Effects of Stand Density and NPK Fertilizer on Physiological Parameters of Rice Varieties

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ABSTRACT
Two field trials were conducted in 2016 dry season at the Institute for Agricultural Research (IAR) farm Ahmadu Bello University Zaria located at Samaru (Latitude 11º N 39' Longitude 08º 02'E), 686m above sea level and Kadawa ((Latitude 11^0 11' N Longitude 7^0 38' E), 500m above sea level to study the effects of stand density and NPK fertilizer rate on physiological parameters of rice varieties. The trials consisted of two lowland rice varieties (FARO 44 and FARO 52), three NPK fertilizer rates (40:20:20, 80:40:40, 120:60:60) kgha^{-1} and three level of plants/stand density (2, 4 and 6). The treatments were factorially combined and laid out in a randomized complete block design of three replications. The result shows that, increasing NPK fertilizer rate significantly enhanced physiological parameters which translated into higher paddy yield. Except that the application of lower rate of NPK fertilizer produced longer days to 50% heading while the number of days to physiological maturity didn't show significant response to the application NPK fertilizer. 2 plants/stand density recorded the highest mean value for crop growth rate, relative growth rate and net assimilation rate which translated into higher grain yield.
Among the two varieties evaluated, FARO 52 gave higher value for most yield components, however, FARO 44 produced higher grain yield. The interaction between 2 plants/stand densities with the application of NPK 120:60:60 kgha^{-1} resulted in maximum yield of 6479.3 kgha^{-1} at Kadawa and 5762.5 kgha^{-1} at Samaru. The interaction between FARO 44 with the application of NPK 120:60:60 kgha^{-1} gave maximum yield of 5882 kgha^{-1}. It can be concluded that, sowing FARO 44 at 2 plant/stand with the application of NPK fertilizer at 120:60:60 kgha^{-1} gave optimum grain yield per ha of 6479.3kgha^{-1} in Kadawa and 5762.5 kgha^{-1} in Samaru.

Keywords: *Lowland, density, NPK, Rice and Variety,*

1.0 INTRODUCTION

Rice holds the key to sustainable food sufficiency in Nigeria as it occupies a pivotal position in the food security of Nigeria. It has moved from a ceremonial to a staple food in many homes and occupies a special place in the rain-fed rice production system in the West African sub-region by covering about 9 percent of the total rice area and contributing 8 percent of the production (FAO 2008). Nigeria along with many countries across the world has ecologies that are suitable for different rice varieties and that can be harnessed to boost rice production to meet domestic demands and even to produce a surplus for export (Anonymous 1997a).

The country has a potential land area for rice production of between 4.6 million and 4.9 million hectares. However, 1.7 million hectare, or 35 percent of Nigeria's total land mass is cropped to rice. The cultivable land to rice is spread over five major ecologies –upland, shallow swamp, irrigated rice, deep water and tidal mangrove. The latter is not fully developed because there is a lack of appropriate technology (Singh *et al*., 1997).

At the continental level, Nigeria contributes 5 percent of rice land area and 4 percent of the production (African Rice Centre, WARDA, 2002). However, Nigeria produces about 1.35 metric tons of rice per hectare that is below the world average of about 2 metric tons. Also the country produced 3.4 million tons of rice in 1997 -1998, so the country is deficit to the tune of a million tons making her a net importer of rice.

Presently, weak and inefficient production dominates the sector –market linkages due to poor infrastructures including lack of technical know-how and poor access to inputs. These have led to low productivity of 1.7 metric tons per hectare and attendant low income for the farmers (USAID, 2008). In spite of these, Nigeria is the largest rice producing country in West Africa and the third largest in Africa, after Egypt and Madagascar (WARDA 1996).

