Acta Agron. (2017) 66 (4) p 558-565 ISSN 0120-2812 | e-ISSN 2323-0118 https://doi.org/10.15446/acag.v66n4.59101

Growth, yield and agronomic efficiency of rice (*Oryza sativa* L.) cv. IAPAR 117 affected by nitrogen rates and sources

Crecimiento, rendimiento y eficiencia agronómica del arroz (*Oryza sativa* L.) cv. IAPAR 117 influenciado por dosis y fuentes de nitrógeno

Héctor Augusto Sandoval Contreras*, Renan Ribeiro Barzan, Mario Sandoval Contreras and Osmar Rodrigues Brito

Universidade Estadual de Londrina-UEL. Rodovia Celso Garcia Cid Campus Universitário Londrina - PR Brasil. Author for correspondence: hectorsanco@hotmail.com

Rec.: 16.07.2016 Accep.: 29.05.2017

Abstract

The aim of this research was to evaluate two traditional N sources (urea and ammonium sulfate) and an alternative one (sulfamooâ) with increasing rates (0, 40, 80, 120 and 160 kg N ha^{-1}, respectively) affecting aspects of upland rice crop cv. IAPAR 117. The experiment was carried out in greenhouse conditions, using a completely randomized design in 3x5 factorial scheme, with four replicates. It was evaluated the number of tillers (NT), plant mean height (PMH), dry matter of shoots (DMS), crop yield/mass of filled grains (MFG), content of N-DMS, agronomic efficiency of nitrogen (AE), mass of 100 filled grains (M100FG) and grain harvest index (GHI). The nitrogen rates application as ammonium sulfate resulted in a greater increasing of NT, DMS, MFG and N-DMS, respectively. In fact, higher agronomic efficiency obtained with urea and sulfamooâ at 40 kg N. ha^{-1}, although AE decreased within the higher rates of N, independently from the source. The M100FG and GHI were higher when sulfamooâ and urea were used, although the high N supply negatively affected these two variables for all N evaluated sources.

Key words: Absorption, fertilizer formulations, plant growth parameters, productive performance, upland.

Resumen

El objetivo de este estudio fue evaluar fuentes tradicionales (urea y sulfato de amonio) y una fuente alternativa de nitrógeno (sulfamooâ) con dosis crecientes (0, 40, 80, 120 y 160 kg ha^{-1}) sobre aspectos del cultivo de arroz de tierras altas, cv. IAPAR 117. El experimento se realizó en un invernadero, utilizando un diseño factorial 3x5 completamente aleatorizado con cuatro repeticiones. Evaluaron el número de macollos (NM), altura de la planta (AP), peso seco de parte aérea (PSPA), la productividad/masa de grano lleno (MGL), el contenido de N-PSPA, la eficiencia agronómica de nitrógeno (EA), peso de 100 granos llenos (P100GC) y el índice de cosecha de grano (ICG). La aplicación de nitrógeno en forma de sulfato de amonio proporcionó mayor aumento de NM, PSPA, MGL y N-PSPA. La mayor EA entre las fuentes se obtuvo con urea y sulfamooâ a una dosis de 40 kg N ha^{-1}, aún que reduce debido al aumento de la dosis, independientemente de la fuente. El P100GC y ICG fueron mayores cuando se utiliza la urea y sulfamooâ, pero el suministro de altas dosis de N influye adversamente en las dos variables evaluadas para todas las fuentes.

Palabras clave: Absorción, formulaciones de fertilizantes, parámetros de crecimiento vegetal, rendimiento productivo, tierras altas.

Introduction

Rice (*Oryza sativa* L.) crop is extremely important for food security, considering that many researchers categorize it as part of the basic diet for most of world population, serving as calories and proteins source.

In Brazil, upland rice is sown mainly in Cerrado regions (Fageria & Baligar, 2005), where the soils are characterized by low natural fertility, high exchangeable aluminum, low organic matter content, low phosphorus availability and almost exclusive dependence of rainfall to supply the crop water requirements (Fageria, Moreira & Coelho, 2011; Fageria, Carvalho & dos Santos, 2014). Therefore, the yield of upland rice is low, contributing with only 41% of Brazilian production, despite having more than 60% of rice cultivation areas in Brazil (Alvarez, Crusciol & Nascente, 2014).

It was observed that rice plant is characterized by high requirements of nutrients, especially nitrogen (N), considered one of the major factors limiting the grain yield in most of the areas where rice is grown (Fidelis, Rotili, Santos, Barros & Rodrigues, 2012). Nitrogen presents primary functions in plant biochemistry and plant physiology as follows: constituting hormones, enzymes, chlorophyll, nucleic acids and proteins, interfering directly on yield components such as the number of tillers, panicles, grains per panicle, etc. (Fageria & Baligar, 2005). Given these concerns, one of the main reasons for lowest yield of upland rice is the poor efficiency of recovering the applied nitrogen, being around 33 to 37%, depending on the source (Fageria, Moreira, Moraes & Moraes, 2014b). For instance, an adequate and rational nitrogen fertilization management had achieved a key role to diminish crop losses and the risks of environmental pollution, raising the efficiency of N use. This is even more urgent when considering the need for increasing the food production in order to meet the demand of a growing world population.

