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SOIL SCIENCE

Understanding the dynamics of attributes of medium and short cycle rice cultivars under nitrogen effect

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ABSTRACT: *Nitrogen (N) is the element supplied by the soil that limits the development of irrigated rice. The hypothesis of the present is that to meet higher demand for N by the plant due to the higher potential yield, it is not necessary to apply a higher dose of N fertilizer. This studyevaluated the efficiency of N utilization, the rate of growth and accumulations of N by plants and the grain yield of two rice cultivars, short cycle and medium cycle, with and without N fertilization. A field experiment was installed in the Rio Grande do Sul, southern Brazil. The treatment factors evaluated were cultivar, with medium and short cycles, with doses of 0 and 150 kg N ha^{-1}. Growth curves, absorption rate, N content and leaf area index over time, root area and grain yield were analyzed. The medium cycle cultivar has a greater potential to explore the environment when compared to the short cycle rice cultivar, both for greater leaf area and root area per cultivation area, as well as for longer exploration times. Thus, the medium cycle cultivar has greater N utilization efficiency and higher grain yield.*
Key words: *irrigated rice, nitrogen fertilization, growth curve, absorption.*

Compreendendo a dinâmica de atributos de cultivares de arroz de ciclo médio e curto sob efeito do nitrogênio

RESUMO: *O nitrogênio é o elemento fornecido pelo solo que mais limita o desenvolvimento do arroz irrigado. A hipótese do presente trabalho é que para atender a uma maior demanda de nitrogênio pela planta devido ao maior potencial de rendimento, não é necessário aplicar uma dose maior de fertilizante nitrogenado. O objetivo do estudo foi analisar o efeito do potencial produtivo de cultivares de arroz na resposta ao nitrogênio. Um experimento de campo foi instalado no Rio Grande do Sul, sul do Brasil. Os fatores de tratamento avaliados foram cultivar, com ciclos médio e curto sob doses de 0 e 150 kg N ha^{-1}. Foram analisadas curvas de crescimento, marcha de absorção, teor de nitrogênio e índice de área foliar ao longo do tempo, área radicular e produtividade de grãos. A cultivar de ciclo médio apresenta maior potencial de exploração do ambiente quando comparada a cultivar de arroz de ciclo curto, tanto pela maior área foliar quanto pela maior área superficial da raiz por área. Assim, a cultivar de ciclo médio tem maior capacidade de exploração de recursos e maior eficiência no aproveitamento do nitrogênio, o que é de grande importância para uma agricultura mais sustentável.*
Palavras-chave: *arroz irrigado, adubação nitrogenada, curva de crescimento, marcha de absorção.*

INTRODUCTION

The irrigated rice cultivation in southern Brazil is the most technically advanced rice production system in the country and the regions with the highest grain yield globally (CARLOS et al., 2020; SOSBAI, 2018; SOUSA et al., 2021). The crop's yield has increased consistently, especially over the past decade. In the Rio Grande do Sul, the average crop yield reached 9,010 Kg ha^{-1} in the crop season 2020/2021 (IRGA, 2021). Such yield results from the use of cultivars with high genetic potential and technical advances in crop management, mainly regarding irrigation, fertilization (CARDOSO et al., 2020; CARLOS et al., 2021; OGOSHI et al., 2020), sowing time density and weed control (SOSBAI, 2018).

The fertilizer doses with nitrogen (N), phosphorus (P) and potassium (K) has increased over time in proportion to the grain yield despite the fact the maximum recommended doses in the 1990s were 90, 60 and 60 kg ha^{-1} of N, P_2O_5 and K_2O, the current

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maximum recommendations for very high yield expectations are 150, 80 and 125 kg ha^{-1} of N, P_2O_5 and K_2O, respectively (SOSBAI, 2018). Although, it is stated that, on average, such doses of fertilizers have an economic return at current prices, it is possible that in many cases high doses are used much more as a guarantee of obtaining high yields than because of the real need for culture. That is, in many cases it is possible that high yields can be obtained with lower fertilizer doses than currently recommended.

Furthermore, the recommendations presented in SOSBAI (2018) do not consider that there may be differences in the responses of rice cultivars to N, solely based on soil organic matter content and expected grain yield. To reach this level of specification, more in-depth knowledge of nutritional requirements throughout the crop cycle and its interaction with other factors of production is required.

The efficiency of using N refers to the plant's ability to use N for grain production (SHARMA et al., 2018). Currently, several strategies are developed worldwide to improve the efficiency of the use of N-fertilizers, so that the losses that occur in the flooded system, through processes such as volatilization, leaching and denitrification can be mitigated (AN et al., 2018; CHEN, G. et al., 2015; HUANG, L. et al., 2019). In addition to the adequacy of doses, the regular application of N in the form of instalments as well as the introduction of sustainable management practices such as green manure can help to reduce losses in irrigated cultivation and assist in increasing the efficiency use of applied N (ALAM et al., 2019; CARLOS et al., 2022; THAKUR; MANDAL; RAYCHAUDHURI, 2020).