Paddy rice production had risen from 134 000 to 344 000 tonnes in 1970 and area cultivated from 156 000 to 255 000ha. Tremendous increases in area planted, output and productivity in paddy rice production were achieved over the last two decades and now stand at 666 000 ha, 1.09 million tonnes and 2.07 tonnes/ha respectively. By 1990, the country produced 3.4 million tonnes of rice from about 1.2million hectares (Imolehin 1991a). This healthy production trend would have been sustained but for the unsteady government policy on rice importation affected it negatively. The increased production over the last decades could be attributed to the ban imposed on rice imports in 1985 but in 1997 the ban was lifted. Importation of rice rose from 7000 tonnes in the 1960s to 657 000 tonnes in the 1990s (IRRI, 1991). This created a serious drain on Nigeria's foreign exchange reserve, which stood at US$407.5 Million in the 1960s but dropped to US$58 million in the 1990s (IRRI 1991). Paddy rice production increased between 2001 and 2006, followed by decline in 2007 and postive peak in 2008. Then decreased again from 2009 to 2010. There has been a steady increase in production since 2011 to 2013 (FAO 2013). However, despite the increase in rice production, rice importation in Nigeria is still high with an average of 2.1 million tonnes from 2009-2011 while rice importation in 2012 and 2013 were 3.0 and 2.5 million tonnes respectively (FAO 2013).

Planting population mainly depends on the variety, its duration of growth, soil fertility and growing season (Salin and Lenka, 1966). Optimum range of plant population per unit area depends on environment, genotype, soil fertility, season of planting, duration of variety and age of seedlings (De-Datta, 1981). Selection of the right types of genotype, adequate plant population and optimum fertilization play an important role in maximizing production.

Manipulation of planting density appears to have a promising potential for increasing the rice yield as it is assured to have pronounced effect on tillering, interception and utilization of light, which in turn influences rice yield. The grain production potential of any newly developed variety can be achieved only when it is matched with proper rate of fertilizer application.

It is in light of the above observed constraints to rice production that this research was conceived.

2.0 MATERIALS AND METHODS

2.1 Experimental Site

The experiment was conducted at the farms of Institute for Agricultural Research (I.A.R), Ahmadu Bello University located at Samaru (Latitude 11^0N 39' Longitude 08^0 02' E), 686m above sea level and Kadawa (Latitude 11^0 11' N Longitude 7^0 38' E), 500m above sea level in Northern Guinea and Sudan Savannah ecological zones of Nigeria, respectively, during the 2016/2017 dry season.

2.2 Treatments and Experimental Design

The treatments consisted of two lowland rice varieties (FARO 44 and FARO 52), three NPK fertilizer rates (40:20:20, 80:40:40, 120:60:60) and three level of plant/stand density (2, 4 and 6 plant/stand). The treatments were factorially combined and laid out in a randomize complete Block design with three replicate. Gross and net plot size of 3.0m x 3.0m and 2m x 2m, respectively.

2.3 Varietal Description and Source

FARO 44 (Sipi) is an improved semi- dwarf cultivar with a maturity period of 90 -100 days with a potential yield of 4-6t/ha. FARO 52 (Wita 4), which has an outstanding characteristic of high yield and tolerance to African rice gall midge, matures between 100 - 120 days with a potential yield of 5 -6t/ha. All were sourced from Premier Seed Company Nigeria limited in Zaria.

2.4 Cultural Practices

The field were harrowed to produce fine tilt before making out gross and net plot size of 3.0m x 3.0m and 2m x 2m, respectively. Sowing of seeds was carried out on the 21st of February, 2017 at Samaru and 28th February, 2017 at Kadawa by dibbling according to the treatment at a spacing of 20 x 20cm. The germinated rice was thinned to 2 weeks after sowing (WAS). NPK (15:15: 15) fertilizer was applied by deep placement (2-3cm) according to the treatment. Half dose of N and full dose of P and K were applied at sowing, while the remaining half dose of N was applied at 6 WAS using Urea (46%N). Pre-emergence herbicide (Pendimethalin) was applied day after sowing at 4 litres/ha (455g ai/l) for weed control. Supplementary weeding were done at 3, 6 and 9 WAS. The fields were irrigated through controlled flooding of the plots (basins) at three days interval throughout the period of the experiment.

