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Yield, Yield Components and Economic Returns of Upland Rice as Influenced by Population Densities and Cultivars in Uyo, Nigeria

Ofonmbuk S. Aderi[1] and Nyaudoh U. Ndaeyo[1*]

[1]*Department of Crop Science, University of Uyo, Uyo, Nigeria.*

Authors' contributions

This work was carried out in collaboration between both authors. Author NUN design the experiment, read the entire manuscript and made suggestions and revisions. Author OSA managed the field, conducted statistical analysis and wrote the first draft of the manuscript. Both authors read and approved the final manuscript.

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ABSTRACT

Background: One reason for the low yield of rice in Nigeria is the use of inappropriate plant density. It has been found that as seeding rate increased; panicles m^{-2} significantly increased suggesting that adjustments in plant densities could enhance upland rice yield which constitutes 32% of the Nigerian rice growing area. Therefore, this study was undertaken to assess the yield, yield components and economic returns of upland rice as influenced by population densities and cultivars in Uyo, Nigeria

Study Design: A 6 x 5 factorial experiments laid out in a randomized complete block design with three replications were conducted in 2009 and 2010 at the University of Uyo Teaching and Research Farm, Use Offot, Uyo, Nigeria.

Methodology: Treatment combinations were six population densities: 1,600,000 plants ha^{-1} (i.e. 25 cm x 10 cm spacing x 4 plants), 1,066,666 plants ha^{-1} (i.e. 25 cm x 15 cm spacing x 4 plants), 800,000 plants ha^{-1} (i.e. 25 cm x 20 cm spacing x 4 plants), 640,000 plants ha^{-1} (i.e. 25 cm x 25 cm spacing x 4 plants), 533,333 plants ha^{-1} (i.e.25 cm x 30 cm spacing x 4 plants) and 2,054,435 plants ha^{-1} (i.e. 25 cm x drilling) and five upland rice cultivars: FARO 43, FARO 46, FARO55,

**Corresponding author: E-mail: dr_nundaeyo@yahoo.com;*

FARO 56 and a popular local check - *Otokongtian*.

Results: Results indicated that the number of effective panicles m^{-2} increased significantly ($P<0.05$) with increase in density but not beyond 1,600,000 plants ha^{-1}. The 640,000 and 533,333 plants ha^{-1} significantly increased the number and percentage of filled spikelets $panicle^{-1}$. Increase in plant density significantly decreased 1000 seed weight while grain yield increased significantly with increase in population density except that the 1,600,000 density yielded significantly higher than the 2,054,435 density. The local check, *Otokongtian*, produced the highest number of effective panicles, followed by FARO 43. The FARO 56 produced the highest number of spikelets. Percentage filled spikelets $panicle^{-1}$ did not follow a definite trend but FAROs 56 and 43 had higher percentage of filled grains. In both years, FARO 46 had the highest significant 1,000 seed weight while FARO 43 produced the highest significant grain yield. All the cultivars produced higher grain yield at higher than at lower densities

Conclusion: Although variations were observed between years, 1,600,000 plant density had the highest net benefit (Naira (₦) ha^{-1} ₦1.00 = 162 US Dollars) in both years (₦383,074 and ₦303,554 for 2009 and 2010, respectively), which represented 789.65 – 806.24% returns on investment over the 640,000 density, followed by 2,054,435 density. Therefore, FARO 43 and 56 have great potentials for this agro-ecology particularly at 1,600,000 plants ha^{-1} density.

Keywords: Upland rice cultivar; population density; yield; economic return; Nigeria.

