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Growth and Yield Responses of Upland Rice (NERICA 2) under Different Water Regimes in Ibadan, Nigeria

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Abstract: Field experiments were conducted in 2005 on upland rice (NERICA 2) to determine actual water use pattern as it relates to growth and yield parameters for increased production in Nigeria. Results showed that between 200 and 450 mm of applied water is required for reasonable yield. The maximum water use of 3.35 mm/day was recorded during the flowering-milky stage (between 65 -80 DAP) while the lowest, 1.98 mm/day was recorded during the early vegetative stage (10-20 DAP) and late maturity (95-105 DAP). The maximum plant height (89 cm), maximum root depth (23 cm), panicle diameter (4.5 cm) and total grain yield of 1.36 t/ha were significantly excellent results when compared with WARDA's predicted values. The emergence of whiteheads between 65 -75 DAP which ranges between 7 to 16% was an indication of shortfalls in water requirements at flowering stage. Total grain yield of 1.36 t ha^{-1}, the highest was recorded in the treatment that received water most (plot A) while the least grain yield of 0.16 t ha^{-1} was recorded in the treatment with least water application (plot D) The correlation values were high, Leaf Area Index (LAI) and days after planting DAP is 0.85 while Canopy Shading (CS) with DAP is 0.80.The application of water, being the dominant factor affecting growth and grain yield of rice needs to be properly scheduled for improved rice production and to avoid waste. A significant increase in yield up to about 15% can be guaranteed if scheduling is properly done with adequate processing and production cycle can be increased from two to three times a year for upland rice cultivars.

Key words: Rice, NERICA, growth, yield, water, DAP

INTRODUCTION

For centuries, cereal grains have been the primary source of food especially in the great civilizations of the world. The importance of the cereal in the evolution of humanity cannot be overlooked. Cereal grains are unique among our foods, prominent among which is rice. Rice (*Oryza sativa* L.) constitutes one of the most important staple foods of over half of the world's population. On the world basis, it ranks third after Wheat and Maize in terms of production (Bandyopadhay and Roy, 1992). Rice is of significant importance to food security in many African countries. Although per capita rice consumption in some Asian nations is declining, it is growing rapidly in most countries in sub Saharan Africa (Mohapatra, 2006). Annual demand for rice in sub Saharan Africa is increasing by 6% per year, fueled by rapid population growth and changes in consumer preferences. Although rice production in the region rose from 6.2 million tons of paddy (unhulled) rice in 1980 to 12.6 million tons in 2005, it has not been able to keep pace with increasing demand. As a result, the quantity of rice imported yearly by the region increased from 2.5 million tons in 1980 to 7.2 million tons in 2005. Rice imports cover more than 45% of sub Saharan Africa consumption and represent a third of world's rice imports (Mohapatra, 2006).

In Nigeria, it ranks sixth major crop in cultivated area after sorghum, millet, cowpea, cassava and yam (Olaleye *et al*., 2004; Dauda and Dzivama, 2004). It is the only crop grown nationwide in all agro ecological zones from Sahel to the coastal swamps. It remains an important diet in Nigeria and due to this, demand for rice rose far above its supply. Olaleye *et al.* (2004) remarked that an estimated 2.1 million tons of rice are consumed annually. In Nigeria, the potential for rice production is about 4.6-4.9 million hectares of land but the actual area under cultivation is only 1 million hectare representing 22% of the total potential available area (Kehinde, 1997). Due to this shortfall, the country resulted to importation to bridge the gap occasioned by the shortfall

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between domestic demands and supply spending over US$4 billion on rice importation (Akpokodje *et al*., 2001) this creates serious drains in Nigeria's foreign reserves. WARDA's recent breakthrough in research led to the introduction of NERICA varieties into the Nigeria market in 2002 in a bid to alleviate hunger, reduce cost of importation and also improve livelihood (WARDA, 2003). Despite rice's obvious importance and relevance to this region, its supply is far below its demand due to a number of factors, chiefly among them is water.

The objective of this study therefore is to determine irrigation requirements of NERICA 2, a predominantly upland variety under irrigated conditions in IITA yard, Ibadan, Nigeria.

MATERIALS AND METHODS

The study was carried out at the yard of IITA, Ibadan, Nigeria (Lat. 3°54'E and Long. 7°30'N). Experimental site is at an elevation of 200m above MSL. Water from dam was supplied to the field consisting of four plots of 5×5m each. A 4hp water pump with rotating speed of 4000 rpm was used to supply water to the plots through sprinkler heads at specified irrigation scheduling rate. Plots configuration is such that A received water 7 times a week, B 6 times, C 5 times and D 4 a week. The experimental design was a Randomized Complete Block Design (RCBD) with four treatments.

