

Aims: To evaluate population densities and cultivars on the biomass and crop growth rate (CGR) of upland rice and their correlation with grain yield.

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.

Results: Rice biomass for 1,600,000 and 2,054,435 densities increased significantly (0.177-0.286 and 0.172-0.246g/hill) at 3 WAS in 2009 and 2010 respectively ($P=0.05$). 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* from 12 to 15 WAS. At 3-6 WAS, 2,054,435 produced the highest significant CGR in both years (5.83 and 5.193 g/m²/day 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 positive correlation between rice biomass, CGR and grain yield.

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

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 5kg in the 1960s, 11kg in the 1980s to 25kg 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 tha^{-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 tha^{-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].

[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 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 a first step toward increased yield potential in rice. According to [7], increasing the biomass productivity of rice is critical for improving the yield potential. They observed greater biomass production and grain yield in plants with high hill density. 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.

Materials and Methods

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 $05^{\circ}, 01^{\prime}, 56.2''\text{N}$ and $05^{\circ}, 01^{\prime}, 56.6''\text{N}$ and longitude $07^{\circ}, 58^{\prime}, 20.2''\text{E}$ and $07^{\circ}, 58^{\prime}, 20.6''\text{E}$ and 55 – 57m above sea level. [9] reported that this humid rain forest zone received an annual rainfall of about 2,500mm and a mean relative humidity of 87%. The mean annual temperature varies between 22 and 32°C and day length (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:

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

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90 The rice cultivars were:

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

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

95 In both years, each experimental unit measured 3m x 4m and treatments were
96 assigned randomly to each plot within a block. Seeds were sown by dibbling (except
97 25cm x drill), using six seeds hill⁻¹. At two weeks after sowing (WAS), seedlings were
98 thinned to four per hill. Weeds were controlled using *paraquat* at the rate of 1.0kg
99 active ingredient ha⁻¹ pre-emergence and by hand hoeing at 3, 6, 9 and 12 WAS.

100 **Fertilizer application:** NPK 15-15-15 fertilizer was applied at 400kg ha⁻¹ to supply
101 60kg N, 60kg P₂O₅ and 60kg K₂O in split doses at 2, 6 and 9 WAS by side placement.
102 Human bird scarers were employed to chase birds.

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104 **Data collection:** The biomass of rice was determined by sampling four hills per plot at
105 3, 6, 9, 12, and 15 WAS into four bags after separating them into leaves and stems.
106 They were dried in thermostatic ventilated oven model DHG 9202 at 80°C [11] for 48
107 hours. They were then weighed using Mettler Toledo (AB 204) and a mean of the four
108 samples was recorded as the mean biomass hill⁻¹. Crop growth rate (CGR) was
109 estimated with the equation given by Radford [12]:

$$110 \quad \text{CGR} = \frac{W_2 - W_1}{SA(t_2 - t_1)} \quad \text{gm}^{-2}\text{d}^{-1}$$

112 Where,

113 W_1 and W_2 = dry weight of plant at the beginning and end of the sampling interval

114 t_1 and t_2 = sampling times 1 and 2

115 SA = the soil area occupied by the plant at each sampling.

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

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Results

121 **Rice Biomass:** At 3 WAS in 2009 and 2010, the biomass of rice for 1,600,000 and
122 2,054,435 densities were similar and significantly greater than biomass 533,333 density
123 which produced the least biomass (Table 1).

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**Table 1: Effects of population density and cultivars on biomass of rice (g/hill)
at 3 WAS in 2009 and 2010 in Uyo, Nigeria**

Population Density ha^{-1}	Rice Cultivars					Mean
	FARO 43	FARO 46	FARO 55	FARO 56	<i>Otokongtian</i>	
<u>2009</u>						
1,600,000	1.141	0.195	0.146	0.117	0.286	0.177
1,066,666	0.187	0.183	0.157	0.168	0.130	0.165
800,000	0.161	0.231	0.144	0.141	0.144	0.164
640,000	0.168	0.125	0.103	0.167	0.134	0.140
533,333	0.110	0.138	0.135	0.162	0.115	0.132
25cm x drill ($\bar{x}$ = 2,054,435)	0.144	0.199	0.142	0.185	0.191	0.172
Mean	0.152	0.178	0.138	0.157	0.167	0.158
<u>2010</u>						
1,600,000	0.255	0.228	0.173	0.247	0.417	0.286
1,066,666	0.260	0.260	0.141	0.211	0.204	0.215
800,000	0.250	0.209	0.151	0.198	0.192	0.200
640,000	0.157	0.234	0.153	0.181	0.262	0.197
533,333	0.125	0.238	0.134	0.142	0.167	0.161
25cm x drill ($\bar{x}$ = 2,054,435)	0.246	0.307	0.274	0.207	0.194	0.246

