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Effect of Nitrogen Fertilizer Dose and Application Timing on Yield and Nitrogen Use Efficiency of Irrigated Hybrid Rice under Semi-Arid Conditions

Djaman K[1*], Mel VC[2], Ametonou FY[2], El-Namaky R[2,3], Diallo MD[4] and Koudahe K[5]

[1]*Department of Plant and Environmental Sciences, Agricultural Science Center at Farmington, New Mexico State University, PO Box 1018, Farmington, NM 87499, USA*

[2]*Africa Rice Center, Regional Sahel Station, Senegal, BP 96 Saint-Louis, Senegal*

[3]*Rice Research and Training Center, 33717 Sakha Kafr Elsheikh, Egypt*

[4]*Agronomic, Aquaculture and Agri-Food Technologies, Gaston Berger University, St. Louis, Senegal*

[5]*ADA Consulting Africa, 07 BP 14284, Lomé, Togo*

[*]**Corresponding author:** Djaman K, Department of Plant and Environmental Sciences, Agricultural Science Center at Farmington, New Mexico State University, PO Box 1018, Farmington, NM 87499, USA, Tel: +15059607757; E-mail: kdjaman@nmsu.edu

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Abstract

Nitrogen fertilizer is the major input in rice production and the optimum rate and application timing management assure profitability and sustainability of the production system. This study aims to investigate hybrid rice response to different nitrogen fertilizer levels and the timing of application and quantify hybrid rice nitrogen use efficiency. Field experiments were conducted during the dry and the wet seasons 2016 at the research station of Africa Rice at Ndiaye in Senegal. Six nitrogen rates (0, 60, 90, 120, 150 and 180 kg N/ha) and three hybrid rice varieties (AR031H, AR032H, AR033H) and one inbred variety (Sahel108) and two nitrogen fertilizer application timings (three split and four split) were combined within a split-split plot design. The results showed significant effect of nitrogen rate and timing on rice grain yield that varied from 4.10 to 11.58 tons/ha and most the yield components. Rice grain yield exhibited curvilinear relationship with the applied nitrogen rates during the dry season under both nitrogen application timings and a linear relationship during the wet season under three splits. Nitrogen rate of 150 kg/ha was revealed optimum with best performance achieved by the Hybrid rice AR033H. Hybrid rice genotypes achieved greater nitrogen use efficiency compared to the inbred rice Sahel108. Hence, hybrid rice genotypes, and nitrogen rate of 150 kg/ha applied in four splits could be recommended to improve rice production and food security for achieving self-sufficiency in rice as targeted by Senegal and the neighboring countries.