In Rio Grande do Sul six rice regions are well defined according to the prevailing climatic variables in each with different yield potentials (SOSBAI, 2018). In addition, the cultivars in use have different genetic potentials (KLERING et al., 2008). Therefore, the quantitative requirements of N for the crop to reach its maximum yield in each crop must vary between cultivars and between climatic regions. From the point of view of fertilization practice, it leads to the following question: to meet a higher demand for N by the rice plants due to the higher potential yield, is it necessary to apply a higher doses of N fertilizer? As a hypothesis, the answer is no. When a plant grows more, either due to its genetic potential or to more appropriate environmental conditions, the plant's ability to acquire nutrients from the soil increases proportionately. The increase in the root system as a result of increased plant growth alone already compensates for the need for additional absorption. Experimentally, this comparison is difficult to make between regions or even between different places within a region because the differences between soils can mask the results. In the same place, comparing cultivars with different genetic potentials, the hypothesis can be tested. In this case, the research hypothesis is that the medium cycle cultivar has a greater capacity to exploit the resources of the environment, greater N utilization efficiency and achieves higher yields than a shorter cycle cultivar.

The theoretical basis to justify any differences in yield between cultivars, as well as the effects of N on yield can be sought from the analysis of the growth of the different organs and of the absorption and distribution of N among the plant organs along with its development cycle, under conditions of insufficient and sufficient N supply. In Brazil, there are no previous studies comparing cultivars from different cycles in relation to N utilization and grain yield.

Thus, the objective of this research was to evaluate the efficiency of N utilization, the rate of growth and accumulation of N by plants and the grain yield of two rice cultivars, of short and medium cycle, with and without N fertilization

MATERIALS AND METHODS

Site description

The experiment was conducted in the municipality of Manoel Viana, which is an important irrigated rice-producing regions in the state of Brazil. Located by definition of the geographical coordinates 29º 25' 34.64" S and 55º 43' 49.78" W, at an altitude of 81 m. The soil is classified as Haplic Luvisol (STRECK et al., 2008) and flat relief. The region's climate is classified as humid temperate with hot summer (Cfa), according to the Köppen classification with an average temperature of 20.7 ºC and annual rainfall of 1371 mm year^{-1}. The location of the experimental area is shown in figure 1.

For the installation of the experiment, a survey of the chemical attributes of the area, was previously made. Table 1 shows the main results of the soil analysis, carried out before the installation of the experiment. To certify the homogeneity of the site, and mesh samplings were carried out every five meters. In each sample, the contents of phosphorus, potassium, organic carbon and pH in water and in Shoemaker, McLean, Pratt (SMP) buffer solutions were determined (TEDESCO et al., 1995).

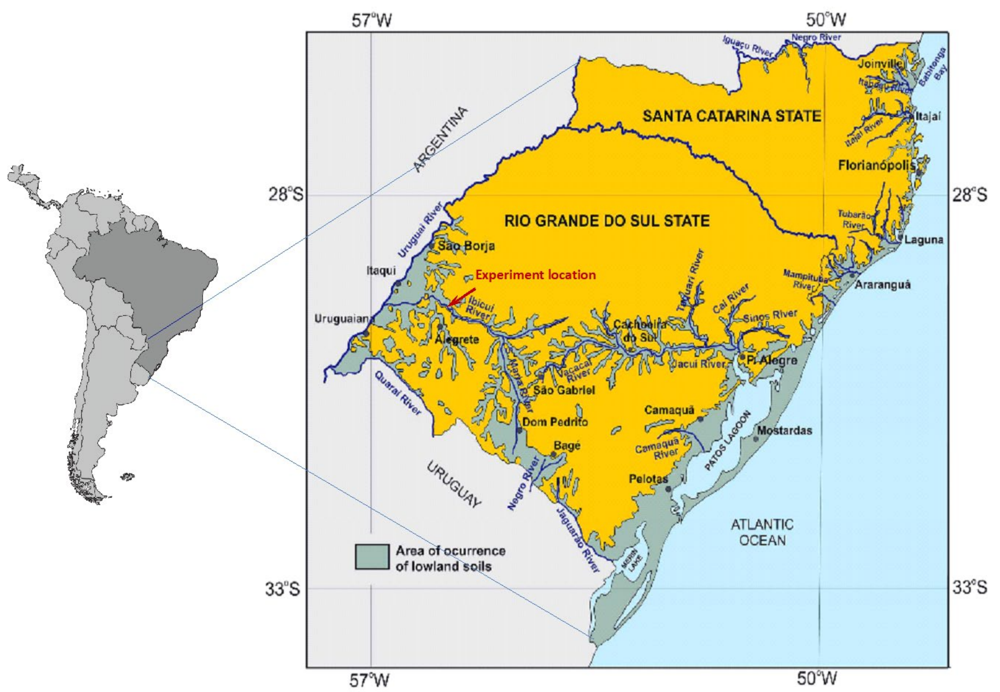

Figure 1 - Experimental location in the municipality of Manoel Viana, state of Rio Grande do Sul, Brazil. Adapted from Sousa et al. (2021).