Undoubtedly, raising the agronomic efficiency of nitrogen fertilization in upland rice crop depends on the adoption of management techniques, which involve the genotype selection, the definition of the best rate, timing and fertilizer application (Fageria & Baligar, 2005; Fidelis *et al.,* 2012). Some literature citations (Fageria, Moreira & Coelho, 2011; Fageria, Moreira, Moraes & Moraes, 2014), on the effects influence of N sources and N rates on yield of upland rice crop in Brazilian conditions are limited, especially for newly released genotypes. In that sense, continuous studies are necessary to adjust the aspects of nitrogen fertilization for new cultivation realities.

Given these concerns, the aim of this research was to evaluate the influence of nitrogen rates from traditional and alternative sources on the nutrient uptake and the plant growth and yield performance of upland rice crop in Londrina-Parana, Brazil.

Materials and methods

The experiment was carried out in greenhouse conditions at the Agronomy Department of the Agrarian Sciences Center of State University of Londrina (UEL), Londrina, Parana, Brazil (23° 23' S, 51° 11' W and altitude of 560 m.a.s.l.)

The soil was collected from the surface layer (0.0 to 0.2 m) of a Eutroferric Red Latosol (Embrapa, 2013), in the experimental area of the UEL School Farm (FAZESC/UEL), and filled in plastic pots. The soil was sieved using a 4.0 mm mesh sieve. Therefore, subsamples were passed through a 2.0 mm mesh sieve, which were pooled for subsequent analyses in order to evaluate the soil granulometry and chemical characteristics. The granulometry analysis have allowed to classify the collected soil as vary clayey, presenting 630 g kg^{-1} of clay, 130 g kg^{-1} of silt and 240 g kg^{-1} of sand. The results for chemical characteristics were as follows: pH $CaCl_2$ = 4.4; P Mehlich$_{-1}$ = 6.13 mg dm^{-3}; Ca^{2+} = 4.47 $cmol_c$ dm^{-3}; Mg^{2+} = 1.4 $cmol_c$ dm^{-3}; K^{+} = 0.43 $cmol_c$ dm^{-3}; H + Al^{3+} = 5.58 $cmol_c$ dm^{-3}; Al^{3+} = 0.1 $cmol_c$ dm^{-3}; CEC pH 7,0 = 11.56 $cmol_c$ dm^{-3}; V = 51.64% and S.O.M. = 25.0 g dm^{-3}.

For the establishment experiment, plastic pots with 25 cm of diameter and capacity for 8.0 kg, were used. The fertilization with phosphorus and potassium consisted in the application of 1.15 g of P_2O_5 per pot, by using triple superphosphate and 1.44 g of K_2O per pot, by using potassium chloride.

Each pot received eight pre-germinated seeds of rice cv. IAPAR 117, distributing them homogeneously to cover the entire soil surface in the pot. After ten days from seed emergence, thinning was performed letting three seedlings per pot. In fact, the cv. IAPAR 117 presents a 125-day cycle, 120 cm of plant height, inflorescences at 95 days, high yield and long-thin type of grains.

The experimental design was a randomized completely block design with four replicates. The treatments resulted from a 3x5 factorial scheme, in which the factors were three N sources [urea (U: 45% N), ammonium sulphate (AS: 20% of N and 21% S), sulfamooª (SFM: 29% N; 9% S; 5% Ca and 2% Mg)] and five N rates (0, 40, 80, 120 and 160 kg N ha^{-1}, respectively), applied 1/3 at sowing and 2/3 at topdressing, 25 and 45 days after emergence (DAE). After the applications, the pots were watered, aiming to maintain the moisture between 70 and 80% of maximum retention capacity. This moisture interval was maintained throughout experimental phase by daily replacement of evapotranspired water.

In order to evaluate the response of rice plants, the evaluated variables were as follows: number of tillers per pot (NT), plant mean height (PMH), dry mass of the shoots (DMS), mass of filled grains (MFG), nitrogen content in the dry mass of shoots (N-DMS), agronomic efficiency of nitrogen (AE), mass of 100 filled grains (M100FG) and grain harvest index (GHI), respectively.

The evaluation of the number of tillers was performed by counting the stems in each experimental plot at 65 DAE (end of tillering phase). The plant mean height was measured from the soil surface to the larger end panicle at the final phase of the experiment, using a measuring tape (Pinheiro, Lopes, Oliveira, Guimarães, Stone, Madari, Filippi, Pereira, Eifert, Silva, Wedland, Lobo & Ferreira, 2009).

For the obtainment of the dry mass of the shoots, the material was collected at the end of the experiment and have allowed dried in air circulating oven at 60°C until constant mass. Subsequently, the plant tissues were weighed in a semi analytical balance.