Keywords: Hybrid rice; Genotypes; Grain yield; Nitrogen fertilizer

Introduction

Nitrogen fertilizer is one of the most important nutrients that determine rice yields [1-4]. It positively influences tillers development, yield and yield components [5]. Harrell et al. [3] reported nitrogen fertilizer rates to achieve maximum yield were 157 and 151 kg ha^{-1} under two tillage practices. Usually farmers apply higher rate of applied N fertilizer than the recommended amount with the assumption that increasing N would always result in increasing crop yields [6], which can result in altering and negatively affecting the sustainability of the production system and increasing the production cost. Djaman et al. [5] found nitrogen fertilizer requirement of 90 kg N ha^{-1} for most of the aromatic rice varieties to achieve maximum yield while optimum nitrogen fertilizer for the non-aromatic rice varieties was 120kg N ha^{-1}. Peng et al. [7] reported optimum Nitrogen rates range 60–120 kg N ha^{-1}. In Louisiana, optimum nitrogen rates for the maximum rice yield were reported to be 157 and 151 kg N ha^{-1} under fall-stale seeded tillage and conventional tillage, respectively [3], while N fertilizer recommendation ranged from 134 to 179 kg N ha^{-1} [8]. The quadratic production functions were reported by Djaman et al. [5] for the aromatic rice varieties (Sahel 177, Sahel 328, Sahel 329, Pusa Basmati) in the Senegal River valley with coefficient of determination (R^2) varying from 0.53 to 0.99. There can be an inter-seasonal variability in rice genotype yield response to nitrogen rate even in the same environment due to influence of climatic factors and management practices on this relationship. Peng et al. [9] reported curvilinear response of rice yield to nitrogen. Rice yield exhibited a linear response to nitrogen rate below 150 kg N ha^{-1} and a plateau off when the applied N rate is greater than 150 kg N ha^{-1} [3]. Watkins et al. [10] reported four different yield response functions on potential N response functions (quadratic, quadratic-plateau, linear-plateau, and Mitscherlich) estimated depending on location and year. Zhao et al. [11] reported rice NUE values varying from 7.1 to 13.1 kg grain kg^{-1} N under traditional flooding. Cassman and Pingali [12] reported farmers' field NUE range of 15-20 kg kg^{-1} in the Philippines while very low NUE value of 9.1 kg kg^{-1} N was reported by Peng et al. [13] in China and Wang et al. [14] reported NUE as low as 6.4 kg kg^{-1} N in farmers' field. Peng et al. [15] indicated that the low NUE of the nitrogen fertilizer is due to the high nitrogen inputs 180-240 kg N ha^{-1} applied by farmers. Yang et al. [16] reported higher NUE obtained by the hybrid rice as compared to the inbred rice genotypes. Cassman et al. [17] indicated that improvement in crop yields is attributed to the increase in fertilizer use, especially nitrogen fertilizer. In the dynamics of sustainable system intensification, there is a need for proper fertilizer.

Application of the optimum nitrogen rate in different splits and timing has significant effects on grain yield and yield components.

Perez et al. [18] indicated that several splits of nitrogen fertilizer recommendation are requirement for high yielding varieties, mostly nitrogen application at flowering stage. Blumenthal et al. [19] reported 6% increase in rice yield and 25% increase in grain protein due to nitrogen dressing at flowering stage. Hybrid rice is developed to improve yield at farm level and to reduce the increasing food demand due to population growth. Hybrid rice contributes to an increase of rice yield potential by 9% compared to the irrigated lowland elite inbred varieties [9]. Moreover, Zhang et al. [20] reported that the Super hybrid rice varieties show increase in yield potential by 12% with comparison to the ordinary hybrid and inbred varieties. Hybrid rice cultivars are characterized by large panicles or extra-heavy panicle types with numerous spikelets per panicle [9,21]. Despite this enormous potential for production, these cultivars frequently do not exhibit their high yield potential due to their poor grain-filling, as in a slow grain-filling rate and many unfilled grains [9,22]. In irrigated condition when water supply is not a limiting factor, we hypothesize that the low grain weight (unfilled grain) can be attributed to the limitation of carbohydrate supply. Moreover, it was found that the later-flowering inferior spikelets of hybrid cultivars have more soluble carbohydrate and sucrose than earlier-flowering superior spikelets at the early grain-filling stage [23-25]. All these constraints raise the nitrogen management issue particularly the appropriate rate and the right time of application. For irrigated rice in the Sahel environment it is recommended to apply nitrogen by splitting in three (e.g., 40% of the total dose until two weeks after transplanting, 40% of the total dose at panicle initiation and the remaining 20% at the booting stage). We hypothesize again that a fourth nitrogen application at early flowering can improve the grain filling of high yielding cultivars including hybrid rice.

Nitrogen fertilizer management (rate and timing of application) under high yield rice varieties and the hybrid rice should retain attention of the researchers and decision makers relative to the self-sufficiency program in rice and system sustainability for several sub-Saharan African countries like Senegal [26]. Thus, the objectives of this study were to investigate hybrid rice response to different nitrogen fertilizer levels and the timing of application and quantify hybrid rice nitrogen use efficiency in the paddy field under the Sahelian conditions in the Senegal River Delta.