The crop was harvested when mature rice panicle changed colour from green to a golden brown colour prior to grain shattering. It was done by cutting the stands with sickle close to the ground level. The harvest from each net plot was bundled into sheaves, weighed and threshed by beating with sticks for each net plot in a 100kg sag bag. The grain obtained was winnowed and grains cleaned, dried and used for the determination of yield parameters.

Data were collected from the following parameters;

Physiological parameters were measured and the average were recorded at 6 and 9 week after sowing (WAS) from the five randomly selected tagged plants from each net plot.

Crop growth rate was measured using the formula described by Watson, (1947), shown below;

$$CGR = \frac{W_2 - W_1}{T_2 - T_1} \quad (g.cm^2wk^1),$$

Where W_1 and W_2 are whole plant dry weights at respective times T_1 and T_2.
Relative growth rate ($g\ g^{-1}\ wk^{-1}$) was calculated according to the formula described by Radford, (1967),

$$RGR = \frac{\log_e w_2 - \log_e w_1}{t_2 - t_1} \ (g\ g^{-1}\ wk^{-1})$$

Where w_2 and w_1 are dry weights in g/plant at respective time t_2 and t_1 in weeks and $\log_e$ represents natural logarithm.
Net assimilation rate was determined in m^2 using formulae suggested by Watson (1958):

$$NAR = \frac{w_2 - w_1}{t_2 - t_1} \times \frac{\log_e A_2 - \log_e A_1}{A_2 - A_1} \ (g\ m^{-2}wk^{-1})$$

Where w_2 and w_1 are plant dry weights in g/plant at time t_2 and t_1, respectively while A_2 and A_1 are plant leaf area per respective sampling period.

The number of days to 50% heading was determined by counting the number of days from sowing in each subplot to when 50% of the plants within the subplot had flowered and the result recorded.

The number of days to physiological maturity was determined by counting the number of days from sowing in each subplot to when 50% of the panicles have matured as indicated by change in colour of the grain from green to golden brown and the result was recorded for each treatment combination.

The harvested grains from each net plot were threshed; winnowed, cleaned and weighed and the values was converted to kg/ha and recorded. Data collected were subjected to Statistical Analysis of Variance (ANOVA) and the differences between the treatments means was compared using Duncan Multiple Range Test (DMRT) (Duncan, 1955).

3.0 RESULT

3.1 Leaf Area Index (LAI)

The effects of NPK fertilizer rate and stand density on Leaf Area Index (LAI) of two lowland varieties of rice at 12WAS during the 2016 dry season in Kadawa and Samaru is shown on table 1. Application of NPK had significant effects on LAI at both locations, where application of 120:60:60 kg NPK ha^{-1} gave the highest mean value of LAI in both locations but was at par with that of 80:40:40 kg NPK ha^{-1} at Samaru. Application of 40:20:20kg NPK ha^{-1} gave the least mean value of LAI in Samaru and Kadawa but was at par with 80:40:40kg NPK ha^{-1} in both locations.

The effect of stand density and variety on LAI was not significant in both locations.

Factor interaction on leaf area index was not significant at both locations

3.2 Net Assimilation Rate (NAR)

Net assimilation rate of two lowland rice varieties as influenced by NPK fertilizer and stand density at 12WAS during the 2016 dry season in Kadawa and Samaru is shown on table 1.

In Kadawa, increasing the application of NPK fertilizer from 40:20:20 to 120:60:60 kg ha-^{1} led to a corresponding increase in NAR. While at Samaru, application of 80:40:40kg NPKha^{-1} had the highest NAR followed by 120:60:60kgNPK ha^{-1} and 40:20:20kgNPKha^{-1}.

The response of stand density to NAR was significant. Each increase in hill density from 2 to 4 and further to 6 plants resulted in a corresponding decrease in NAR in both locations.

There was significant variation in NAR between the two varieties of lowland rice used in both locations. FARO 52 gave higher mean NAR value in both locations.

