,435 (Table 5).

The check cultivar – *Otokongtian* produced the highest biomass followed by FARO 43 and FARO 56 while FARO 55 produced the lowest plant biomass. Higher rice biomass was produced by cultivars at higher than at lower densities in both years.

3.2 Crop Growth Rate (CGR)

The crop growth rate of rice between 3 and 6 WAS in 2009 and 2010 increased significantly with an increase in density (Table 6).

FARO 43 increased CGR by 42.79% and *Otokongtian* by 30.98% compared with FARO 55 which had the lowest CGR in 2009, but in 2010, FARO 43 produced similar CGR with FARO 46 and they were significantly higher than other cultivars. Similar CGR was produced by FARO 56 and *Otokongtian* in 2010. Higher densities produced higher CGR than lower densities.

Apart from 533,333 and 640,000 densities with similar CGR in 2009, there was a significant increase in CGR with increase in plant density in both years between 6 and 9 WAS, (Table 7).

Table 3. Effects of plant density and cultivars on biomass of rice (g m^{-2}) at 9 WAS in 2009 and 2010 in Uyo, Nigeria

Density plant/ha	Rice cultivars					
	FARO 43	FARO 46	FARO 55	FARO 56	*Otokongtian*	Mean
			2009			
1,600,000	224.08	321.20	178.80	238.20	247.68	**242.00**
1,066,666	179.69	220.46	139.91	170.61	201.58	**182.41**
800,000	128.06	181.88	120.40	120.50	148.04	**139.78**
640,000	112.16	132.69	85.12	112.46	122.70	**113.02**
533,333	91.73	130.13	68.29	91.60	104.69	**97.28**
25cm x drill ($\bar{x}$ = 2,054,435)	140.96	158.76	114.55	135.15	147.95	**139.47**
Mean	**146.11**	**190.85**	**117.85**	**144.75**	**162.11**	**152.33**
			2010			
1,600,000	253.28	294.88	201.72	293.84	258.84	**260.51**
1,066,666	194.94	203.23	141.35	169.29	205.34	**182.83**
800,000	131.46	151.76	106.96	143.72	145.48	**135.88**
640,000	105.98	132.62	81.33	114.74	117.50	**110.43**
533,333	95.11	112.09	67.95	97.11	92.04	**92.86**
25cm x drill ($\bar{x}$ = 2,054,435)	137.09	155.75	120.77	136.99	138.67	**137.85**
Mean	**152.98**	**175.06**	**120.01**	**159.28**	**159.65**	**153.39**

Year	2009	2010
LSD (*P*=.05) for population density means (P)	4.87	5.79
LSD (*P=.05*) for cultivar means (C)	3.95	4.75
LSD (*P=.05*) for P x C means	9.66	11.60

Table 4. Effects of plant density and cultivars on biomass of rice (g m^{-2}) at 12 WAS in 2009 and 2010 in Uyo, Nigeria

Density plant/ha	Rice cultivars					
	FARO 43	**FARO 46**	**FARO 55**	**FARO 56**	***Otokongtian***	**Mean**
			2009			
1,600,000	458.56	410.12	275.24	358.48	374.56	**375.40**
1,066,666	315.36	306.34	211.17	265.44	320.22	**283.69**
800,000	251.48	234.52	167.32	196.64	257.46	**221.48**
640,000	276.61	264.64	254.26	270.21	300.58	**273.26**
533,333	224.41	238.16	192.19	228.01	253.46	**227.24**
25cm x drill ($\bar{x}$ = 2,054,435)	232.87	306.61	197.47	237.86	243.07	**243.58**
Mean	**293.22**	**293.40**	**216.28**	**259.44**	**291.56**	**270.78**
			2010			
1,600,000	615.28	461.72	393.36	553.76	589.16	**522.66**
1,066,666	411.05	409.10	321.98	360.40	417.99	**384.10**
800,000	302.06	264.70	235.50	303.40	323.60	**285.85**
640,000	279.47	260.14	211.01	253.33	239.97	**248.78**
533,333	208.57	228.53	160.85	231.57	234.82	**212.87**
25cm x drill ($\bar{x}$ = 2,054,435)	260.66	307.02	236.18	256.12	260.61	**264.12**
Mean	**346.18**	**321.87**	**259.81**	**326.43**	**344.36**	**319.73**