Materials and Methods

Experimental site and experimental design

Field experiment was conducted at Africa Rice Center (Africa Rice) research station at Ndiaye (16° 11’ N, 16° 15’W) in the Senegal River Delta (SRV) (Senegal, West Africa) during the hot and dry season (HDS) and wet season (WS) 2016. The local climate is Sahelian climate with a long dry period from October to June and a short-wet season from July to September. The highest average temperatures are recorded in April-May and the lowers in December-January. Rice double cropping is adopted in the Senegal River Valley and takes place from February to July during the HDS, and from August to November in the (WS). At the site the soil is an orthothionic Gleysol, containing 40-54% clay, (smectite and kaolinite) with average permeability of 2.8 mm d^{-1} [27,28]. Weather variables were measured at the experimental site. Daily average wind speed, maximum and minimum air temperature, maximum and minimum relative humidity, incoming solar radiation and precipitation were measured over a well-watered grass surface using automated weather station (the automatic agro-weather station CimAGRO) that was installed in experimental field.

Experimental design and crop management

Three hybrid rice genotypes (AR031H, AR032H and AR033H) and one inbred rice variety Sahel 108, the most popular grown rice variety in the Senegal River Valley used as check were tested in this study. For fertilizer management sustainability, there is a need to determine the optimum nitrogen dose of the hybrid rice genotypes, new technology introduced in the rice hubs in Senegal. Five nitrogen rates Nitrogen application rates (0, 50, 100, 150, 200 kg ha^{-1}) were investigated in tin two application timings. Phosphorus and potassium were applied at constant dose of 26 and 50 kg ha^{-1} respectively. The first timing consisted of nitrogen splits of 40, 40 and 20% applied two weeks after transplanting, at the panicle initiation and the booting stages while the second timing involved nitrogen splits of 40, 30, 20 and 10% applied two weeks after transplanting, at the panicle initiation, at the booting, and the grain filling (approximately 10 days after flowering) stages. The three factors were arranged under a split-split plot design with three replications. Nitrogen application timing, nitrogen rate, and the rice genotype were the main plots, subplots, and sub-subplots, respectively. Rice seedlings were transplanted at the rate of 25 hills m^{-2}. A constant water layer of 5-10 cm was maintained during the whole cropping season under the continuous flooding regime according to the growth stages. The herbicide (propanyl, 6 L ha^{-1}) was applied two weeks after transplanting, one day before the first N application; and thereafter, plots were kept weed-free by manual weeding. Insecticide [carbofuran (Furadan)] was sometimes used at 25 kg ha^{-1} for insect-pest control at the start of tillering, maximum tillering, panicle initiation and flowering. At crop physiological maturity stage, rice was harvested, and grain yields were determined in each sub-subplot and adjusted to a standard moisture content of 14%.

Rice accumulated thermal unit

Some of the rice variables were related to the thermal unit (TU), which is the accumulation of the growing degree days (GDD), which is cumulative temperature that contributes to plant growth during the growing season and is commonly expressed as:

$$TU = \sum_{i=1}^{n}\left(\frac{T_{max}+T_{min}}{2} - T_{base}\right) (1)$$

where T_{max}=maximum air temperature, T_{min}=minimum air temperature, T_{base}=base temperature threshold for rice (10°C), n is the number of days. The base temperature for calculating growing degree days is the minimum threshold temperature at which plant growth starts. The maximum and minimum temperature thresholds of 35°C and 10°C, respectively, were used for rice growth in the Sahelian environment. All temperature values exceeding the threshold were reduced to 35°C and values below 10°C were taken as 10°C, because no growth occurs above or below the threshold (base) temperature values.