Factor interaction on NAR was not significant at both locations

3.3 Crop Growth rate

The effect of NPK fertilizer and stand density on crop growth rate of rice varieties during the 2016 dry season at 6 and 9 WAS in Kadawa and Samaru (table 1). Results indicated that application of NPK fertilizer significantly affected crop growth rate. Application of 120:60:60 kg NPK ha-^{1} gave the highest mean value in both Kadawa and Samaru. Application of 80:40:40 and 40:20:20 kg NPK ha-^{1} were statistically at par in Samaru. While 40:20:20 kg NPK ha- ^{1}gave the least mean value of crop growth rate in Kadawa.

The responses of crop growth rate to stand density were significant. 2 plants/stand gave highest mean value at both locations. This was follow by 4 and 6 plants/stand respectively at both locations.

There was significant variation in crop growth rate between the varieties of lowland rice used in Samaru where FARO 52 gave higher value of mean than FARO 44.

3.4 Relative Growth Rate (RGR)

The influences of NPK fertilizer and stand density on relative growth rate of two lowland rice varieties during 2016 dry season. Results indicated that increasing the fertilizer rate from 40:20:20 to 80:40:40 kg NPK ha^{-1} and further to 120:60:60 Kg NPK ha^{-1} in Kadawa had led to a corresponding increased in relative growth rate. While in Samaru, application of 80:40:40 Kg NPK ha^{-1} gave the highest mean followed by 120:60:60 kg NPK ha^{-1} and the least was for 40:20:20kg NPK ha^{-1}.

The effect of stand density on relative growth rate was significant. 2 plants per stand gave the highest RGR at both locations and was followed by 4 and then 6 plants per stand.

Variation in relative growth rate between the rice varieties was significant at both locations. FARO 52 gave higher mean in Kadawa while FARO 44 gave higher mean value of RGR in

Samaru.

3.5 Days to 50% Heading

Table 3 shows the effects of NPK and stand density on Days to 50% heading of two low land rice varieties at Kadawaa and Samaru during the 2016 dry season (table 2). Result revealed that NPK significantly influence the number of days to heading, increasing NPK rate from 40:20:20 to 120:60:60 kg NPK ha^{-1} decrease the number of days to heading. 40:20:20kg NPKha^{-1} gave higher number of days to heading while 80:40:40 and 120:60:60kg NPKha^{-1} were statically at par in both locations.

Stand density effects on days to 50% heading was not significant at both Kadawa and Samaru.

Variation in number of days to heading of the two rice varieties used was significant. Faro 44 gave lower mean value of number of days to heading in both locations.

3.6 Days to Physiological Maturity

The influences of NPK rate and stand density on days to maturity two lowland rice verities at Kadawa and Samaru is presented in table 2. Results revealed that NPK significantly affect number of days to physiologically maturity. Increasing NPK level from 40:20:20 to 80:40:40kg NPKha^{-1} significantly reduces the number of days to physiological maturity. Application of 120:60:60 kg NPK ha-^{1} was at par with 80:40:40 kg NPK ha-^{1} in both locations

The effect of stand density on number of days to physiological maturity was not significant.

Varietal response was significant in both location with faro 44 having lower number of days to physiological maturity

3.7 Grain Yield

The response of grain yield of the two rice varieties to application of NPK fertilizer and stand density is shown on table 2. Results indicated that each increase in NPK fertilizer rate from 40:20:20 to 80:40:40 and further to 120:60:60 kgha^{-1} had led to a corresponding grain yield increase.

Stand density effects on grain yield per plot was significant in both locations. Two plants per stand gave the higher mean grain yield at both Kadawa and Samaru than for 4 and 6 plants/stand that were statistically similar.

There was no significant variation in yield between FARO 44 and FARO 52 in Kadawa and Samaru.