The production of mass of filled grains (MFG), considered as yield measurement, was evaluated for each experimental plot by harvesting, cleaning, drying and weighing the grains, correcting their moisture content to 13%. The mass of 100 filled grains was evaluated following these same steps, but using subsamples of 100 grains. The processing for obtainment of clean grains was conducted using an air density separator (Pinheiro, Lopes, Oliveira, Guimarães, Stone, Madari, Filippi, Pereira, Eifert, Silva, Wedland, Lobo & Ferreira, 2009).

For instance, N content determination in the dry mass of shoots was performed by grounding the dry plant tissues in Wiley type mill and submitting to sulfuric acid digestion. Subsequently, N quantification was made according to the Kjeldahl distillation-titration method.

For the evaluation of agronomic efficiency of the N sources and N rates, was used the Equation 1 (Fageria & Baligar, 2005).

$$AE\ (g.g^{-1}) = \frac{(MFG_{UN})-(MFG_{WUN})}{QNA} \quad \text{Equation 1}$$

Where: AE = agronomic efficiency (g MFG g^{-1} N); MFG_{UN} = mass of filled grains (g) produced in the pot using nitrogen, MFG_{WUN} = mass of filled grains (g) produced in the pot without using nitrogen and QNA = quantity of nitrogen (g) applied in the pot.

The grain harvest index (GHI) was obtained dividing the dry mass of filled grains by the whole shoots dry mass (including the grains), as the Equation 2.

$$GHA\ (g.g^{-1}) = \frac{Dry\ mass\ of\ filled\ grains\ (gpot^{-1})}{Dry\ mass\ of\ filled\ grains\ (gpot^{-1}) + Dry\ mass\ of\ straw\ (gpot^{-1})}$$

Equation 2

The data obtained were submitted to ANOVA analysis. To identify significant difference among treatments and statistical significance for all comparisons was made at $p<0.05$. Tukey's multiple range test was used to compare the mean values of treatments. Therefore, polynomial regressions was used for quantitative treatments, using SISVAR ® v.5.3. Software.

Results

Plant growth parameters

The ammonium sulphate was the source with higher NT values when the rates 120 and 160 kg N ha^{-1} were used (Table 1), differing from the results obtained by Lopes, Buzetti, Teixeira, Benett & Arf (2013), who did not observe significant effects of applied N sources (urea, ammonium sulphate and ammonium sulfonitrate, respectively) on rice tillering.

Table 1. Number of tillers per pot (NT), plant mean height (PMH) and dry mass of the shoots (DMS) of upland rice cv. IAPAR 117, as a function of N sources within N rates.

N sources [1]	N rates (kg.ha^{-1})				
	0	40	80	120	160
			NT (nº)		
AS	3.84 a	6.91 a	9.20 a	12.08 a	12.33 a
U	3.91 a	7.00 a	8.22 a	9.33 b	8.00 b
SFM	4.00 a	6.58 a	7.91 a	9.44 b	7.83 b
C.V. (%)			8.01		
L.S.D.			1.04		
			PMH (cm)		
AS	92.33 a	114.79 a	115.79 a	108.70 a	108.79 a
U	91.95 a	105.09 b	113. 66 a	111.81 a	116.86 a
SFM	94.32 a	112.42 ab	113.40 a	110.40 a	114.16 a
C.V. (%)			4.36		
L.S.D.			8.07		
			DMS (g pot^{-1})		
AS	23.94 a	49.57 a	81.19 a	95.37 a	100.19 a
U	25.66 a	51.34 a	71.96 ab	85.35 b	84.98 b
SFM	25.85 a	49.12 a	71.26 b	74.83 c	80.59 b
C.V. (%)			8.73		
L.S.D.			9.64		

Means followed by the same letters in the columns are not different by Tukey test at 5% significance. [1] AS = Ammonium sulphate; U = Urea; SFM = Sulfamoo®. C.V. = Coefficient of variation; L.S.D. = Least significant difference.

The ammonium sulphate was the source with higher NT values when the rates 120 and 160 kg N ha^{-1} were used (Table 1), differing from the results obtained by Lopes, Buzetti, Teixeira, Benett & Arf (2013), who did not observe significant effects of N sources (urea, ammonium sulphate and ammonium sulfonitrate) on rice tillering.

An increasing in rice tillering as a function of N rates was adjusted to quadratic model for all the N evaluated sources (Figure 1a).