Estimation of Nitrogen Use Efficiency (NUE)

Nitrogen use efficiency (NUE) was estimated as grain yield advantage divided by the N application rate [29,30]. It is a parameter that excludes contributions to N-use efficiency from indigenous N of the soil-floodwater system.

$$NUE = \frac{Y_N - Y_o}{Applied\ Nitrogen\ Rate}$$

where NUE is nitrogen use efficiency in kg grain/kg N, Y_N=grain yield of plot receiving nitrogen fertilizer in kg ha^{-1}, Y_0=grain yield of plot with no nitrogen fertilizer in kg ha^{-1}, applied nitrogen rate in kg ha^{-1}.

Statistical analysis

The analysis of variance (ANOVA) was performed to analyze the main effects of the three factors (Nitrogen application rate, timing, and genotypes) and their interactions using the statistical SAS software [31] and the means were cross paired and compared using LSD at 5% of significance level.

Results and Discussion

Weather conditions and thermal unit during the HDS and WS 2016

Rice double cropping is adopted in the Senegal River Valley accounting for the HDS from February to July and the WS from August to December. There is variation in weather conditions between the two seasons. During the HDS, T_{max} varied from 25.5 to 41.8°C and averaged 32.9°C while T_{min} varied from 13.2 to 25.2°C and averaged 19.32°C (Figure 1a). Higher temperatures were registered during the WS with T_{max} ranging from 28.2 to 40.7°C and T_{min} varying from 13.0 to 27.5°C. Average T_{max} and T_{min} during the WS were 34.8 and 22.7 oC, respectively (Figure 1a). Mean daily temperature was 26.1°C during the HDS and 28.8°C during the WS. Consequently, the accumulated thermal unit by rice during the HDS and WS was 2552.4 and 2278.6°C, respectively, showing an average growing degree day of 16.13 and 18.75°C for the respective seasons (Figure 2). Rice plant reached maturity earlier (122 day) during the WS and during the HDS (151 days) which was characterized by low temperatures from February to early April as shown in Figure 1a. RH_{max} and RH_{min} varied from 49 to 100% and 7.5 to 71%, and averaged 86.2 and 35.6%, respectively, during the HDS; and from 66 to 100% and 8.0 to 79.5% (Figure 1b), respectively, and averaged 93.8 and 40.5%, respectively, during the WS (Figure 1b). Seasonal average relative humidity was 60.9% during the HDS and 67.2% during the WS. Whenever water is not a limiting factor in the irrigated lowland rice production system in the downstream Senegal River Valley, the contribution of precipitation to water input was not negligible during the WS and might have influenced the relative humidity difference between the two seasons. There were 177 mm of precipitation during the WS against 7.5 mm during the HDS (Figure 1c). Daily income shortwave solar radiation varied from 9.8 to 26.3 MJ m^{-2} and averaged 22.4 MJ m^{-2} during the HDS and from 5.9 to 25.6 MJ m^{-2}, averaging 18.4 MJ m^{-2} during the WS (Figure 1c). Radiation availability was therefore 22% higher during the HDS than the WS and may play a major role in determining biomass accumulation and grain yield and that will show increase in rice yield during the HDS. Wind speed was 71% higher during the HDS than the WS and varied from 1.8 to 4.3 ms^{-1} averaging 2.9 ms^{-1} while it varied from 0.7 to 3.8 ms^{-1} during the WS and averaged 1.7 ms $^{-1}$ (Figure 1d).

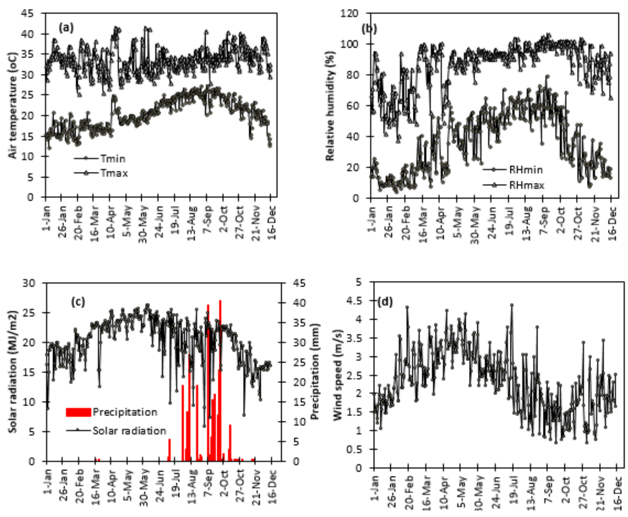

Figure 1: Variation of the (a) daily maximum and minimum temperature, (b) daily maximum and minimum relative humidity, (c) daily solar radiation and precipitation, and (d) wind speed from January 1st to December 14, 2016.