4.0 DISCUSSION

4.1 Response of lowland rice to application of NPK fertilizer

Increasing the rate of NPK fertilizer from 40:20:20 to 120:60:60 Kg ha^{-1} resulted in higher mean value for the physiological parameters measured. This could be due to positive roles of NPK fertilizer in promoting vegetative growth as a result of enhanced assimilate production and effective partitioning due to efficient photosynthesis. This is in line with the finding of Ndaeyo *et al.* (2008). Also Awan *et al.* (1984) reported that increasing rate of NPK fertilizer favour the vegetative growth in rice plant.

The application of 120:60:60 resulted in higher mean value for the grain yield. This result is in line with the finding of Olanrewaju (2006) who reported that application of 120 NPK Kg ha^{-1} produced significant higher number of grains per panicle, grain weight, 1000 grain weight and grain yield in Kg ha^{-1} than other rate of 0:0:0 and 40:40:40 kg ha^{-1} NPK.

The finding is also similar to Krishnakumar *et al.* (2005) and Maurya *et al.* (2014) who observed that application of 150: 75 :50 Kg NPK and 120: 80:40 Kg NPK ha^{-1} gave maximum yield, net profit and benefit cost ratio.

Significantly the highest dry matter production was recorded with increasing levels of NPK fertilizer at all growth stages of rice (Yashoda Rani *et al*., 1997)

4.2 Response of Rice Variety to Stand Density

Physiological components were higher with the parameters such as crop growth rate, relative growth rate and leaf area index measured in this study responded to number of plant per hill with highest value with the 2 plants/stand. This is in line with the finding of Micheal (2002) who reported that plant density influenced solar radiation interception, nutrient uptake, rate of photosynthesis and yield of rice. In highly populated rice field, intra-specific competition among the plant is high.

This result also show that 2 plants/ stand gave highest grain yield which were statistically at par. This may be due to high competition among the plant at 4 and 6 plants/stand at late growth stage which resulted in gradual shading and lodging and thus favour increased production of straw instead of grain. Das (1988) reported that plant geometry and density govern the light regime in different layer of the plant canopy in which plant modifies the carbohydrate synthesis at different levels which reflects in the growth and other yield attributes of the plant

4.3 Varietal Response

The variations among the physiological parameters to FARO 44 and FARO 52 could be attributed to the genetic makeup of the individual variety. FARO 44 gave higher grain yield than FARO 52. This could be attributed to the superiority of FARO 44 over FARO 52 in efficient conversion of assimilate into higher grain yield. This is in line with the finding of Akinwale *et al.* (2011) who attributed variation in plant height and yield of rice to the differences in the genetic makeup of the varieties and their differences in response to environment. Furthermore, Ghush and Masajo (1983) observed some rice cultivars generally associated with high yield potential and nitrogen responsiveness in both upland and lowland varieties, which he attributed to short or semi dwarf stature, lodging resistance, high tillering ability, non spreading culms and related short and erect leaves, strong seedling vigour and photoperiod insensitivity.

5. CONCLUSION

It can be concluded that, sowing FARO 44 at 2 plant/stand with the application of NPK fertilizer at 120:60:60 kgha^{-1} gave optimum grain yield per ha of 6479.3kgha^{-1} in Kadawa and 5762.5 kgha^{-1} in Samaru.

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Table 1: Effects of NPK and Stand Density of Rice Varieties on Physiological Parameters at 12WAS in Kadawa and Samaru in 2016 Dry Season