1. INTRODUCTION

Rice, *Oryza sativa* L. and *Oryza glaberrima* Steud, are important food crops of the family Poaceae. They are staples for more than half of the world's population as about a billion households in Asia, Africa and the America depend on rice cultivation for employment and main source of livelihood [1]. The Central Bank of Nigeria [2] classified rice as a food staple for over 60% of Nigeria homes. According to West African Rice Development Association [3], 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. However, Nigeria's annual demand for rice (about 5 million tonnes of milled rice) is far greater than the supply (estimated at 3 million tonnes annually) [4] with the result that the rice self-sufficiency ratio is only 0.64 [5]. The shortfall in Nigeria's rice demand is often met by importation which not only poses a great constraint on the country's foreign reserves [6] but also a threat to national food security. One of the strategies to ameliorate the situation could be by increasing per hectare yield of rice through modifying the existing recommended plant density. Kahlown et al. [7] and Mahmood et al. [8] reported that one reason for the low yield of rice in Pakistan was the low plant density. Similarly, Khuong et al. [9] found that as seeding rate increased, panicles m^{-2} significantly increased. This strongly suggests that by making adjustments in the current plant densities as practiced in Nigeria, better yields could be obtained on the upland ecology which constitutes 32% of the Nigerian rice growing area. Therefore, the study reported here was undertaken to assess the yield, yield components and economic returns of upland rice influenced by population densities and cultivars in Uyo, Nigeria.

2. MATERIALS AND METHODS

Field experiments were conducted at the Teaching and Research Farm of the University of Uyo, located in Use Offot, Uyo, Akwa Ibom State, during the 2009 and 2010 cropping seasons. In 2009, the location of the experiment was 05°, 01' 56.2" N, 07°, 58' 20.3" E and 57m above the mean sea level (measured using the Global Positioning System (GPS), Model Germin Etrex)). In 2010, the experimental site was adjacent to the 2009 site and located specifically at 05°, 01' 56.6"N, 07°, 58' 20.6" E and 55m above the mean sea level. Peters [10] reported that this humid rain forest zone receives an annual rainfall of about 2,500mm and a mean relative humidity of 78%. 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 a broad soil classification group, ultisol, formed from acid plain sand [11].

2.1 Treatments and Experimental Design

A 6 x 5 factorial treatment combinations comprising six population densities namely: 1,600,000 plants ha^{-1} (from 25cm x10cm spacing x4 plants), 1,066,666 plants ha^{-1} (from 25cm x

15cm spacing x 4 plants), 800,000 plants ha^{-1} (from 25cm x 20cm spacing x 4 plants), 640,000 plants ha^{-1} (from 25cm x 25cm spacing x 4 plants), 533,333 plants ha^{-1} (from 25cm x 30cm spacing x 4 plants) and 2,054,435 plants ha^{-1} (from 25cm x drilling), respectively and five rice cultivars: FARO 43 , FARO 46, FARO55, FARO 56 and a popular local check called *Otokongtian* were laid out in a randomized complete block design and replicated three times.

In each year, the experimental area measured 119 m x 20 m and was divided into three blocks with each measured 119 m x 4 m. A block was then subdivided into 30 plots, each measuring 4m x 3m and separated from each other by a1.0 m path while the space between two adjacent blocks was 2.0 m. A space of 2.0 m was also maintained around the experimental area to ensure proper farm sanitation.

2.2 Cultural Practices

Seeds were sown manually by dibbling using six seeds per hill according to the spacing earlier mentioned above. At two weeks after sowing (WAS), seedlings were thinned to four per hill. Within 24 hours after sowing, pre-emergent herbicide, *Paraquat*, was applied at the recommended rate of 1.0 kg active ingredient ha^{-1} [12] to control weeds and weed seeds on the soil surface. NPK (15:15:15) fertilizer was applied in split doses at two; six and nine WAS by side banding. Human bird scarers were employed to scare birds.

2.3 Data Collection and Analysis

Data were collected on the number of effective tillers m^{-2}, number of spikelet panicle^{-1}, 1000 seed weight, and grain yield (tha^{-1}). Grain yield was estimated using Fageria [13] method thus: Grain yield (t/ha) = number of panicles m^{-2} x number of spikelets panicle^{-1} x percentage of filled spikelets x average grain weight of 1,000 grains $x\,10^{-5}$. Data collected were subjected to analysis of variance using Genstat Discovery Edition 4 and means that indicated significant differences were compared using Fisher's Protected Least Significant Difference at 5% level of probability. Analysis of economic returns on investment was done by using crop enterprise budgets technique [14,15] developed annually for each treatment. Crop prices and operational costs used in the budgets were the seasonal prices that prevailed in the study area during the cropping season. The marginal rate of returns which compared the extra (or marginal) cost with the extra (or marginal) net benefit was calculated according to CIMMYT [16] and Ndaeyo [15] as:

$$\frac{Extra\ benefit\ from\ the\ new\ technology}{Extra\ investement\ in\ that\ new\ technology}\, x\, \frac{100}{1}$$