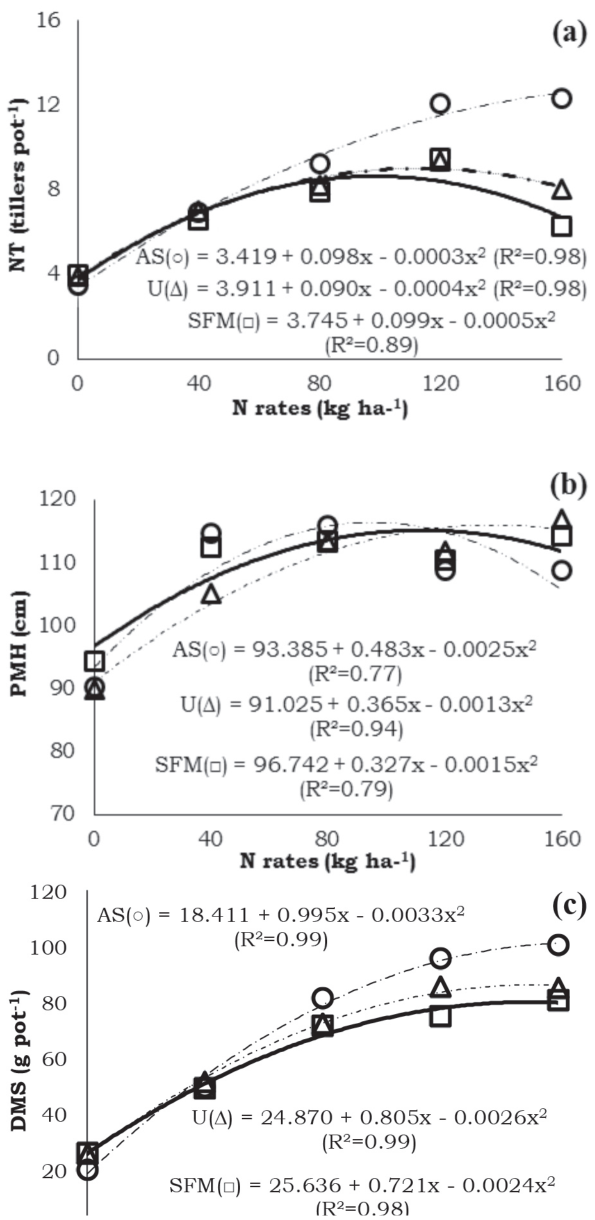


Figure 1. Number of tillers per pot (NT) (a), plant mean height (PMH) (b) and dry mass of shoots (DMS) (c) of upland rice plants, cv. IAPAR 117, as a function of N rates from the sources ammonium sulphate (AS), urea (U) and sulfamooâ (SFM).

However, it was observed that ammonium sulphate had achieved the major increments, nearing a linear response. In fact, it was possible to estimate the highest number of tillers, due to the rates of 163, 113 and 99 kg N ha^{-1}, respectively, for ammonium sulphate, urea and sulfamooâ.

Evaluating the rate effects (Figure 1b), could verify the changes in PMH have allowed to be adjusted to quadratic models, with maximum points estimated for the rates of 96.6, 109.1 and 140.3 kg N ha^{-1}, respectively, for ammonium sulphate, sulfamooâ and urea. For some researchers the rice height growth is affected by N rates, which was better represented by the linear model.

Nitrogen content and agronomic efficiency

The use of ammonium sulphate resulted a higher accumulation of N-DMS compared to urea and sulfamooâ, since the lower N rates (Table 2). Holzschuh, Bohnen, Anghinoni, Meurer, Carmona & Costa (2009), obtained different results, observing N toxicity in plants fertilized with ammoniacal source.

It was verified an increasing in N-DMS for different N sources, which have adjusted to linear models, indicating the applied N rates were not sufficient to reach the maximum points (Figure 2a).

Table 2. Content of nitrogen in the dry mass of shoots (N-DMS) and agronomic efficiency of nitrogen (AE) of upland rice plants, cv. IAPAR 117, as a function of N sources within N rates.

N sources [1]	N rates (kg ha^{-1})				
	0	40	80	120	160
		N-DMS (mg pot^{-1})			
AS	128.57 a	382.60 a	611.30 a	1023.05 a	1246.39 a
U	141.32 a	269.10 b	486.64 b	806.83 b	849.52 c
SFM	139.81 a	329.69 ab	544.41 b	868.91 b	916.48 b
C.V. (%)			6.29		
L.S.D.			62.67		
		AE (g grains g^{-1} N)			
AS	-	129.01 b	115.48 a	101.11 a	66.93 a
U	-	168.14 a	111.21 a	89.69 a	68.16 a
SFM	-	161.18 a	109.21 a	84.77 a	48.42 a
C.V. (%)			11.81		
L.S.D.			21.32		

Means followed by the same letters in the columns are not different by Tukey test at 5% significance. [1] AS = Ammonium sulphate; U = Urea; SFM = Sulfamooâ. C.V. = Coefficient of variation; L.S.D. = Least significant difference.

The agronomic efficiency (AE) of the N sources, considering the filled grains production by unit of N applied, has varied significantly only for the rate 40 kg N ha^{-1} (Table 2). Urea and sulfamooâ presented higher values, overcoming ammonium sulphate at 30.33 and 24.93%, respectively.

Undoubtedly, AE is linearly reduced according to the raising of N rates, independently of the source used (Figure 2b). For each gram of N applied as sulfamooâ, urea and ammonium sulphate, there is a reduction of 0.90, 0.80 and 0.50 on the yield increment rate, respectively. This behavior is in accordance with the Mitscherlich law of diminishing increments, which states that the great returns of production as a function of nutrient applied, which were obtained with low rates, performing a decreasing for each increasing with fertilizer amount.