Year	**2009**	**2010**
LSD (*P*=.05) for population density means (P)	6.90	15.17
LSD (*P=.05*) for cultivar means (C)	5.22	12.12
LSD (*P=.05*) for P x C means	12.80	29.69

Table 5. Effects of plant density and cultivars on biomass of rice (g m^{-2}) at 15 WAS in 2009 and 2010 in Uyo, Nigeria

Density plant/ha	Rice cultivars					
	FARO 43	**FARO 46**	**FARO 55**	**FARO 56**	***Otokongtian***	**Mean**
			2009			
1,600,000	754.44	596.12	668.32	715.04	828.76	**712.56**
1,066,666	531.23	455.68	510.95	562.71	616.19	**535.36**
800,000	451.90	414.36	403.92	438.36	509.08	**443.52**
640,000	365.20	348.11	313.81	368.13	378.94	**354.83**
533,333	289.91	294.05	262.47	296.26	299.49	**288.43**
25cm x drill ($\bar{x}$ = 2,054,435)	315.28	415.14	266.12	320.79	328.90	**329.26**
Mean	**451.33**	**420.58**	**404.27**	**450.22**	**493.56**	**443.99**
			2010			
1,600,000	806.04	628.80	548.20	724.84	863.44	**714.26**
1,066,666	558.77	451.66	482.81	561.71	613.74	**533.74**
800,000	392.88	407.36	355.00	365.68	468.08	**397.80**
640,000	367.46	330.58	295.65	344.70	366.88	**341.05**
533,333	301.46	292.14	228.36	298.42	316.80	**287.44**
25cm x drill ($\bar{x}$ = 2,054,435)	366.23	425.44	336.75	361.59	377.71	**373.54**
Mean	**465.47**	**422.66**	**374.46**	**442.82**	**501.11**	**441.31**

Year	2009	2010
LSD (*P*=.05) for population density means (P)	0.248	0.362
LSD (*P=.05*) for cultivar means (C)	0.226	0.330
LSD (*P=.05*) for P x C means	0.554	0.809

Table 6. Effects of plant density and cultivars on the crop growth rate of rice (g/m^2/day) at 3-6 WAS in 2009 and 2010 in Uyo, Nigeria

Density plant/ha	Rice cultivars					
	FARO 43	**FARO 46**	**FARO 55**	**FARO 56**	***Otokongtian***	**Mean**
			2009			
1,600,000	3.337	3.497	2.220	2.587	2.976	**2.923**
1,066,666	1.747	2.163	1.526	2.129	1.824	**1.878**
800,000	1.536	1.445	1.117	1.553	1.336	**1.398**
640,000	1.282	1.370	0.882	0.890	1.216	**1.128**
533,333	0.831	0.976	0.660	0.890	0.953	**0.862**
25cm x drill ($\bar{x}$ = 2,054,435)	7.794	4.306	5.157	5.052	6.841	**5.830**
Mean	**2.755**	**2.293**	**1.927**	**2.183**	**2.524**	**2.336**
			2010			
1,600,000	2.992	2.589	1.531	2.413	2.070	**2.519**
1,066,666	1.994	2.391	1.020	1.608	1.370	**1.678**
800,000	1.496	1.794	0.766	1.207	1.035	**1.260**
640,000	1.196	1.435	0.612	0.965	0.828	**1.007**
533,333	0.963	1.155	0.493	0.776	0.666	**0.811**
25cm x drill ($\bar{x}$ = 2,054,435)	5.748	3.935	3.883	5.990	6.411	**5.193**
Mean	**2.398**	**2.383**	**1.384**	**2.160**	**2.065**	**2.078**