3. RESULTS

3.1 Yield and Yield Components

The number of effective panicles m^{-2} increased significantly as population density increased from 533,333 ha^{-1} to 1,600,000ha^{-1} in both years (Table 1). As population density increased to 2,054,435ha^{-1} effective panicle m^{-2} decreased compared to 1,600,000 density ha^{-1}. In both years, the local cultivar – *Otokongtian*, produced the highest number of effective panicles, followed by FARO 43 while FARO 46 and 55 produced the least number of effective panicles m^{-2} at higher than at lower densities. In 2009 , 640,000 plant density produced the highest significant number of spikelets panicle^{-1}, followed by 533,333 density while 1,600,000 and 2,054,435 densities had the least but similar number of spikelets panicle^{-1} (Table 2). In 2010, the number of spikelets panicle^{-1} for 640,000 and 533,333 densities was similar and significantly higher than those for other densities. There was no significant difference in the number of spikelets panicle^{-1} between 1,600,000 and 1,066,666 plant densities in 2010. In both years, all the cultivars followed similar trend on the number of spikelets panicle^{-1}, with the highest significant spikelets obtained from FARO 56, followed by the local, *Otokongtian* and the least from FARO 46. Lower plant densities produced greater number of spikelets panicle^{-1}than higher densities in both years.

In 2009, the highest significant percentage of filled spikelets panicle^{-1} was obtained from 640,000 population density followed by 533,333 density and 2,054,435 densities (Table 3). The least significant percent of filled spikelets panicle^{-1} was obtained from 1,066,666 and 1,600,000 plant densities. In 2010, 640,000 also produced the highest significant percentage of filled spikelets panicle^{-1} compared with other densities. It was followed by 533,333 and 800,000 plant densities. The least significant percent of filled spikelets panicle^{-1} was obtained from 1,066,666 and 1,600,000 densities. In general and in both years, the percentage of filled spikelets panicle^{-1} increased with lower plant densities. In 2009, 1,000 seed weight was similar for 1,066,666, 800,000, 640,000 and 533,333 plant densities (Table 4). They were significantly higher than 1,000 seed weight for 1,600,000 and 2,054,435 plant densities. In 2010, 1,000 seed weight for 800,000, 640,000 and 533,333 plant densities were also similar but significantly higher than 1,000 seed weight for 1,066,666, 1,600,000 and 2,054,435 plant densities. In both years, 1,000 seed weight from 1,600,000 and 2,054,435 populations was similar. Effect of rice cultivars on 1,000 seed weight followed similar trend in both years. FARO 46 produced the highest significant seed weight, followed by FARO 43, while *Otokongtian* had the least 1,000 seed weight. The interaction effect showed that lower densities produced heavier rice seeds than higher densities.

In 2009 and 2010, grain yield increased significantly with increased in population density except that the 1,600,000 density yielded significantly higher than 2,054,435 density (Table 5). However, cultivar effect showed significant differences in 2009 while FARO 56 and *Otokongtian* had similar grain yield in 2010. The interaction effect between density and cultivar showed consistently higher yield of rice at higher than at lower densities.