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2009

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0.013

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FARO 46 produced the highest significant biomass, followed by *Otokongtian* compared with FARO 55 which produced the least 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, similar biomass was obtained from 1,600,000; 1,066,666; 800,000; and 640,000 densities (Table 2).

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Table 2: Effects of population density and cultivars on biomass of rice (g/hill) at 6 WAS in 2009 and 2010 in Uyo, Nigeria

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Population Densityha ⁻¹	Rice Cultivars					Mean
	FARO 43	FARO 46	FARO 55	FARO 56	Otokongtian	
	<u>2009</u>					
1,600,000	1.893	2.031	1.311	1.528	0.848	1.722
1,066,666	1.563	1.887	1.360	1.845	1.567	1.645
800,000	1.774	1.748	1.317	1.770	1.547	1.631
640,000	1.877	1.924	1.261	1.335	1.731	1.626
533,333	1.420	1.675	1.174	1.564	1.616	1.490
25cm x drill ($\bar{x}$ = 2,054,435)	0.962	0.815	0.699	0.675	0.821	0.794
Mean	1.581	1.680	1.187	1.543	1.522	1.485
	<u>2010</u>					
1,600,000	1.803	2.257	0.940	1.570	1.571	1.628
1,066,666	1.996	2.156	1.131	1.385	1.458	1.625

800,000	1.680	1.862	1.308	1.091	1.605	1.509
640,000	1.225	2.168	0.764	1.433	1.495	1.417
533,333	1.496	1.524	0.926	1.276	1.222	1.289
25cm x drill (X = 2,054,435)	0.813	0.778	0.698	0.786	0.786	0.772
Mean	1.502	1.791	0.961	1.257	1.356	1.373

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2009 **2010**

LSD ($P=0.05$) for population density means (P) 0.108 0.114

LSD ($P=0.05$) for cultivar means (C) 0.099 0.104

LSD ($P=0.05$) for P x C means 0.242 0.254

The 2,054,435 density produced the lowest biomass. In both years FARO 46 produced significantly higher biomass than other cultivars, followed by FARO 43 while the least biomass was produced by FARO 55 during the period. Apart from 2,054,435 density which produced the lowest biomass during the period, cultivars always produced higher biomass at higher densities.

Biomass production at 9 WAS in 2009 and 2010 increased significantly with 533,333, followed by 640,000 density while 2,054,435 produced the least (Table 3).

Table 3: Effects of population density and cultivars on biomass of rice (g/hill) at 9 WAS in 2009 and 2010 in Uyo, Nigeria

Population Density ha^{-1}	Rice Cultivars					Mean
	FARO 43	FARO 46	FARO 55	FARO 56	<i>Otokongtian</i>	
<u>2009</u>						
1,600,000	5.602	8.030	4.470	5.955	6.192	6.050
1,066,666	6.655	8.165	5.182	6.319	7.466	6.756
800,000	6.403	9.094	6.020	6.025	7.402	6.989
640,000	7.010	8.293	5.320	7.029	7.669	7.064
533,333	7.056	10.010	5.253	7.046	8.053	7.483
25cm x drill ($\overline{x}$ = 2,054,435)	2.764	3.113	2.246	2.650	2.901	2.735

Mean	5.915	7.784	4.748	5.837	6.614	6.180
			<u>2010</u>			
1,600,000	6.332	7.372	5.043	7.346	6.471	6.513
1,066,666	7.220	7.527	5.235	6.270	7.605	6.771
800,000	6.573	7.588	5.348	7.186	7.274	6.794
640,000	6.624	8.289	5.083	7.171	7.344	6.902
533,333	7.316	8.622	5.227	7.470	7.080	7.143
25cm x drill ($\bar{x}$ = 2,054,435)	2.688	3.054	2.368	2.686	2.719	2.703
Mean	6.126	7.075	4.717	6.355	6.416	6.138

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FARO 46 produced the highest significant biomass, followed by *Otokongtian*. Lower 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 lower than at higher densities during this period of growth.