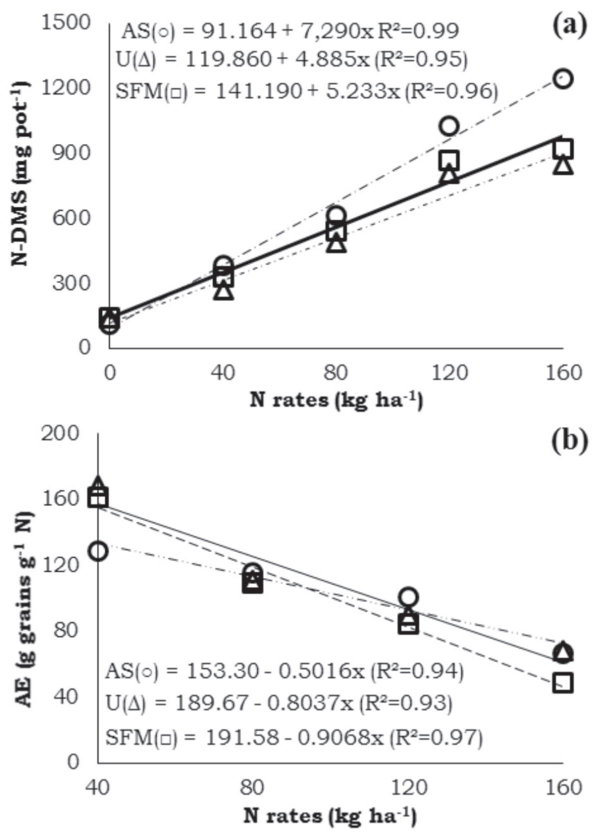


Figure 2. Content of nitrogen of the dry mass of shoots (N-DMS) (a) and agronomic efficiency of nitrogen (AE) (b) of upland rice cv. IAPAR 117 plants, as a function of N rates from the ammonium sulphate (AS), urea (U) and sulfamooâ (SFM) sources, respectively.

In this sense, the highest rate applied of 160 kg N ha^{-1}, the AE reductions related to the rate of 40 kg N ha^{-1}, which were as follows: 52.3%, 52.4% and 80.4%, respectively, for ammonium sulphate, urea and sulfamooâ, application, respectively.

Rice yield performance

The highest M100FG was obtained with sulfamooâ, differing from ammonium sulphate (Table 3).

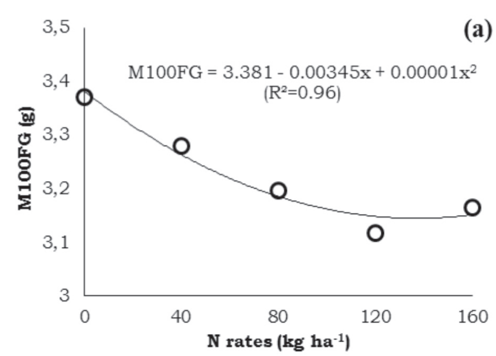
Table 3. Mass of 100 filled grains (M100FG), grain harvest index (GHI) and mass of filled grains (MFG) of upland rice cv. IAPAR 117 plants as a function of N sources and rates.

N sources (1)	M100FG (g)
AS	3.18 b
U	3.21 ab
SFM	3.28 a
C.V. (%)	2.65
L.S.D.	0.065
	GHI (g g^{-1})
AS	0.41 b
U	0.43 a
SFM	0.43 a
C.V. (%)	5.80
L.S.D.	0.019

MFG (g pot^{-1})					
N sources (1)	N rates (kg ha^{-1})				
	0	40	80	120	160
AS	14.29 a	36.26 a	51.31 a	55.90 a	57.19 a
U	14.99 a	41.12 a	47.54 a	56.49 a	55.42 ab
SFM	16.85 a	40.78 a	49.94 a	45.75 b	45.70 b
C.V. (%)			13.71		
L.S.D.			9.83		

Means followed by the same letters in the columns are not different by Tukey test at 5% significance. (1) AS = Ammonium sulphate; U = Urea; SFM = Sulfamooâ. C.V. = Coefficient of variation; L.S.D. = Least significant difference.

In addition, the 100-grain mass was reduced as a function of N rates, being adjusted to a quadratic model with minimum point estimated as 136 kg N ha^{-1} (Figure 3a), independently of the N source.