3.2 Cost of Production and Return on Investment

The challenges associated with the upland rice were mainly those due to cost of production and return on investment. Although variations were observed between years, 1,600,000 plant density had the highest net benefit (in Naira (₦) ha^{-1}) in both years (₦383, 074 and ₦303, 554 for 2009 and 2010, respectively), which represented 789.65 – 806.24% returns on investment over the 640,000 density (Table 6). It was followed by 2,054,435 density (₦214, 596 and ₦166, 816, respectively for 2009 and 2010 or 607.91 – 759.21% over 640,000 density. The net benefit for the 1,066,666 density (₦183,118 and ₦53, 518 for 2009 and 2010, respectively or 473.20 – 755.50% over 640,000 density) and 800,000 density (₦103,345 and ₦18,8884for 2009 and 2010, respectively or 587.24 – 868.6% over 640,000 density were positive. However, net benefit for 640,000 density was positive in 2009 (₦52, 799) but negative (–₦49,057) in 2010, while the net benefit for 533,333 density was negative in both years (–₦38,295 and –₦128,537, respectively for 2009 and 2010 or –962.04 to –987.34% compared to 640,000 density). Consequently, for every ₦1.00 spent to produce upland rice, the density, 1,600,000 realized ₦1.54 to ₦1.84 returns; ₦1.10 to ₦1.43 returns for 1,066,666 density, ₦1.04 to ₦1.25 returns for 800,000 density; ₦0.90 to ₦1.13 returns for 640,000 density, ₦0.74 to ₦0.90 (net loss) for 533,333 density and ₦1.31 to ₦1.50 returns for 2,054,435 density. Effect of cultivars (calculated as means across densities) showed that the highest net benefit (₦ha^{-1}) was obtained from *Otokongtian* (₦522,882 to ₦535,749, respectively for 2009 and 2010), followed by FARO 43 ₦504,321 to ₦514,264 or 10.98 to 23.81% over *Otokongtian* (Table 7). FARO 56 (₦387,276 to ₦391,883 or –1,383.82 to –1,760.42 (from *Otokongtian*), FARO 55 (₦325,959 to ₦339,190 or –1,910.45 to –2,124.92% from *Otokongtian*), while the benefit of ₦286,614 to ₦293,253 was obtained from cultivating FARO 46 which represented –674.13 to –678.63% return on investment. In every ₦1.00 spent to cultivate upland rice, *Otokongtian* realized ₦4.04 to ₦4.05, while FARO 43 realized ₦3.57; FARO 46 was ₦3.18 to ₦3.20; FARO 56 realized ₦3.14 and the least return was from FARO 55 (₦3.02 to ₦3.03).

One major component of cost is labour (Table 6) as results indicated that while increase in labour cost ranged between 22.86 and 30.57% in 2010 compared with 2009, the percentage increase in gross revenue in 2010 was only 12.23% compared with the previous year. Increase in labour cost was associated with land preparation (8.66 - 8.86%) sowing of seeds (3.0 – 3.9%) manual weeding (10.63 – 11.42%), manual fertilizer application (10.63 – 11.42%), bird scaring (21.25 – 25.69%), cost of harvesting (9.51 – 11.81%) which increased with increase in paddy yield and subsequent packing, sun drying, threshing, and winnowing, excluding parboiling (including sourcing for fuel wood and water (11.13 – 12.87%), other costs (14.03 – 25.19%). These items of cost greatly reduced the marginal revenue and in some instances net loss.

Table 1. Effects of population density and rice cultivars on the number of effective panicles m^{-2} in 2009 and 2010 in Uyo, Nigeria

Population density	Rice cultivars					Mean
	FARO 43	FARO 46	FARO 55	FARO 56	*Otokongtian*	
2009						
1,600,000	235.33	218.78	206.33	220.11	242.00	224.51
1,066,666	172.44	145.78	134.56	137.22	203.00	158.60
800,000	132.44	113.78	107.89	120.67	142.89	123.53
640,000	109.67	93.56	93.56	95.33	124.33	103.29
533,333	91.89	74.67	70.67	74.22	99.11	82.11
25cm by drill (x = 2,054,435)	194.11	152.45	160.11	170.67	196.89	174.85
Mean	**155.98**	**133.17**	**128.85**	**136.37**	**168.04**	**144.48**
2010						
1,600,000	236.33	219.67	222.00	226.33	245.67	230.00
1,066,666	173.00	144.00	141.00	142.67	181.33	156.40
800,000	133.67	116.00	109.33	122.33	145.67	125.40
640,000	109.33	91.67	93.00	96.00	125.33	103.07
533,333	93.33	71.00	70.33	74.67	99.33	81.73
25cm by drill (x = 2,054,435)	204.00	156.33	164.33	174.67	206.00	181.07
Mean	**158.28**	**133.11**	**133.33**	**139.44**	**167.22**	**146.28**

x =mean

	2009	2010
LSD (P<0.05) for population density means (P)	2.62	1.76
LSD (P<0.05) for cultivars means (C)	2.40	1.60
LSD (P<0.05) for P x C means	5.87	3.93

Table 2. Effects of population density and rice cultivars on the number of spikelets $panicle^{-1}$ in 2009 and 2010 in Uyo, Nigeria