Agronomic measurements yield plant height, root depth, numbers of leaves, canopy shading, leaf area index (using canopy Li2000 Analyzer) were made and soil moisture monitoring was also done. Digital Tensiometer measured soil water potential and moisture content was determined using gravimetric method. Crop's water use was determined using the modified Hargreaves model (with rice's crop coefficient for the 3 stages of growth) and statistical analyses, carried out.

RESULTS AND DISCUSSION

Soil classification: Physical and chemical properties of soil on the site were determined which was found out to be loamy sand (% sand; 74, % silt; 14 and % clay; 12) using the USDA textural triangle, which permits easy downward movement of water to the lower layout of the soil and therefore can benefit deep-rooted crops.

Water resources: Water from IITA dam was analyzed to determine its suitability or otherwise for the research. Physical, chemical and bacteriological properties were determined. The results showed that the presence of parameters determined fall within the FAO tolerance limits

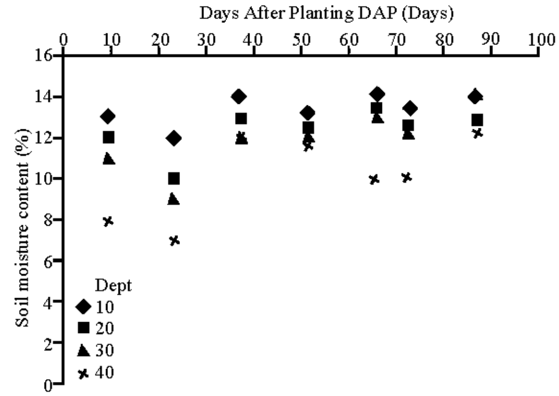

Fig. 1: Moisture content vs. days after planting

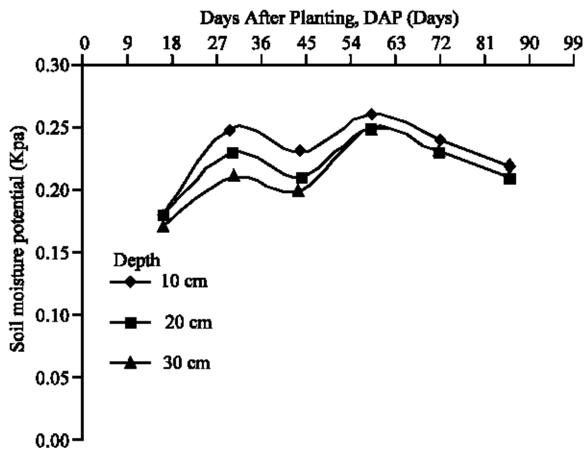

Fig. 2: Moisture potential vs. days after planting

of irrigation water for crop production. The salinity content, using electrical conductance is also allowable to permit crop growth, therefore, water from the dam is found suitable for irrigation purposes.

Moisture content and soil water potential variation during crop growth: The soil's Moisture Content (MC) using gravimetric method was determined with 15 days interval throughout the entire growing season. The moisture content storages at 10, 20, 30 and 40 cm depths were within 12, 10, 9 and 7%, respectively (Fig. 1) which shows that the available water at 30 cm depth is still sufficient enough for root use (since the maximum root depth is about 23 cm). For the soil moisture potential, a digital Tensiometer was used to determine the energy at the 10, 20, 30cm the ranges of values are between 0.20 and 0.25 (Fig. 2) which still bearable for crops to extract water from the soil.

Agronomic responses: The maximum plant height throughout the growing season is 89 cm maximum root