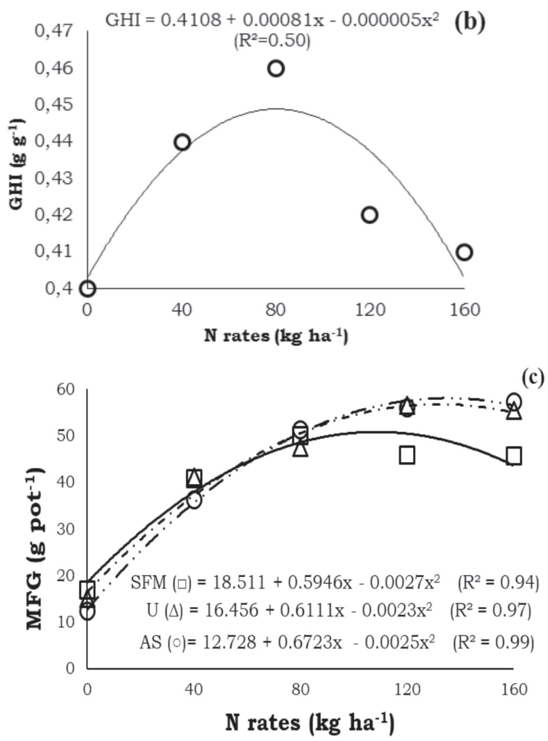


Figure 3. Mass of 100 filled grains (M100FG) (a), grain harvest index (GHI) (b) and mass of filled grains (MFG) (c) of upland rice plants, cv. IAPAR 117, as a function of N rates from the sources ammonium sulphate (AS), urea (U) and sulfamooª (SFM).

Alternatively, for the rate of 120 kg N ha^{-1}, ammonium sulphate and urea presented MFG higher than sulfamooª, while for the rate of 160 kg N ha^{-1}, this last source was only inferior than ammonium sulphate, due to a slight MFG reduction by urea application, statistically equaling it to sulfamooª (Table 3).

An increasing of N rates have allowed a quadratic model for the N evaluated sources (Figure 3c). It was observed that the highest mass of filled grains production (57.92 g pot^{-1}) was obtained with the application of ammonium sulphate at the estimated rate of 134.46 kg N ha^{-1}. For the sources urea and sulfamooª, the maximum values were 57.04 and 51.24 g pot^{-1}, estimated, respectively, for the rates 132.84 and 110.11 kg N ha^{-1}. Souza, Sá, Martins, Abrantes, Silva & Arruda (2010), did not obtained N effects with N rates, which ranged from 0 to 80 kg N ha^{-1}, as urea, on seeds yield of rice cv. IAC 202. On the contrary, Hernandes, Buzetti, Andreotti, Arf & Sá (2010), have reported rice yield increasing until 122 kg N ha^{-1}, followed by a decreasing in similitude to the present study.

Discussion

Fageria, Baligar & Jones (2010), also reported that nitrogen fertilization, besides raising the number of leaves, increases the number of tillers in rice plants.

Poletto, Mundstock, Grohs & Mazurana (2011), observed distinct results, reporting negative effects of increasing ammoniacal N supplying on flooded rice tillering, being ameliorated with higher nitrate proportions. However, it is worth pointing out that these authors worked with nutrient solution (anaerobic conditions). In soil aerobic conditions, much of the NH_4^+ released from the ammoniacal fertilizers may pass through the nitrification process before N uptake by plants.

Lopes *et al.* (2013), also observed a quadratic response of the number of tillers as a function of N rates from urea, ammonium sulfonitrate with nitrification inhibitor and ammonium sulphate, obtaining the maximum point with the rate of 198 kg N ha^{-1}.

The effects of N sources on PMH was only observed for the rate of 40 kg N ha^{-1}, in which the ammonium sulphate was superior to urea (Table 1). Similar results were obtained by Fageria *et al.* (2011), working with upland rice. These authors observed higher plant height when using ammonium sulphate compared to urea at low N rates. On the other hand, Lopes *et al.* (2013), did not observe plant height effects due to N sources in upland rice.

Similarly, Fabre, Cordeiro, Ferreira, Vilarinho & Medeiros (2011), observed that for flooded rice, the plant height response (linear or quadratic), depends on the plant stage development when N rates are applied.

The ammonium sulphate was also superior for DMS when N rates were higher than 80 kg N ha^{-1} (Table 1), diverging from the observed by Boldieri, Cazetta & Fornasieri (2010), in flooded rice, in which the ammonium sulphate and urea N sources were applied at 150 kg N ha^{-1}, which provided resembling values for DMS. The sulfamooª source had achieved a minor increasing in DMS compared to other N sources, especially when applied at higher rates (Table 1, Figure 1c). This is due to its characteristic of slower N release, delivering less nitrogen throughout plant development for biomass synthesis. In fact, the maximum values are obtained with the application of 150.7, 154.8 and 150.0 kg N ha^{-1} for ammonium sulphate, urea and sulfamooª, respectively (Figure 1c).

For their part, Fageria *et al.* (2011), verified that the maximum production of DMS for rice was obtained with much higher N rates, being estimated as 952 kg N ha^{-1} for ammonium sulphate and 540 kg N ha^{-1} for urea. The effects of N rates on DMS increasing are related to the role of this nutrient in plant metabolism, concerning the enzymatic activity for biosynthesis of new plant tissues.

This provides more accurate and reliable estimates of linear behavior, which demonstrates the rice plants, had achieved a higher efficiency of N uptake rather than utilization for biomass production and conversion to product of economic interest. Junior, Souza, Fernandes & Rossiello (1997), observed that efficiency of N use by bred genotypes is mainly due to their absorption efficiency compared to the utilization of N absorbed.