Population density	Rice cultivars					Mean
	FARO 43	FARO 46	FARO 55	FARO 56	*Otokongtian*	
2009						
1,600,000	136.00	98.00	130.00	171.00	151.00	137.20
1,066,666	135.00	96.00	133.00	175.33	150.67	138.00
800,000	165.00	97.33	165.00	176.33	150.56	150.85
640,000	168.00	98.00	164.67	166.33	177.00	156.80
533,333	170.00	96.00	165.33	177.00	169.00	155.47
25cm by drill(x = 2,054,435)	139.00	98.00	138.00	164.00	150.00	137.80
Mean	**152.17**	**97.22**	**149.33**	**173.33**	**158.04**	**146.18**
2010						
1,600,000	139.33	100.67	131.00	162.67	152.33	137.20
1,066,666	134.33	97.33	133.67	165.67	150.67	136.33
800,000	165.67	97.67	165.00	177.33	155.00	152.13
640,000	167.67	97.67	165.33	177.67	174.33	156.53
533,333	173.33	99.67	165.33	178.67	175.33	158.47
25cm by drill (x = 2,054,435)	142.00	99.33	138.67	167.00	159.67	141.33
Mean	**153.72**	**98.72**	**149.83**	**171.50**	**161.22**	**147.00**

x =mean

	2009	2010
LSD (P<0.05) for population density means (P)	0.27	1.96
LSD (P<0.05) for cultivars means (C)	0.25	1.79
LSD (P<0.05) for P x C means	0.61	4.37

Table 3. Effects of population density and rice cultivars on the percent of filled spikelets panicle^{-1} in 2009 and 2010 in Uyo, Nigeria

Population density	Rice cultivars					Mean
	FARO 43	FARO 46	FARO 55	FARO 56	*Otokongtian*	
			2009			
1,600,000	90.58	84.46	90.52	90.74	85.40	88.34
1,066,666	90.38	84.71	90.31	90.52	85.64	88.31
800,000	90.09	86.44	89.04	90.37	88.37	88.86
640,000	90.97	87.67	90.34	90.23	88.65	89.57
533,333	90.09	86.14	90.68	90.32	88.62	89.17
25cm by drill (x = 2,054,435)	90.14	88.76	89.64	90.13	86.41	89.02
Mean	**90.38**	**86.36**	**90.09**	**90.39**	**87.18**	**88.88**
			2010			
1,600,000	90.45	85.40	90.37	90.05	85.81	88.41
1,066,666	90.34	85.12	90.44	90.05	85.97	88.38
800,000	90.47	87.30	90.28	90.43	87.72	89.24
640,000	90.59	88.48	90.40	90.40	88.84	89.74
533,333	90.70	86.71	90.56	90.60	88.76	89.47
25cm by drill (x = 2,054,435)	90.49	88.00	90.45	90.58	86.33	89.17
Mean	**90.51**	**86.84**	**90.42**	**90.35**	**87.24**	**89.07**

x =mean

	2009	2010
LSD (P<0.05) for population density means (P)	0.03	0.02
LSD (P<0.05) for cultivars means (C)	0.03	0.02
LSD (P<0.05) for P x C means	0.06	0.05

Table 4. Effects of population density and rice cultivars on 1,000 seeds weight (g) of rice in 2009 and 2010 in Uyo, Nigeria

Population density	Rice cultivars					Mean
	FARO 43	FARO 46	FARO 55	FARO 56	*Otokongtian*	
			2009			
1,600,000	27.44	30.93	27.33	23.96	23.00	26.53
1,066,666	28.67	30.93	28.00	25.33	23.03	27.13
800,000	28.33	31.67	26.67	25.33	23.43	27.09
640,000	28.00	31.17	27.32	25.90	23.04	27.09
533,333	27.87	31.20	27.33	25.33	22.83	26.92
25cm by drill (x = 2,054,435)	27.50	30.95	26.27	25.00	22.11	26.37
Mean	**27.97**	**31.09**	**27.15**	**25.14**	**22.91**	**26.85**
			2010			
1,600,000	27.33	31.00	27.19	24.33	23.00	26.57
1,066,666	27.42	31.00	27.27	25.29	23.04	26.80
800,000	28.00	31.19	26.88	25.96	23.09	27.03
640,000	28.05	31.03	27.03	25.94	23.03	27.02
533,333	28.08	31.00	27.02	26.034	23.08	27.05
25cm by drill (x = 2,054,435)	27.55	31.00	27.03	24.67	22.81	26.61
Mean	**27.74**	**31.04**	**27.07**	**25.37**	**23.01**	**26.85**

x =mean

	2009	2010
LSD (P<0.05) for population density means (P)	0.41	0.18
LSD (P<0.05) for cultivars means (C)	0.37	0.16
LSD (P<0.05) for P x C means	0.91	0.40