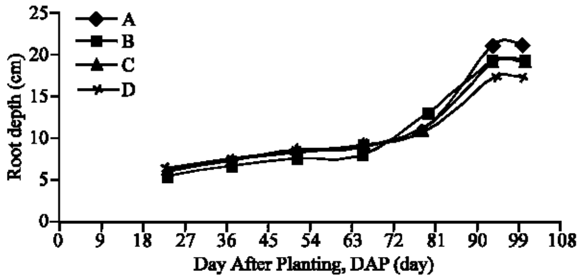

Fig. 3: Root depth vs. days after planting

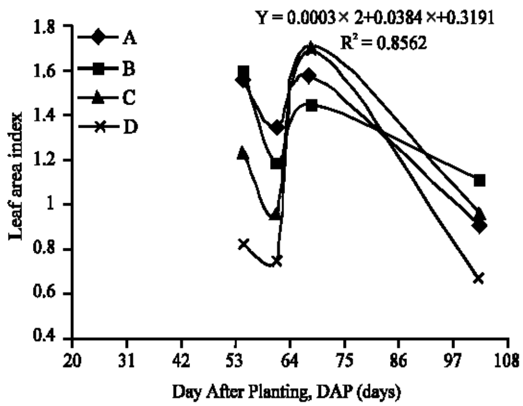

Fig. 4: Leaf area index vs. Days after planting

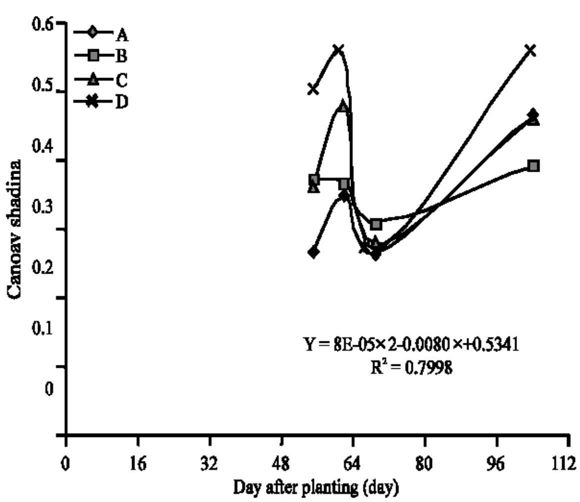

Fig. 5: Canopy shading vs. days after planting

depth through entire season ranges between 22 and 23 cm (Fig. 3). The roots can reach water at 30cm depth and the potential can be overcome in order to use the water. The leaf area index LAI, measured using the canopy Li2000 analyzer which is highly dependent on the amount of water received ranged between 0.6 and 1.9 and is as shown in Fig. 4 while the degree of canopy density

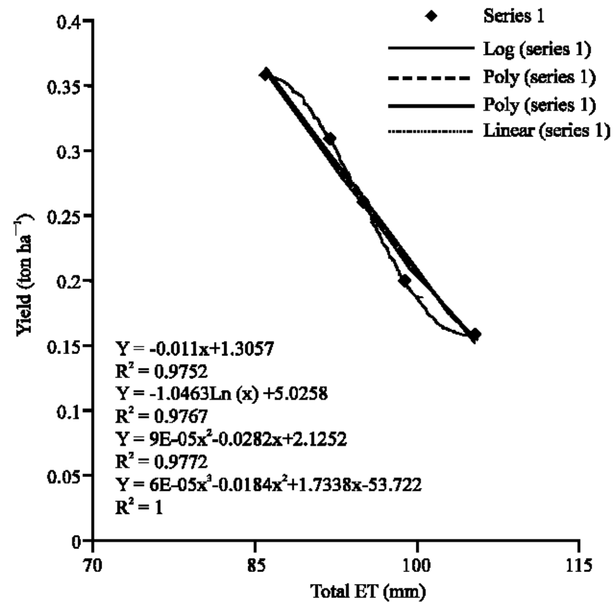

Fig. 6: Yield vs. total evapotranspiration

Table 1: Grain, biomass and total yield of rice

Plot	Grain yield ($t\ ha^{-1}$)	Biomass yield ($t\ ha^{-1}$)	Total yield ($t\ ha^{-1}$)
A	1.36	1.84	3.2
B	0.81	2.35	3.2
C	0.30	2.30	2.6
D	0.16	1.64	1.8

Table 2: Total irrigation water applied, grain yield and total ET in each of the treatment plots

Treatment yieldplots	Irrigation water applied (mm)	Total ET_a (mm)	Total grain ($t\ ha^{-1}$)
A	1190.50	86.01	1.36
B	1040.75	91.98	0.81
C	850.00	99.04	0.30
D	694.17	105.83	0.16

Table 3: Number of whiteheads in each of the plots at 78 Days After Planting (DAP)