Quintero *et al.* (2011), did not observe differences between the efficiency of N sources in flooded rice. On the other hand, for upland rice genotypes originating from Brazil and Colombia, Contreras, Contreras, Barzan, Silvestre & Brito (2016), reported higher agronomic efficiency of calcium nitrate than ammonium sulphate.

Despite having the observed reductions, even the lower values of AE, obtained with the higher N rates, are correlated to previous report carried out by Fageria, Santos & Cutrim (2007), where were obtained 19 kg of grain per kg of N applied for different flooded rice genotypes.

Different results were obtained by Fageria *et al.* (2011), who observed an increase of 1000-grain mass with increasing N rates until the maximum point of 308 kg N ha^{-1}. Under this described conditions, there is a higher restriction to the production and allocation of photosynthates for grain filling. In addition, can be observed that tillering had achieved a higher quantity of panicles and grain number, intensifying the competition for photosynthates among individual grains.

According to Fageria & Baligar (2005), higher values of GHI are related to higher efficiency of photosynthates translocation. Considering the isolated effects of N rates, it was possible to observe that GHI variations were adjusted to a quadratic model (Figure 3b). The maximum point was obtained with 80.70 kg N ha^{-1}, far below the observed for the other evaluated parameters, reinforcing the idea that excessing N could be attributed to an imbalance in plant growth and plant breeding.

Therefore, among N sources, GHI varied from 0.41 to 0.43 (Table 3) and this result is in accordance with Fageria *et al.* (2010), who indicates IGH values for commercial crops ranged from 0.36 and 0.52. Nevertheless, N sources, which determined the lowest DMS and N-DMS increasing, were the same, which also presented the highest values for GHI, as well as the M100FG. This corroborates the idea that the higher is the N uptake, which was observed with ammonium sulphate, the higher is the vegetative growth, generating an imbalance in the photosynthates distribution, which generates smaller grains and lower GHI.

These results differ from that obtained by Hernandes *et al.* (2010), who did not observe significant differences between three N sources (ammonium sulfonitrate, ammonium sulphate and urea) for grain yield of rice genotypes BRSMG Curinga and IAC 202. Similarly, Lopes *et al.* (2013), working with the sources Entec, ammonium sulphate and urea at the rates of 0, 50, 100, 150 and 200 kg de N ha^{-1}, respectively, did not observe significant effects of these N sources on rice cv. IAC 202 grain yield.

Conclusions

The yield and yield components of upland rice cv. IAPAR 117 are influenced by N sources and rates. The ammonium sulphate is the N source, which presents the higher increments for tillering, dry mass of shoots, N content in the dry mass of shoots and grain yield, exceeding the other N sources mainly at higher N rates.

Given these concerns, urea and sulfamooâ sources, presented the higher agronomic efficiency when the lower N rate was used (40 kg N ha^{-1}), whereas an increasing in N rate, reduces the efficiency independently of the N source. As a conclusion, it has long been thought that these two N sources, promote a better equilibrium between vegetative organs and the grains, providing higher values of 100-grain mass and grain harvest index. Both parameters, however, are negatively affected by nitrogen fertilization at higher rates.

References

Alvarez, R. F, Crusciol, C. A & Nascente, A. S. (2014). Produtividade de arroz de terras altas em função de reguladores de crescimento. *Rev Ceres*, 61(1), 42-49. *http://dx.doi.org/10.1590/S0034-737X2014000100006*

Boldieri, F. M., Cazetta, D. A. & Fornasieri-Filho, D. (2010). Adubação nitrogenada em cultivares de arroz de terras altas. *Rev Ceres*, 57(3), 421-428. *http://dx.doi.org/10.1590/S0034-737X2010000300020*

Contreras, H. A. S.; Contreras, M. S.; Barzan, R. R.; Silvestre, J. P.; Brito, O. M. (2016). Doses de nitrogênio de fontes nítrica e amoniacal exigidas por cultivares de arroz de sequeiro originárias do Brasil e da Colômbia. *Semina: Ci Agr*, 37(3), 1267-1276. *https://doi.org/10.5433/1679-0359.2016v37n3p1267*

EMBRAPA. Centro Nacional de Pesquisa de Solos. (2013). Sistema Brasileiro de classificação de solos. Embrapa (Eds.) 3rd edição. Brasília, DF. 353 p.

Fabre, D. V. O., Cordeiro, A. C. C., Ferreira, G. B., Vilarinho, A. A. & Medeiros, R. D. (2011). Doses e épocas de aplicação de nitrogênio em arroz de várzea. *Pesq Agropec Trop,* 41(1), 29-38. *https://www.revistas.ufg.br/pat/article/view/7776.*

Fageria, N. K., Baligar, V. C. & Jones, C. A. (2010). Growth and Mineral Nutrition of Field Crops. CRC Press (Eds.). 3rd edition. Boca Raton, Florida. 586 p.