Table 5. Effects of population density and cultivars on grain yield of rice (tha^{-1}) in 2009 and 2010 in Uyo, Nigeria

Population density	Rice cultivars					Mean
	FARO 43	FARO 46	FARO 55	FARO 56	*Otokongtian*	
			2009			
1,600,000	7.95	5.60	6.63	8.18	7.18	7.11
1,066,666	6.03	3.63	4.51	5.53	6.03	5.15
800,000	5.58	3.03	4.23	4.87	4.41	4.42
640,000	4.69	2.50	3.80	3.93	4.49	3.88
533,333	3.92	1.93	2.90	3.00	3.39	3.03
25cm by drill (x = 2,054,435)	6.69	4.10	5.21	6.31	5.62	5.59
Mean	**5.81**	**3.47**	**4.55**	**5.30**	**5.19**	**4.86**
			2010			
1,600,000	8.15	5.85	7.15	8.06	7.39	7.32
1,066,666	5.76	3.70	4.65	5.38	5.41	4.98
800,000	5.61	3.08	4.38	5.09	4.57	4.55
640,000	4.66	2.46	3.77	4.00	4.47	3.87
533,333	4.12	1.90	2.85	3.15	3.57	3.12
25cm by drill (x = 2,054,435)	7.22	4.24	5.46	6.52	6.47	5.98
Mean	**5.92**	**3.54**	**4.71**	**5.37**	**5.31**	**4.97**

x =mean

	2009	2010
LSD (P<0.05) for population density means (P)	0.11	0.07
LSD (P<0.05) for cultivars means (C)	0.10	0.07
LSD (P<0.05) for P x C means	0.24	0.15

Table 6. Cost of production and economic return for upland rice as influenced by population density (Mean across cultivars) in Uyo, Nigeria

Operation (₦)	Population density											
	1,600,000		1,066,666		800,000		640,000		533,333		25cm x drill (x=2054,435)	
	2009	2010	2009	2010	2009	2010	2009	2010	2009	2010	2009	2010
Average crop yield (t ha^{-1})	7.11	7.32	5.15	4.98	4.42	4.55	3.88	3.87	3.03	3.12	5.59	5.98
Gross revenue ((₦)[+]	836,720	861,760	609,880	588,080	52,600	534,800	459,680	458,020	358,320	369,320	658,120	706,640
Soil analysis	2,500	2,500	2,500	2,500	2,500	2,500	2,500	2,500	2,500	2,500	2,500	2,500
Land preparation	35,000	43,000	35,000	43,000	35,000	43,000	35,000	43,000	35,000	43,000	35,000	43,000
Labour**	33,570	426,330	309,418	408,418	302,775	392,636	294,121	385,517	285,223	337,665	312,024	403,524
Seed purchase	17,176	17,176	11,444	11,444	8,580	8,580	6,860	6,860	5,492	5,492	21,600	21,600
Fertilizer	64,000	64,000	64,000	64,000	64,800	64,000	64,800	64,000	64,000	64,800	64,000	64,800
Insecticide	4,400	4,400	4,400	4,400	4,400	4,400	4,400	4,400	4,400	4,400	4,400	4,400
Total cost (₦)	453,646	558,206	426,762	534,562	417,255	515,916	406,881	507,077	396,615	497,857	439,524	539,824
Net benefit (₦ha^{-1})	383,074	303,554	183,118	53,518	103,345	18,884	52,799	-49,057	-38,295	-128,537	218,596	166,816
Marginal rate of return(%)***	806.24	789.65	755.50	473.20	587.24	868.65	-	-	-987.34	-962.04	607.91	759.21
Benefits/costratio	1.84	1.54	1.43	1.10	1.25	1.04	1.13	0.90	0.90	0.74	1.50	1.31