Year	2009	2010
LSD (*P*=.05) for population density means (P)	0.140	0.185
LSD (*P=.05*) for cultivar means (C)	0.127	0.169
LSD (*P=.05*) for P x C means	0.312	0.413

During the period, FARO 46 produced the highest CGR, followed by *Otokongtian* compared with FARO 55. In 2010, FARO 56 produced the highest CGR, followed by FARO 43 and the least was produced by FARO 55. Cultivars produced higher CGR at higher than lower densities.

Between 9 and 12 WAS, higher densities produced significantly higher CGR, except in 2009 when 1,066,666 and 800,000 densities produced similar CGR, (Table 8).

During the growth stage, *Otokongtian*, FAROs 43 and 56 produced similar CGR that was significantly higher than FAROs 46 and 55, whereas in 2010, the CGR for *Otokongtian* and FARO 43 was similar, followed by FARO 56 while FAROs 46 and 55 produced the lowest CGR. In both years, greater CGR was obtained from cultivars at higher than lower densities.

Between 12 and 15 DAS in 2009 and 2010, CGR increased with increase in sowing density with the exception of 640,000 and 533,333 densities which produced similar CGR in 2010, (Table 9).

Otokongtian produced the highest CGR in 2009 and 2010, followed by FARO 56 and FARO 43; the lowest CGR was obtained from FAROs 56 and 55. Greater CGR was obtained from cultivars at higher than lower densities.

3.3 Correlation between Biomass, Crop Growth Rate and Grain Yield of Rice

Positive correlation between the biomass, crop growth rate and grain yield was observed at various stages of measurement in 2009 and 2010, (Table 10).

Generally, in both years, the highest correlation between rice biomass and grain yield was observed at 9 to 12 weeks after sowing while the correlation between crop growth rate and grain yield was greater at 9 to 15 WAS in 2009 and 6 to 12 weeks in 2010.

Table 7. Effects of plant density and cultivars on the crop growth rate of rice ($g/m^2/day$) at 6-9 WAS in 2009 and 2010 in Uyo, Nigeria

Density plant/ha	Rice cultivars					
	FARO 43	FARO 46	FARO 55	FARO 56	*Otokongtian*	Mean
			2009			
1,600,000	7.066	11.444	6.016	8.433	8.274	**8.246**
1,066,666	6.888	7.967	4.850	5.677	7.486	**6.573**
800,000	4.409	6.996	4.479	4.050	5.577	**5.102**
640,000	3.910	4.851	3.092	4.336	4.522	**4.142**
533,333	3.578	5.292	2.590	3.481	4.086	**3.805**
25cm x drill ($\bar{x}$ = 2,054,435)	17.159	10.070	13.710	18.508	19.710	**17.031**
Mean	**7.168**	**8.770**	**5.789**	**7.414**	**8.276**	**7.483**
			2010			
1,600,000	11.368	9.514	7.714	11.638	9.867	**10.020**
1,066,666	7.574	6.3339	5.140	7.754	6.574	**6.676**
800,000	5.684	4.757	3.857	5.819	4.933	**5.010**
640,000	4.545	3.804	3.085	4.653	3.945	**4.006**
533,333	3.789	3.171	2.571	3.879	3.289	**3.340**
25cm x drill ($\bar{x}$ = 2,054,435)	18.993	19.014	15.296	19.665	20.923	**18.778**
Mean	**8.659**	**7.767**	**6.277**	**8.901**	**8.255**	**7.972**

Year	2009	2010
LSD (*P*=.05) for population density means (P)	0.511	0.523
LSD (*P=.05*) for cultivar means (C)	0.467	0.477
LSD (*P=.05*) for P x C means	0.144	1.169