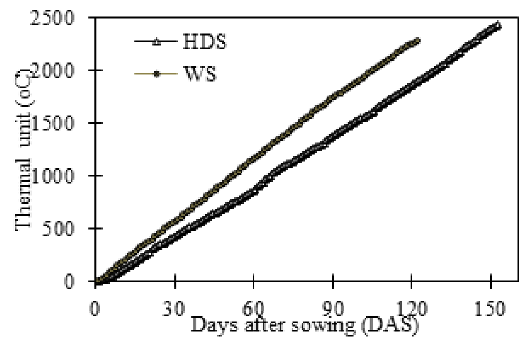

Figure 2: Cumulative thermal unit in the hot and dry growing season (HDS) and the wet growing season (WS) at the experimental site.

Effect of nitrogen rate and application timing on hybrid rice grain yield

Rice yield varied from 4.11 to 11.58 t/ha during the HDS and from 4.60 to 8.60 t/ha during the WS. Hybrid rice AR033H gave the highest yield during the HDS (11.58 t/ha) while AR031H obtained the lowest yield (4.11 t/ha) among the hybrid rice varieties as compared with the control inbred variety Sahel 108 during the HDS (Figure 3). During the WS, AR033H showed similar greatest yield as AR032H (8.60 t/ha) and the lowest yields (4.60 t/ha) were recorded for Sahel 108 under nitrogen application in three splits (timing 1). Overall, rice yield increased with increasing nitrogen applied rate and the maximum grain yields were achieved under 150 kg N/ha for all rice varieties and should be the nitrogen management option for maximizing grain yield under the Senegal River Delta climate and irrigation management conditions. Considering the nitrogen applied rate of 150 kg N/ha, the

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split of nitrogen rate into four applications induced yield increase of 2.12, 7.29, 10.18 and 4.45% for AR031H, AR032H, AR033H and Sahel 108 during the HDS, respectively, compared to the split of the N rate into three applications. During the WS there was yield increase of 2.80, 14.06 and 9.13% for AR031H, AR033H and Sahel 108, respectively while there was yield decrease of 3.25% for AR032H. Thus, AR033H responded better to late nitrogen application at flowering, enhancing grain filling. Overall, there was yield increase of 6.13 and 5.39% due to late nitrogen application during the HDS and WS, respectively. Particularly at nitrogen rate of 150 kg/ha, all varieties combined, yield increased by 9.56% during the HDS and 7.63% during the WS.