	Relative Growth Rate (g g^{-1} wk^{-1})		Net Assimilation Rate (g $m^{-2}wk^{-1}$)		Crop Growth Rate ($g.cm^2wk^1$)		Relative Growth Rate (g g^{-1} wk^{-1})	
TREATMENT	**Samaru**	**Samaru**	**Kadawa**	**Samaru**	**Kadawa**	**Samaru**	**Kadawa**	**Samaru**
20:10:10 NPK(kg ha^{-1})								
40:20:20	0.664 b	1.170 b	0.0236c	0.0057c	7.13c	12.76 b	0.1657c	0.2987c
80:40:40	0.819b	1.492ab	0.0285b	0.0397a	10.84b	12.49b	0.1867b	0.5299a
120:60:60	1.133a	1.542a	0.0474a	0.0235b	12.98a	13.97a	0.2654a	0.4132b
SE±	0.0645	0.1127	$1.5*10^{-5}$	$1.6*10^{-5}$	$2.6*10^{-5}$	$1.6*10^{-4}$	$2.9*10^{-5}$	$3.6*10^{-5}$
Number of Plant per Stand								
2	0.9200	1.463	0.0456a	0.0324a	14.51a	19.05a	0.2585a	0.4856a
4	0.8794	1.422	0.0384b	0.0324b	11.98b	15.15b	0.2163b	0.3998b
6	0.816	1.320	0.0156c	0.0025c	4.46c	15.02c	0.1429c	0.3568c
SE±	0.0645	0.1127	$1.5*10^{-5}$	$1.6*10^{-5}$	$2.6*10^{-5}$	$1.6*10^{-4}$	$2.9*10^{-5}$	$3.6*10^{-5}$
Variety								
Faro 44		1.349	0.0301b	0.0102b	9.80b	16.41	0.1803b	0.4404a

Faro 52	0.879	1.455	0.0362a	0.0282a	10.82a	16.41	0.2316a	0.3875b
SE±	0.0526	0.0921	$1.3*10^{-5}$	0.865	$7.7*10^{-5}$	$4.7*10^{-4}$	$2.6*10^{-5}$	$3.1*10^{-5}$
interaction								
FX S	NS	NS	NS	NS	NS	NS	NS	NS
S X V	NS	NS	NS	NS	NS	NS	NS	NS
F X V	NS	NS	NS	NS	NS	NS	NS	NS
F X S X V	NS	NS	NS	NS	NS	NS	NS	NS

1. Mean in a column of any sets of treatment followed by unlike letter (s) is significantly different at 5% level of probability using DMRT, **2.** WAS= Week after sowing, **3.** NS= Not significant, *= significant, **= highly significant

Table 2: Effects of NPK and Stand Density on Number of Days to 50% Heading, Number of Days to Physiological Maturity and Grain Yield of Rice Varieties at Kadawa and Samaru 2016 Dry Season

	Days 50% Heading		**Days to Physiological Maturity**		**Grain Yield (Kg**	
Treatment	**Kadawa**	**Samaru**	**Kadawa**	**Samaru**	**Kadawa**	**Samaru**
20:10:10 NPK (kg ha^{-1})						
40:20:20	87.06a	100.278a	122.27	133.333	1029.28c	822.1c
80:40:40	78.11b	92.500b	122.83	132.556	1940.04b	1723.5b
120:60:60	78.83b	92.500b	122.83	134.111	2268.84a	1981.0a
SE±	1.2338	0.2245	0.3207	0.5079	1.870	2.220
Number of Plant per Stand						
2	80.39	94.833	127.5a	138.778a	1895.90a	1700.2a
4	81.61	94.833	119.9b	130.222b	1670.78b	1394.9 b
6	82.00	95.611	120.5b	131.000b	1671.47b	1431.2b
SE±	1.2338	0.2245	0.3207	0.5079	1.870	2.220

Variety						
Faro 44	72.41b	84.852b	111.96b	126.852b	1769.74	1546.59a
Faro 52	90.26a	105.333a	133.3a	139.815a	1223.6	1471.17b
SE±	1.0074	0.1833	0.2619	0.4147	1.673	1.995
Interaction						
FX S	NS	NS	NS	NS	NS	NS
S X V	NS	NS	NS	NS	NS	NS
F X V	NS	NS	NS	NS	NS	NS
F X S X V	NS	NS	NS	NS	NS	NS

1. Mean in a column of any sets of treatment followed by unlike letter (s) is significantly different at 5% level of probability using DMRT, **2.** WAS= Week after sowing, **3.** NS= Not significant, *= significant, **= highly significant