Plots	Whiteheads	% Composition per plot
A	47	7.4
B	81	15.7
C	94	16.1
D	98	16.6

(canopy shading) measured using the same equipment ranged between 0.25 and 0.7 and is as shown in Fig. 5. All this conforms to the predicted behaviour with respect to the quantity of water administered at each treatment level. Grain and biomass yield were also measured after harvest (Table 1), total irrigation water applied, grain yields and total ET (Table 2) and the number of whiteheads in each treatment plot at 78 DAP (Table 3), which is a reflection of quantity of water required and water administered to each plot.16.6% (98) whiteheads was recorded in plot D, inevitably due to the amount of water received 694.17 mm

Table 4: Results of measured plant parameters after harvest from field experiment

Plots	Plant height (cm)	Root depth (cm)	No. of leaves	No. of tillers	Leaf length (cm)	Leaf width (cm)	Panicle diameter (cm)	Panicle length (cm)	Total tiller
A	88.8	21.12	11	15	36.42	1.44	3.72	26.08	14
B	85.6	19.2	9	13	35.94	1.3	3.56	25.5	11
C	88.8	19	11	8	32.3	1.28	4.5	25.6	7
D	76.4	17.2	8	10	29.46	1.24	3.34	23.84	8

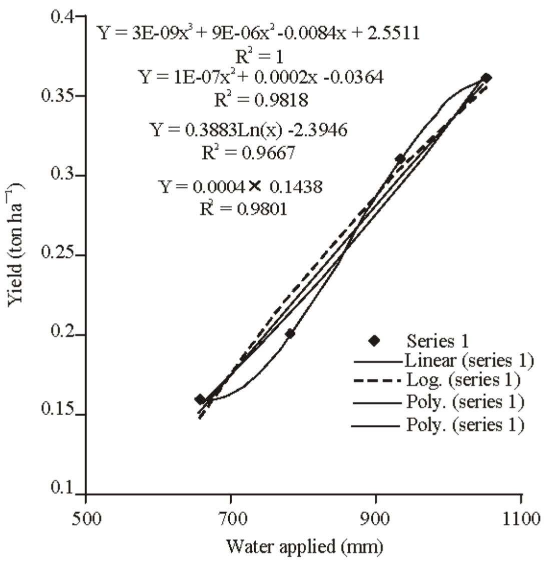

Fig. 7: Yield vs. water applied

(from Table 2) and the least number of whiteheads was recorded in plot A, 47 or 7.4% also due to the quantity of water received throughout the entire growing season, 1190.50 mm (Table 2). Post harvest measurements made showed that the maximum plant height was 89 cm, root depth, 22 cm, number of leaves 11, leaf width, 1.44 cm and maximum total number of tiller was 14 (Table 4).

Figure 6 shows the relationship between yields and total Evapotranspiration, which indicates that the yield decreased almost linearly with increasing amount of irrigation. Reference Evapotranspiration was determined using modified Hargreaves model which has been proven and tested to be the best among all the models in the study area while the actual ET is a product of reference ET and K_c (crop coefficient) for each of the growing stages. For Fig. 7 comparing yield and water applied, shows that a linear corresponding increase exists between the yield and total water applied.

CONCLUSION

Estimating the irrigation requirement of rice is difficult. An attempt has been made using field experiment to determine actual water use of NERICA 2 as it relates to growth and yield parameters for increased rice production. The correlation values were high, Leaf Area Index (LAI) and Days After Planting DAP is 0.85 while Canopy Shading (CS) with DAP is 0.80. Total grain yield of 1.36 t ha^{-1}, the highest was recorded in the treatment that received water most (plot A) while the least grain yield of 0.16 t ha^{-1} was recorded in the treatment with least water application (plot D). Results showed that between 200mm and 450 mm of applied water is required for reasonable yield. The maximum water use of 3.35 mm/day was recorded during the flowering-milky stage (between 65-80 DAP) while the lowest, 1.98 mm/day was recorded during the early vegetative stage (10-20 DAP) and late maturity (95-105 DAP). The maximum plant height (89 cm), maximum root depth (23 cm), panicle diameter (4.5 cm). The emergence of whiteheads between 65 -75 DAP which ranges between 7 to 16% was an indication of shortfalls in water requirements at flowering stage.

Based on our findings, water application is the dominant factor affecting growth and yield, as it was evidently clear in its effect on the agronomic responses at all stages of production.

Further research to determine the consumptive water use of upland rice varieties (NERICA) and if possible, lowland rice varieties in the other agro ecological zones of the country with different climatic and soil conditions are seriously being considered. Also, more upland rice cultivars (NERICA family) are recommended to have wider range of water use for proper irrigation scheduling. Finally, the need to establish and validate an appropriate crop-water yield model for upland rice in the study area is ongoing.

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