4. DISCUSSION

4.1 Biomass Production

Biomass production was very slow during the first 3 weeks of growth, followed by gradual but slow growth rate at 6 weeks after sowing. This was followed by rapid biomass production from 9 to 15 weeks after sowing. The increase in biomass at higher densities at 3 WAS was related to lower inter plant competition as a result of smaller leaf area index and unlimited solar radiation interception, soil moisture and nutrients. Similar observation was reported by Lack et al. [13]. The difference in biomass production at different densities at 6 WAS could be due to differences in the availability and utilization of adequate growth factors when their canopies had begun to close. Takai et al. [6] attributed high biomass production at tillering stage to vigorous tiller increase and improvement in canopy photosynthesis. However, competition effect had begun to occur among higher densities during this growth stage. This was confirmed by the fact that the 2,054,435 density produced lower biomass compared to 1,600,000 and 1,066,666 as a result of competition for below and above ground growth factors. At 9 to 15 WAS, higher densities produced higher biomass with the exception of 2,054,435 density. Lack et al. [13] reported that as density increased, vegetative growth decreased in each hill because of reduction in free space, diminishing radiation and competition for nutrients. In this study, competition for space, and especially, solar radiation and soil nutrients would have been responsible for the greater reduction in biomass production by 2,054,435 density at advanced growth stages. It should be noted that Slus [9] reported low sunshine hours for the study area which could be an important factor for competition beside edaphic factors.

Cultivar differences were observed on their biomass production throughout the periods of observation. According to Aruna et al. [14], dry matter production and remobilization in rice were affected by environmental conditions and cultivar differences. It seemed likely that lower densities per hill due to low tillering ability for FAROs 46 and 55 lowered the biomass they produced during the period of study. This finding agreed with the report of Ntanos et al. [15] that the amount of dry matter mobilized by rice was influenced by cultivar characteristics. The maximum vegetative growth corresponded with the highest leaf area attainment (LAI) and thereafter started to decline. Additionally, biomass production is also influenced by the photosynthetic organ structure of the cultivar. San-oh et al. [7] noted that erect leaves in the canopy improved light-intercepting character of the cultivar. In this study, FARO 46 with characteristic droopy leaves could not capture solar radiation as efficiently as other cultivars for biomass production while FARO 55 produced a lower number of tillers.

4.2 Crop Growth Rate

The crop growth rate of upland rice increased consistently albeit gradually with increase in density in all the times of measurement. The soil areahill^{-1} constituted one of the major sources of variation in the CGR. The narrower the spacing, the higher the CGR. The soil area for a hill using 1,600,000 density (0.025 m^{-2}) was 5.10 times larger than the soil area for 2,054,435 density (0.0049 m^{-2}); soil area for 1,066,666 was 7.65 times as large as that for 2,054,435 while the soil area for 533,333 density was 15.31 times larger than the area for 2,054,435 density. However, 2,054,435 density was sown at one seed per hill while other densities were thinned to four seedlings per hill. CGR generally increased rapidly from 3 to 12 WAS and started declining between 12 and 15 WAS. According to Fageria [16], crop growth rate is usually low in the early growth stages and increased with time, reaching a maximum value at about the time of flowering before it started to decline. The maximum CGR coincided with the maximum vegetative growth which corresponded with the highest leaf are attainment (LAI) and thereafter started to decline.

Cultivars differed in their CGR throughout the period of observation. The magnitude of difference became distinct from 9 to 15 WAS with *Otokongtian*, FAROs 43 and 56 having greater CGR compared with other cultivars. Takai et al. [6] reported that a large genotypic variability in CGR during the late reproductive period was mainly due to differences in radiation use efficiency. Therefore, it could be stated that *Otokongtian* and FAROs 43 and 56 were more efficient in light capturing and conversion abilities.