The 533,333 density continued to produce the highest significant biomass at 12 WAS in 2009 and 2010, followed by 640,000, while 2,054,435 produced the least biomass (Table 4).

Table 4: Effects of population density and cultivars on biomass of rice (g/hill) at 12 WAS in 2009 and 2010 in Uyo, Nigeria

Population Density ha^{-1}	Rice Cultivars					Mean
	FARO 43	FARO 46	FARO 55	FARO 56	<i>Otokongtian</i>	
			<u>2009</u>			
1,600,000	11.464	10.253	6.881	8.962	9.364	9.385
1,066,666	11.680	11.346	7.821	9.831	11.860	10.507

800,000	12.574	11.726	8.366	9.832	12.873	11.074
640,000	17.288	16.540	15.891	16.888	18.786	17.079
533,333	17.262	18.320	14.784	17.539	19.497	17.480
25cm x drill ($\bar{x} = 2,054,435$)	4.566	6.012	3.872	4.664	4.766	4.776
Mean	12.473	12.366	9.602	11.286	12.858	11.717
<u>2010</u>						
1,600,000	15.382	11.543	9.834	13.844	14.729	13.067
1,066,666	15.224	15.152	11.925	13.348	15.481	14.226
800,000	15.103	13.235	11.775	15.170	16.180	14.293
640,000	17.467	16.259	13.188	15.833	14.998	15.549
533,333	16.044	17.579	12.373	17.813	18.063	16.374
25cm x drill ($\bar{x} = 2,054,435$)	5.111	6.020	4.631	5.022	5.110	5.179
Mean	14.055	13.298	10.621	13.505	14.093	13.115

177		2009	2010
178	LSD ($P=0.05$) for population density means (P)	0.248	0.545
179	LSD ($P=0.05$) for cultivar means (C)	0.226	0.497
180	LSD ($P=0.05$) for P x C means	0.554	1.218
181	The highest significant biomass was obtained from <i>Otokongtian</i> during the		
182	period in 2009, followed by FARO 43 whereas <i>Otokongtian</i> produced similar biomass		
183	with FARO 43 in 2010. In both years lower densities produced greater biomass than		
184	higher densities at 12 WAS.		
185	Lower densities produced higher biomass at 15 WAS in 2009 and 2010 (Table 5).		

186 **Table 5: Effects of population density and cultivars on biomass of rice (g/hill)**
187 **at 15 WAS in 2009 and 2010 in Uyo, Nigeria**
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Population Density ha^{-1}	Rice Cultivars					Mean
	FARO 43	FARO 46	FARO 55	FARO 56	<i>Otokongtian</i>	
	<u>2009</u>					
1,600,000	18.861	14.903	16.708	17.876	20.719	17.814

	2009	2010
LSD ($P=0.05$) for population density means (P)	0.248	0.362
LSD ($P=0.05$) for cultivar means (C)	0.226	0.330
LSD ($P=0.05$) for P x C means	0.554	0.809

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

Crop Growth Rate (CGR)

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

Table 6: Effects of population density and cultivars on the crop growth rate of rice ($\text{g/m}^2/\text{day}$) at 3-6 WAS in 2009 and 2010 in Uyo, Nigeria

Crop Growth Rate (CGR)

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

Table 6: Effects of population density and cultivars on the crop growth rate of rice (g/m²/day) at 3-6 WAS in 2009 and 2010 in Uyo, Nigeria

Population Densityha ⁻¹	Rice Cultivars					Mean
	FARO 43	FARO 46	FARO 55	FARO 56	<i>Otokongtian</i>	
	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
<u>2010</u>						
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

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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 significant increase in CGR with increase in plant density in both years between 6 and 9 WAS, (Table 7).