Land preparation and marking included ploughing, harrowing, packing of trash and pegs for marking, **Labour for sowing, weeding, bird scaring, harvesting, winnowing, haulage, drying, Fertilizer application, Threshing,**Marginal rate of returns, Gross revenue = Field price $tonne^{-1}$ x milling yield (tha^{-1}). N/B: ₦ 1.00 = 162 US Dollars ,Marginal costs, Gross revenue = Field price $tonne^{-1}$ x milling yield (tha^{-1}) . N/B: ₦ 1.00 = 162 US Dollars*

Table 7. Cost of production and economic return for upland rice as influenced by cultivars (means across population density) in 2009 and 2010 in Uyo, Nigeria

Operation	Rice cultivars									
	FARO 43		FARO 46		FARO 55		FARO 56		*Otokongtian*	
	2009	2010	2009	2010	2009	2010	2009	2010	2009	2010
Average crop yield (tha^{-1}) (N)	5.81	5.92	3.47	3.54	4.55	4.7	5.30	5.37	5.19	5.132
Gross revenue (tha^{-1}) (N)	700,800	713,983	417,900	462,600	487,200	505,067	568,533	571,200	695,000	711,333
Seed purchase	12,793	12,793	14,593	14,593	13,547	13,547	12,320	12,320	6,040	6,040
Seed sowing	17,333	17,333	17,333	17,333	17,333	17,333	17,333	17,333	17,333	17,333
Panicle harvesting	36,000	36,670	21,560	22,000	28,220	29,220	32,670	33,110	32,220	33,000
Threshing	24,515	24,979	14,641	14,937	19,198	19,873	22,363	22,658	21,899	22,405
Parboiling*****	43,598	44,420	26,039	26,564	34,143	35,344	39,771	40,296	38,946	39,846
Milling*****	62,240	63,520	37,120	37,920	48,800	50,560	56,800	57,600	55,680	56,960
Total cost (₦) due to cultivars	196,479	199,719	131,126	133,347	161,241	165,877	181,257	183,317	172,118	175,584
Net benefit (₦ha^{-1})	504,321	514,264	286,614	293,253	325,959	339,190	387,276	391,883	522,882	535,749
Benefit/cost ratio due to cultivars	3.57	3.57	3.18	3.20	3.02	3.04	3.14	3.14	4.04	4.05
Marginal rate of return (%)	23.81	10.98	678.63	674.13	1910.45	2124.92	1383.82	1760.42	-	-

**Land preparation and marking included ploughing, harrowing, packing of trash and pegs for marking*
***Labour for sowing, weeding bird scaring, harvesting, winnowing, haulage, drying, Fertilizer application, Threshing*
****Net benefit =was calculated by subtracting the total cost that varied from the total gross returns*
*****Marginal rate of returns* $\frac{\text{Extra benefit from new technology}}{\text{Marginal costs}} \times 100$
******Parboiling was at ₦700 paddy drum^{-1} (93.2836 kg),******Milling was done at ₦400 bushel^{-1} (25.00 kg milled rice) at 67% milling yield of paddy*
Cross revenue = Field price tonne^{-1} x milling yield (tha^{-1}). N/B: ₦ 1.00 = 162 US Dollars

4. DISCUSSION

The highest significant number of effective panicles m^{-2} was obtained from 1,600,000 plant density ha^{-1} and indicated that besides the plant density of 2,054,435 ha^{-1}, none of the other densities exceeded the threshold that could cause severe competition leading to high seedling mortality. Also, in both years, the local (check) cultivar – *Otokongtian,* produced the highest number of effective panicles m^{-2}, followed by FARO 43. In general, most of the cultivars used had low tillering capacities and became more so when grown in the humid, highly leached acidic soils formed from coastal plain sand with low base saturation. The lowest density of 533,333 plants ha^{-1} did not produce adequate number of tillers to compensate for the low density. Therefore, to compensate for low tillers, 1,600,000 plants ha^{-1} appeared to be the optimum density for increased production of effective panicles. This finding agrees with the report of Khuong et al. [9] that plant population necessary to obtain optimum rice yield was influenced by varieties and seeding rate and that cultivars with high tillering ability increased the number of panicles unit $area^{-1}$. However, the number of spikelets $panicle^{-1}$ increased with lower densities (between 640,000 and 533,333 plants ha^{-1}) – a compensation for lower number of effective panicles. Lack et al. [17] observed that as density increased, vegetative growth decreased in each hill because of reduction in free space, diminishing radiation and competition for nutrients. These factors might have singly or in combination decreased panicle formation at higher densities in this study.