The control inbred rice variety Sahel 108 was shown to be very competitive with the hybrid rice varieties used in this study. All nitrogen rates combined, only AR033H achieved 4.26 and 5.27% under three splits and four splits during the HDS, respectively. Yield difference of 4.57 and 7.56% were observed with AR031H under the respective treatments and the AR032H yielded as Sahel 108. As the nitrogen rate of 150 kg N/ha is revealed the optimum applied N rate that should be the option for fertilizer recommendation for the studied hybrid rice varieties, yields advantage was 3.65% for AR032H and 8.74% for AR033H over Sahel 108 while AR031H showed 6.32% lower yield relative to Sahel 108. Overall during the WS, all hybrid rice varieties showed higher yield than Sahel 108. Yield advantages were 8.25, 14.73 and 8.29% for AR031H, AR032H and AR033H under three split of nitrogen rate, respectively. AR031H and AR032H showed yield advantage of 4.12 and 5.17%, respectively, compared to Sahel 108. Under the nitrogen treatment of 150 kg/ha with no distinction of the application timing, AR031H, AR032H and AR033H showed yield advantage of 5.93, 7.53, and 5.50%, respectively. The yield potential of irrigated rice was further increased by the development of hybrid rice in 1976 in China [32]. Peng et al. [9] reported that indica hybrid rice has increased yield potential by 9% over the best lowland irrigated inbred cultivars in tropical. Zhang et al. [20] indicated that "super" hybrid varieties produced 14% higher yield than ordinary hybrid varieties and 11% higher yield than inbred varieties. In Southern China, Jiang et al. [33] reported yield advantage of Hybrid rice that was 4.7-10.9% over inbred cultivars in Huaiji, Binyang and Haikou, 6.7% more in Changsha; and 18.6% more in Xingyi. Yield difference of 23% higher grain weight in hybrid varieties than inbred cultivars was observed by Huang et al. [34]. Average yield of F1 hybrid rice was 17% and 4% higher than that of indica inbreds in the 1998 wet season and 4% higher in the 1999 dry season [35].

Rice paddy yield response to nitrogen rate and application timing exhibited third order polynomial relationship during the HDS under both timings and WS under timing 2 and linear relationship during the WS under timing 1 with coefficient of determination (R2) varying from 0.79 to 0.89 (Figure 3). From the production functions, optimum nitrogen application rate was revealed to be 150 kg N/ha for most of the rice varieties. Nitrogen rate split in four applications achieved higher yield (Figure 3). Quadratic production functions were also reported by Djaman et al. [5] for the aromatic rice varieties (Sahel 177, Sahel 328, Sahel 329, Pusa Basmati) in the Senegal River Valley with high R^2 values, ranging from 0.53 to 0.99. There is an inter-seasonal variability in rice genotype yield response to nitrogen rate even in the same environment due to influence of climatic factors and management practices on this relationship. Higher yield was obtained during the HDS. The results of this study agree with Peng et al. [9] who reported curvilinear response of rice yield to nitrogen. Linear response of rice to nitrogen rate below 150 kg N ha^{-1} and a plateau off when the applied N rate is greater than 150 kg N ha^{-1} were reported by Harell et al. [9]. Watkins et al. [10] reported four different yield response functions on potential N response functions (quadratic, quadratic-plateau, linear-plateau, and Mitscherlich) estimated depending on location and year.

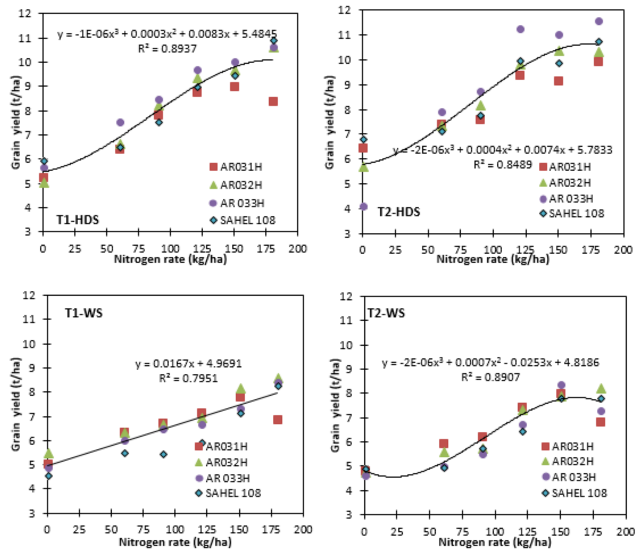

Figure 3: Rice response to the applied nitrogen rates during the Hot and Dry season and the Wet season 2016.