Table 7: Effects of population density and cultivars on the crop growth rate of rice (g/m²/day) at 6-9 WAS in 2009 and 2010 in Uyo, Nigeria

Population Density ha^{-1}	Rice Cultivars					Mean
	FARO 43	FARO 46	FARO 55	FARO 56	<i>Otokongtian</i>	
<u>2009</u>						
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
<u>2010</u>						
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

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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

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.

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

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234 **Table 8: Effects of population density and cultivars on the crop growth rate**
235 **of rice (g/m²/day) at 9-12 WAS in 2009 and 2010 in Uyo, Nigeria**
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Population Densityha ⁻¹	Rice Cultivars					Mean
	FARO 43	FARO 46	FARO 55	FARO 56	Otokongtian	
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

237		2009	2010
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239	LSD ($P=0.05$) for population density means (P)	1.171	0.680
240	LSD ($P=0.05$) for cultivar means (C)	2.618	1.520
241	LSD ($P=0.05$) for P x C means	2.618	1.520

242 During the growth stage, *Otokongtian*, FAROs 43 and 56 produced similar CGR
243 that was significantly higher than FAROs 46 and 55, whereas in 2010, the CGR for

244 *Otokongtian* and FARO 43 was similar, followed by FARO 56 while FAROs 46 and 55
 245 produced the lowest CGR. In both years, greater CGR was obtained from cultivars at
 246 higher than lower densities.

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

250 **Table 9:** Effects of population density and cultivars on the crop growth rate
 251 of rice (g/m²/day) at 12-15 WAS in 2009 and 2010 in Uyo, Nigeria
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Population Densityha ⁻¹	Rice Cultivars					Mean
	FARO 43	FARO 46	FARO 55	FARO 56	Otokongtian	
<u>2009</u>						
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
<u>2010</u>						
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

253		2009	2010
254			
255	LSD ($P=0.05$) for population density means (P)	0.905	0.835
256	LSD ($P=0.05$) for cultivar means (C)	0.826	0.762

257 LSD ($P=0.05$) for P x C means 0.024 1.866

258 *Otokongtian* produced the highest CGR in 2009 and 2010, followed by FARO

259 56 and FARO 43; the lowest CGR was obtained from FAROs 56 and 55. Greater CGR

260 was obtained from cultivars at higher than lower densities.

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

262 Positive correlation between the biomass, crop growth rate and grain yield was

263 observed at various stages of measurement in 2009 and 2010, (Table 10).

264 **Table 10: Correlation coefficient between grain yield and growth parameters**
265 **as influenced by population density and upland rice cultivar (r)**
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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*

267
268 * = Significant at 5% probability level

269 NS = Non-significant at 5% probability level
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271 Generally, in both years the highest correlation between rice biomass and grain

272 yield was observed at 9 to 12 weeks after sowing while the correlation between crop

273 growth rate and grain yield was greater at 9 to 15 WAS in 2009 and 6 to 12 weeks in

274 2010.

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Discussion

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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, soil moisture and nutrients. Similar observation was reported by [13]. The comparable biomass at different densities at 6 WAS could be due to availability of adequate growth factors when their canopies had not yet closed. [6] attributed high biomass production at the 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 the lowest biomass as a result of competition for below and above ground growth factors. At 9 to 15 WAS, lower densities produced higher biomass. [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 higher densities at advanced growth stages. It should be noted that [9] reported low sunshine hours for the study area.

Cultivar differences were observed on their biomass production throughout the periods of observation. According to [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 [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. [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 less number of tillers.

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 (0.025m⁻²) was 5.10 times larger than the soil area for 2,054,435 density (0.0049m⁻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 [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. [6] reported that a large

325 genotypic variability in CGR during the late reproductive period was mainly due to
326 differences in radiation use efficiency. Therefore, it could be stated that *Otokongtian*
327 and FAROs 43 and 56 were more efficient in light capturing and conversion abilities.

328 A positive and significant correlation was observed between CGR and grain
329 yield of rice between 9 to 12 and 12- 15 WAS in 2009 ($r = 0.64, 0.61$ respectively); and
330 between 6 – 9, 9 – 12 and 12-15 WAS in 2010 ($r = 0.62, 0.61$ and 0.65 , respectively)
331 indicating that factors that increased CGR enhanced grain yield during those periods of
332 growth. This finding agreed with the report of [7] that grain yield was most closely
333 related to CGR during the late reproductive period (14-0 days before full heading).