The cultivar, FARO 56, followed by *Otokongtian* consistently produced the highest number of spikelets $panicle^{-1}$ in both years indicating that they adapted better to the environment than others in relation to spikelet formation. ArunaGeetha and Thiyarajan [18] reported that dry matter production and remobilization in rice was affected by cultivar and environmental conditions, which in this case favoured FARO 56 and *Otokongtian* for spikelet production. The percentage of filled spikelets $panicle^{-1}$ increased with decreasing plant density, with the exception in 2009 when 2,054,435 plant density had insignificantly increased percentage of filled spikelets compared to 800,000 density. It should be noted that in that year (2009), the 2,054,435 plant density produced significantly lower number of spikelets $panicle^{-1}$ compared with 533,333, 640,000 and 800,000 plant densities ha^{-1}. Therefore, it is apparent that there was better distribution of the photosynthate to fewer sink (spikelets) for grain filling. As reported by Khuong et al. [9] that as seeding rate increased, the number of panicles m^{-2} significantly increased and filled grains $panicle^{-1}$ decreased significantly. FARO 43 produced greater percentage of filled spikelets $panicle^{-1}$ which showed that it had higher efficiency in its dry matter remobilization to spikelets. In both years, 1,000 rice seed weight decreased significantly with increasing plant density probably due to increased competition among higher densities for available solar radiation and photosynthetic products. Baloch et al. [19] observed that high plant density increased the number of panicles unit $area^{-1}$ but reduced grain weight in each panicle due to competition for photosynthate and shading effect that lowers photosynthesis.

According to Lack et al. [17], as rice density increased, vegetative growth decreased in each hill because of reduction in free space for crop development and diminishing radiation and nutrients resulting from competition. FARO 46 produced the highest 1,000 seed weight in both years despite having the lowest number of and percentage of filled spikelets. The highest 1,000 seed weight of FARO 46 appeared to be due to genetic differences among cultivars on the one hand and having fewer number of spikelets on the other hand as sink for the photosynthate.

The highest grain yield was obtained from 1,600,000 density. Higher seed rate of 2,054,435 plants ha^{-1} did not give yield advantage over 1,600,000 rate, most probably due to competition effect. FARO 43 produced the highest grain yield compared to other cultivars, followed by FARO 56, then *Otokongtian*, while FARO 46 produced the lowest grain yield. Roshan et al. [20] also obtained higher grain yield at higher densities and noted that although individual productivity $hill^{-1}$ was low, when summed across the number of hills unit $area^{-1}$, higher densities produced higher total grain yield. However, competition among plants in 2,054,435 density caused lower tiller production and mortality which probably contributed to its lower yield potential. The lowest yield of 533,333 density showed that tiller production advantages that lower densities could confer were not enough to compensate for the loss of soil area associated with lower densities especially when cultivars with low tillering ability were used and where environmental factors were not optimal e.g. lower sunshine hours day^{-1}. The low returns on investment showed that high cost of production input – especially fertilizer, and high cost of labour – especially for bird scaring, harvesting, fertilizer application and weeding, and their potentials to increase annually, poses a great challenge to rice farmers.

5. CONCLUSION

In general, most of the cultivars used had low tillering capacities. The lowest density of 533,333 plants ha^{-1} did not produce adequate number of tillers to compensate for the low density. Therefore, to compensate for low tillers, 1,600,000 plants ha^{-1} appeared to be the optimum density for increased production of effective panicles. Although variations were observed between years, 1,600,000 plant density had the highest net benefit (₦ha^{-1}) in both years (₦383,074 and ₦303,554 for 2009 and 2010, respectively), which represented 789.65 – 806.24% returns on investment over the 640,000 density. It was followed by 2,054,435 density (₦214, 596 and ₦166, 816 respectively for 2009 and 2010 or 607.91 – 759.21% over 640,000 density. They therefore have great potentials for this agro-ecology particularly at 1,600,000 plants ha^{-1} density.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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