Effect of nitrogen application timing rice yield components

Overall, there were no significant differences in 3 and 4 splits of nitrogen in term of yield components with slightly greater values obtained under 4 splits N treatment (Table 1). The number of tillers and panicles per hill averaged 16.2 and 14.9 under the 3 split of N, respectively while they averaged 16.0 and 14.9 under 4 split of N, respectively. The filled grain weight per panicle was higher under 4 split N treatment and averaged 2.5 g against 2.6 g for the 3 and 4 splits N treatment, respectively. 1000 grain weight averaged 22.8 and 23.5 g under 3 and 4 splits during the WS, respectively. There was not difference in harvest index between the two nitrogen application timings. Non-significant slightly higher 1000 weight was recorded under the 4 split N treatment. Further, Hybrid rice AR033H achieved the greatest 1000 grain weight of 24.2 g against 22.5, 23.0 and 22.8 g for AR031H, AR032H, and Sahel108, respectively. The hybrid rice varieties showed better performance on yield components compared to Sahel108 except to the number of tillers (Table 1). However, the number of productive tillers was higher for the hybrid rice compared to the inbred rice. The results of this study agree with Yang et al. [22] and Haque et al. [36] who reported better performance of two hybrid rice varieties over the inbred rice due to better sink regulation by hybrid rice [37]. Samonte et al. [38] reported the influence of rice yield components such as effective tillers, grain number per panicle, and 1000 grain weight. Similarly, Youseftabar et al. [39] reported that increase split application increased in hybrid rice GRH1 1000 grain weight as 22.9, 23.9 and 25.6 g for the 2, 3 and 4 split N applications, respectively, in Iran.

Rice genotypes	Tillers number		Panicle number		Panicle weight (g)		Grain yield per hill (g)		Total biomass (g)		Harvest index		1000 grain weight (g)	
	Timing 1	Timing 2	Timing 1	Timing 2	Timing 1	Timing 2	Timing 1	Timing 2	Timing 1	Timing 2	Timing 1	Timing 2	Timing 1	Timing 2
AR031H	16.8	16.9	16.5	16.3	2.3	2.5	28.2	31.3	61.1	66.1	0.46	0.47	22.3	22.6
AR032H	15.2	16	15.4	14.5	2.4	2.8	28.8	31.9	59.4	64.2	0.49	0.5	22.3	23.6
AR033H	14.5	15	14.5	13.9	2.6	2.8	29.9	31.8	60.9	63.9	0.49	0.5	24.3	24.1
Sahel 108	18.2	16.3	13.3	15	2.8	2.4	33	30.8	64.9	61.1	0.51	0.5	22.5	23.1
Average	16.2	16	14.9	14.9	2.5	2.6	30	31.4	61.6	63.8	0.49	0.49	22.88	23.35

Table 1: Yield components of hybrid and inbred rice varieties at different nitrogen application timings.

Effect of nitrogen rate and application timing on nitrogen use efficiency of hybrid rice