Table 8. Effects of plant density and cultivars on the crop growth rate of rice ($g/m^2/day$) at 9-12 WAS in 2009 and 2010 in Uyo, Nigeria

Density plant/ha	Rice cultivars					
	FARO 43	**FARO 46**	**FARO 55**	**FARO 56**	***Otokongtian***	**Mean**
			2009			
1,600,000	15.610	7.030	12.850	12.080	15.570	**12.630**
1,066,666	9.080	4.210	10.120	12.070	10.650	**9.230**
800,000	10.320	5.050	8.270	9.980	11.060	**8.930**
640,000	7.830	6.280	8.050	7.510	8.470	**7.630**
533,333	6.590	5.280	6.050	6.660	7.270	**6.370**
25cm x drill ($\bar{x}$ = 2,054,435)	17.170	20.270	15.060	20.760	20.270	**18.700**
Mean	**11.100**	**8.020**	**10.060**	**11.510**	**12.210**	**10.580**
			2010			
1,600,000	14.851	8.927	10.640	9.221	16.724	**12.053**
1,066,666	9.895	5.881	7.089	6.143	11.142	**8.030**
800,000	6.845	4.528	4.832	5.013	7.219	**5.687**
640,000	6.257	3.718	4.482	3.885	7.046	**5.078**
533,333	4.950	2.942	3.547	3.074	5.575	**4.018**
25cm x drill ($\bar{x}$ = 2,054,435)	24.553	24.781	20.717	24.182	25.8777	**24.022**
Mean	**11.225**	**8.446**	**8.551**	**8.586**	**12.264**	**9.815**

Year	2009	2010
LSD (*P*=.05) for population density means (P)	1.171	0.680
LSD (*P=.05*) for cultivar means (C)	2.618	1.520
LSD (*P=.05*) for P x C means	2.618	1.520

Table 9. Effects of plant density and cultivars on the crop growth rate of rice (g/m^2/day) at 12-15 WAS in 2009 and 2010 in Uyo, Nigeria

Density plant ha	Rice cultivars					
	FARO 43	**FARO 46**	**FARO 55**	**FARO 56**	***Otokongtian***	**Mean**
			2009			
1,600,000	9.650	6.060	10.460	10.630	12.110	**9.780**
1,066,666	7.020	6.850	7.750	6.360	7.990	**7.190**
800,000	5.100	6.020	5.230	5.160	2.780	**4.860**
640,000	4.220	3.970	2.840	4.660	3.730	**3.880**
533,333	3.090	2.730	3.430	3.330	2.250	**2.970**
25cm x drill ($\overline{x}$ = 2,054,435)	15.380	14.880	12.460	16.770	18.290	**15.560**
Mean	**7.410**	**6.750**	**7.030**	**7.820**	**7.860**	**7.370**
			2010			
1,600,000	8.640	7.180	6.250	9.360	13.090	**8.900**
1,066,666	5.760	4.790	4.170	6.230	8.720	**5.936**
800,000	4.320	2.590	3.130	4.680	6.550	**4.450**
640,000	3.460	2.870	2.500	3.740	5.240	**3.560**
533,333	2.880	2.390	2.080	3.120	4.360	**2.970**
25cm x drill ($\overline{x}$ = 2,054,435)	21.690	19.400	18.060	21.41	24.850	**21.080**
Mean	**7.790**	**6.700**	**6.030**	**8.090**	**10.470**	**7.820**

Year	**2009**	**2010**
LSD (*P*=.05) for population density means (P)	0.905	0.835
LSD (*P*=*.05*) for cultivar means (C)	0.826	0.762
LSD (*P*=*.05*) for P x C means	0.024	1.866

Table 10. Correlation coefficient between grain yield and growth parameters as influenced by plant density and upland rice cultivar (r)

Growth parameters	Correlation 2009	Coefficient 2010
Rice biomass at (weeks after sowing)		
3	0.18NS	0.40NS
6	0.20NS	0.11NS
9	0.47NS	0.38NS
12	0.58*	0.40NS
15	0.34NS	0.38NS
Crop Growth Rate at (weeks after sowing)		
3-6	0.52*	0.54*
6-9	0.41NS	0.62*
9-12	0.64*	0.61*
12-15	0.61*	0.65*