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Conclusion

336 It was concluded on the basis of research findings that higher densities produced
337 higher biomass and crop growth rate which correlated positively with grain yield.
338 Sowing density of low tillering upland rice should not be beyond $1,600,000\text{ha}^{-1}$.
339 Improving the biomass productivity of rice is very important for improving the
340 productivity of rice.

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References

- 344 1. CBN (Central Bank of Nigeria) (2003): Statistical Bulletin. Lagos: CBN.2003;
345 14:260.
- 346 2. WARDA (West African Rice Development Association) (2003): Five Years of
347 Research (1973 – 1978): A Quinquennial Report of West Africa Rice
348 Development Association on Research Activities. Cotonou, Benin 2003; 12.
349
- 350 3. FAO (Food and Agriculture Organization) of the United Nations Statistical
351 Database, FAOSTAT. 2004.
352
- 353 4. Africa Rice Center. Africa Rice Trends: Overview of Recent Developments in
354 the Sub-Saharan Africa Rice Sector. Africa Rice Center Brief, Cotonou, Benin.
355 2007; 27.
356
- 357 5. FAO (Food and Agriculture Organization) of the United Nations Statistical
358 Database, FAOSTAT. 2013.
359

- 360 6. Takai T, Matsuura S, Nishio T, Ohsumi A, Shiraiwa T, Horie T. Rice Yield
361 Potential is Closely Related to Crop Growth Rate during Late Reproductive
362 Period. *Field Crop Research*. 2006; 96:328-335.
363
- 364 7. San-oh Y, Kondo M, Ookawa T, Hirasawa T. Ecophysiological Analysis on
365 Effect of Planting Pattern on Biomass Production and Grain Yield in Rice.
366 *Japan Agric. Res. Quarterly*. 2008; 42(2):79 (On Press): DOI:10.6090/jarg.
367
- 368 8. Gupta PC, O'Toole JC. Upland Rice: A Global Perspective. International Rice
369 Research Institute, Manila. 1986; 148-180.
370
- 371 9. Slus AK. Physical Background Soils, Land use and Ecological Problems:
372 Technical Report of the Taskforce on Soils and Land use Survey of Akwa Ibom
373 State. The Government Printer, Uyo. 1989; 13.
374
- 375 10. Enwezor WO, Ohiri AC, Opuwaribo EE, Udo EJ. A Review of Fertilizer use on
376 Crops in the South Eastern Zone of Nigeria. In: Enwezor, W. O. (ed.) Literature
377 Review on Soil Fertility Investigations in Nigeria. Federal Ministry of
378 Agriculture and Natural Resources. Lagos – Nigeria. 1990; 49-100.
379
- 380 11. Prudente JA, Signa GC, Kongchum M, Prudente AD. Improving Yield and
381 Nutrient Uptake Potentials of Japonica and Indica Rice Varieties with Nitrogen
382 Fertilization. *World Journ. Agric. Science*. 2008; 4(4):427-434.
383
- 384 12. Radford PJ, (1967): Growth Analysis Formulae: Their use and Abuse. *Crop*
385 *Science*. 1967; 7 (3):171-175.
386
- 387 13. Lack S, Baymani M, Mombeni M. The Study of dry matter Remobilization in
388 Rice Cultivars due to Planting Density Variations. *Adv. Environ. Biology*.
389 2011; 5 (10):3338-3344.
390
- 391 14. Aruna Geetha S, Thiyarajan TM. Remobilization of Nitrogen in Rice Genotype.
392 *Crop Research*. 2003; 25 (3):406-409.
393
- 394 15. Ntanos DA, Koutroubbas SD. Dry Matter and N accumulation and
395 Translocation for Indica and Japonica Rice under Mediterranean Conditions.
396 *Field Crop Research*. 2002; 74 (1):93-101.
397
- 398 16. Fageria NK. (1992): Maximizing Crop Yields. New York: Marcel Dekkar Inc.
399 1992; 65.