Rice NUE varied from 8.91 to 35.68 kg /kg under nitrogen timing 1 and 5.26 to 63.56 kg/ha under nitrogen timing 2 during the HDS (Figure 4). It varied from 9.51 to 21.70 kg/kg under nitrogen timing 1 and 1.26 to 25.29 kg /kg N under nitrogen timing 2 during the WS (Figure 4). Overall, hybrid rice varieties showed higher NUE compared to the inbred rice variety Sahel 108 (Figure 4). NUE averaged 18.33, 29.50, 52.54, and 17.11 kg/kg under nitrogen application timing 1 and 23.98, 32.16, 30.57, and 20.46 kg/kg under nitrogen application timing 2 for AR031H, AR032H, AR033H, and Sahel 108, respectively, during the HDS. Thus, hybrid rice varieties AR031H, AR032H and, AR033H achieved 17.24, 57.20 and 49.44% higher NUE under Nitrogen timing 1 and 7.14, 72.44 and 207.08% higher NUE under Nitrogen timing 2, respectively during the HDS with comparison to Sahel 108. During the WS, NUE averaged 17.36, 14.68, 14.39 and 14.66 kg/kg for AR031H, AR032H, AR033H, and Sahel 108, respectively, under nitrogen timing 1 and 17.89, 17.28, 14.29 and 11.90 kg/kg for the respective varieties under nitrogen timing 2; representing NUE advantage of 18.41, 0.16, and 18.61% under nitrogen timing 1 and 50.36, 45.21 and 25.43% under nitrogen timing 2 for the hybrid rice AR031H, AR032H, and AR033H, respectively. Higher NUE was achieved with late application of 10% of the Nitrogen rate during the HDS while during the WS, the application timing did not impact NUE in rice. Results of this study agree with Youseftabar et al. [39] who found increase in hybrid rice GRH1's yield with increase split application. Wei et al. [40] indicated that nitrogen application at heading stage improved grain filling rate and duration, number of filled grains as compared to nitrogen application at tillering. Wu et al. [41] reported that NUE of the varieties ranged from 35.2 to 62.0 kg/kg and from 43.1 to 58.4 kg/kg during two rice growing season., Koutroubas and Ntanos [42] reported NUE that varied from 60.9 to 90.9 kg/kg for two indica and three japonica rice varieties at an N fertilizer rate of 150 kg ha^{-1} under Mediterranean direct water-seeded conditions. In china, nitrogen use efficiency for grain production of hybrid rice ranged from 35.2 to 62.0 kg/kg [41]. The highest nitrogen rate showed a low NUE that might be due to nitrogen losses through ammonia volatilization, denitrification and nitrogen leaching and leach to environment pollution as reported [43-45]. Similar results were reported by Tirol-Padre et al. [46] and Singh et al. [47] while Koutroubas and Ntanos [42] reported high NUE ranging from 76.2 to 124.2 kg/kg. Non-consistent small difference in NUE between hybrid rice and inbred cultivars was reported by Peng et al. [48]. Li et al. [49] reported NUE within the range of 7.1 to 28.7 kg/kg.

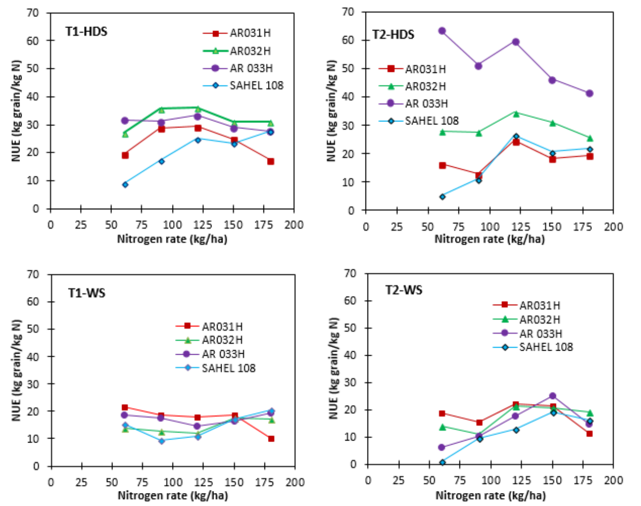

Figure 4: Rice nitrogen use efficiency under different nitrogen rates and application timings during HDS and WS 2016.

Conclusion

A field study was conducted to investigate the effects of nitrogen fertilizer rate and the application timing on grain yield and its components, yield production function, and nitrogen use efficiency of three hybrid and one inbred genotypes during the 2016 dry and wet seasons. The hybrid rice genotypes showed greater performance than the inbred rice variety Sahel108 with the maximum grain yield of 11.58 tons/ha obtained by AR033H. Nitrogen application in four splits with the application of 10% of nitrogen fertilizer rate at grain filling stage achieved better performance of rice. Further, the hybrid rice varieties achieved greater nitrogen use efficiency compared to the inbred rice. The yield production functions showed nitrogen fertilizer optimum rate was 150 kg N/ha that could be recommended for hybrid rice production within the study area and similar climate and management conditions.

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