** = Significant at 5% probability level, NS = Non-significant at 5% probability level*

A positive and significant correlation was observed between CGR and grain yield of rice between 9 to 12 and 12- 15 WAS in 2009 (r = 64, 61 respectively); and between 6 – 9, 9 – 12 and 12-15 WAS in 2010 (r = 0.62, 61 and 65, respectively) indicating that factors that increased CGR enhanced grain yield during those periods of growth. This finding agreed with the report of San-oh et al. [7] that grain yield was most closely related to CGR during the late reproductive period (14-0 days before full heading).

5. CONCLUSION

It was concluded on the basis of research findings that higher densities produced higher biomass and crop growth rate which correlated positively with grain yield. Sowing density of low tillering upland rice should not be beyond

1,600,000 ha^{-1}. Improving the biomass productivity of rice is very important for improving the productivity of rice.

COMPETING INTERESTS

Author has declared that no competing interests exist.

REFERENCES

1. CBN (Central Bank of Nigeria) (2003): Statistical Bulletion. Lagos: CBN. 2003; 14:260.
2. WARDA (West African Rice Development Association) (2003): Five Years of Research (1973 – 1978): A Quinquennial Report of West Africa Rice Development Association on Research Activities. Cotonou, Benin. 2003;12.
3. FAO (Food and Agriculture Organization) of the United Nation Statistical Database, FAOSTAT; 2004.
4. Africa Rice Center. Africa rice trends: Overview of recent developments in the Sub-Saharan Africa rice sector. Africa Rice Center Brief, Cotonon, Benin. 2007;27.
5. FAO (Food and Agriculture Organization) of the United Nations Statistical Database, FAOSTAT; 2013.
6. Takai T, Matsuura S, Nishio T, Ohsumi A, Shiraiwa T, Horie T. Rice yield potential is closely related to crop growth rate during late reproductive period. Field Crop Research. 2006;96:328-335.
7. San-oh Y, Kondo M, Ookawa T, Hirasawa T. Ecophysiological analysis on effect of planting pattern on biomass production and grain yield in rice. Japan Agric. Res. Quarterly. 2008;42(2):79. (On Press). DOI: 10.6090/jarg
8. Gupta PC, O'Toole JC. Upland Rice: A global perspective. International Rice Research Institute, Manila. 1986;148-180.
9. Slus AK. Physical background soils, land use and ecological problems: Technical report of the taskforce on soils and land use survey of Akwa Ibom State. The Government Printer, Uyo. 1989;13.
10. Enwezor WO, Ohiri AC, Opuwaribo EE, Udo EJ. A review of fertilizer use on crops in the South Eastern Zone of Nigeria. In: Enwezor WO, (ed.) Literature Review on Soil Fertility Investigations in Nigeria. Federal Ministry of Agriculture and Natural Resources. Lagos – Nigeria. 1990;49-100.
11. Prudente JA, Signa GC, Kongchum M, Prudente AD. Improving yield and nutrient uptake potentials of Japonica and Indica rice varieties with nitrogen fertilization. World Journ. Agric. Science. 2008;4(4): 427-434.
12. Radford PJ. Growth analysis formulae: Their use and Abuse. Crop Science. 1967; 7 (3):171-175.
13. Lack S, Baymani M, Mombeni M. The study of dry matter remobilization in rice cultivars due to planting density variations. Adv. Environ. Biology. 2011;5(10):3338-3344.
14. Aruna Geetha S, Thiyarajan TM. Remobilization of nitrogen in rice genotype. Crop Research. 2003;25(3):406-409.
15. Ntanos DA, Koutroubbas SD. Dry matter and N accumulation and translocation for Indica and Japonica rice under mediterrancan conditions. Field Crop Research. 2002;74(1):93-101.
16. Fageria NK. Maximizing crop yields. New York: Marcel Dekkar Inc. 1992;65.

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