Fageria, N. K. & Baligar, V. C. (2005). Enhancing nitrogen use efficiency in crop plants. *Adv Agron*, 88, 97–185. *https://doi.org/10.1016/S0065-2113(05)88004-6*

Fageria, N. K.; Carvalho, M. C. S. & dos Santos, F. C. (2014). Response of Upland Rice Genotypes to Nitrogen Fertilization. *Commun Soil Sci Plant*, 45(15), 2058–2066. *http://dx.doi.org/10.1080/00103624.2014.911301*

Fageria, N. K., Moreira, A. & Coelho, A. M. (2011). Yield and yield components of upland rice as influenced by nitrogen sources. *J Plant Nutr*, 34, 361–370. *http://dx.doi.org/10.1080/01904167.2011.536878*

Fageria, N. K., Moreira, A., Moraes, L. A. C. & Moraes, M. F. (2014). Nitrogen uptaken and use efficiency in upland rice under two nitrogen sources. *Commun Soil Sci Plan*, 45(4), 461-469. *http://dx.doi.org/10.1080/00103624.2013.861907*

Fageria, N. K., Santos, A. B. & Cutrim, V. A. (2007). Produtividade de arroz irrigado e eficiência de uso do nitrogênio influenciadas pela fertilização nitrogenada. *Pesq Agropec Bras.* 42(7), 1029-1034. *http://www.scielo.br/pdf/pab/v42n7/16.pdf.*

Fidelis, R. R., Rotili, E. A., Santos, M. M., Barros, H. B. & Rodrigues, A. M. (2012). Eficiência quanto ao uso e resposta à aplicação de nitrogênio de cultivares de arroz em solos de terras altas no Sul do Estado de Tocantins, Safra 2007/2008. *Biosci J*, 28(3), 432-438. *http://www.scielo.br/pdf/brag/v69n3/23.pdf.*

Hernandes, A., Buzetti, S., Andreotti, M., Arf, O. & Sá, E. M. (2010). Doses, fontes e épocas de aplicação de nitrogênio em cultivares de arroz. *Ciênc Agrotec,* 34(2), 307-312. *http://dx.doi.org/10.1590/S1413-70542010000200006*

Holzschuh, M. J., Bohnen, H., Anghinoni, I., Meurer, E. J., Carmona, F. C. & Costa, S.E.V.G.A. (2009). Rice growth as affected by combined ammonium and nitrate supply. *R Bras Ci Solo*, 33(5), 1323-1331. *http://dx.doi.org/10.1590/S0100-06832009000500025*

Junior, A.S.L.F., Souza, S.R., Fernandes, M.S. & Rossiello, R.O.P. (1997). Eficiência do uso de nitrogênio para produção de grão e proteína por cultivares de arroz. *Pesq Agropec Bras.* 32(4), 435-442. *https://seer.sct.embrapa.br/index.php/pab/article/view/4665/7244.*

Lopes, R. A.; Buzetti, S.; Teixeira Filho, M. C. M.; Benett, C. G. S. & Arf, M. V. (2013). Doses, fontes e épocas de aplicação de nitrogênio em arroz de terras altas cultivado em sistema de semeadura direta. *Rev Caatinga*, 26(4), 79 – 87. *http://dx.doi.org/10.1590/S1413-70542010000200006*

Pinheiro, P. V.; Lopes Júnior, S.; Oliveira, J. P.; Guimarães, C. M.; Stone, L. F.; Madari, B. E.; Filippi, M. C. C.; Pereira, H. S.; Eifert, E. C.; Silva, J. F. A.; Wedland, A.; Lobo Junior, M. & Ferreira, E. P. B. (2009). Variáveis experimentais da Embrapa Arroz e Feijão. Embrapa (Eds.). Santo Antônio de Goiás. 80p. *http://www.cnpaf.embrapa.br/transferencia/informacoestecnicas/publicacoesonline/seriedocumentos_250.pdf.*

Poletto, N., Mundstock, C. M., Grohs, D. S. & Mazurana, M. (2011). Padrão de afilhamento em arroz afetado pela presença dos íons amônio e nitrato. *Bragantia* 70(1), 96-103. *http://dx.doi.org/10.1590/S0006-87052011000100015*

Quintero, C. E., Pasa, F. P., Zamero, M. A., Arévalo, E. S., Spinelli, N. B. & Boschetti, N. G. (2011). Absorción de nitrógeno y rendimiento de arroz con diferentes formas de nitrógeno aplicado previo al Riego. *Cienc. del Suelo*, 29(2), 233-239. *http://www.scielo.org.ar/pdf/cds/v29n2/v29n2a12.pdf.*

Souza, L. C. D., Sá, M. E., Martins, H. S. D., Abrantes, F. L., Silva, M. P. & Arruda, N. (2010). Produtividade e qualidade de sementes de arroz em resposta a doses de calcário e nitrogênio. *R Tróp: Ci Agr Biol.* 4(2), 27-35. *http://www.periodicoseletronicos.ufma.br/index.php/ccaatropica/article/view/153/101.*