Experimental design and description

The treatment factors evaluated in this study were factor (1) cultivar (C), medium and short cycle rice cultivar and factor (2) nitrogen dose (N), with 0 kg N ha^{-1} and 150 kg N ha^{-1}. The N fertilizer was urea (46% N) from the company Yara Brasil®. The dose 0 kg ha^{-1} was added to confirm the response to the N applied. Two cultivars from different cycles and with different yield potentials were used to observe whether the period of cycle duration influences the use of N. The short cycle cultivar takes 83 days until full flowering and 115 days until maturation. The short cycle cultivar is IRGA 417, and it was widely cultivated in the early 2000s in Brazil. The medium cycle cultivar takes 96 days until full flowering and 132 days until maturation (SOSBAI, 2018). The medium cycle cultivar is IRGA 424, and it is the most sowed cultivar in Brazil and Latin America in the Clearfield® version (CL). The treatments consisted of varying the levels of N for each cultivar in a 2x2 factorial scheme.

The experimental units were plots with dimensions of 7 x 10 m. The experiment was laid out in strip plot design with three replications. The plots

Table 1 - Chemical characterization performed before the installation of the experiment for the parameters pH in water, effective CEC, CEC at pH 7.0, Aluminum Saturation (AlS), Bases Saturation (BS), organic matter, phosphorus (P) and potassium (K).

pH (water1:1)	CEC Effec.	CEC pH 7.0	AlS	BS	Organic matter	P	K
	-------------cmol$_c$ dm³------------		-----------------------------%--------------------------			------------mg dm³----------	
4.9	18.1	25.7	6.0	66.0	2.4	3.0	84.0

received the same procedures of soil preparation, basic fertilization, seedings, control of invasive plants, pests and diseases, and water management. All crop management procedures are in accordance with the instructions described in SOSBAI (2018), except treatments with N levels. Certified seeds with known germination percentage were used, the sowing density used was sufficient to obtain a population of 300 plants m^{-2} for both cultivars. For the treatment that had N fertilization, it was carried out with the application of 10 kg ha^{-1} in the sowing and 140 kg ha^{-1} in coverage, 50% of the dose when the plants had three expanded leaves when the start of tillering (15 days) and the other fraction (50%) was applied at the end of the vegetative phase (55 days for short cycle cultivar and 65 days for medium cycle cultivar).

Sampling and analyses

The response variables observed were N accumulated and plant growth, growth was evaluated through the accumulation of dry mass and increase in leaf area, root area and grain yields were also evaluated. The method of observation of the accumulation of dry matter and N was by collecting samples of plant tissue, performed at average intervals of 15 days, starting from the phenological stage V2 (COUNCE; KEISLING; MITCHELL, 2000). So, eight collections were made in the short cultivar and ten in the medium cycle cultivar. Collections were made in each experimental unit, totaling three samples, one in each replicate. Each collection consisted of the sampling of 1 linear meter irrigated rice plants that totalled 0.158 m^2 per sampling date in each replicate.

All samples of plant tissue were dried at a temperature of 60 ºC, in a forced ventilation for 72 hours oven until they reach constant weight. After being properly dried, they were partitioned into stems, leaf sheath, leaf blade, panicle and dead tissue. The dry matter (DM) of the plants was weighed with milligram precision and then taken to the Laboratory of Soil and Vegetable Tissue Analysis to determine the N concentration (TEDESCO et al., 1995). So that the sum of the DM of all the organs constitutes the Dry Matter of the Aerial Part (DMAP) in each season, and the Dry Matter of the Panicle (DMP) obtained by the direct weighing of the panicle. The weighted average of the N content of each season multiplied by their respective DMAP gave rise to Total Accumulated Nitrogen (TAN), in the same way the N accumulated in the panicle (NAP) was calculated by multiplying the N content in the panicle and its respective DMP.

The leaf area index (LAI) was calculated by the relation between the leaf area (LA) and the corresponding land surface (0.158 or 0.79 m^2), obtaining leaf area per soil area (m^2 m^{-2}). The leaf area, in turn, was estimated at each collection, using the product of the dry mass of green leaves with the relationship between the mass and the leaf area. This relationship was determined at three different times, the area was estimated in twelve leaves per experimental unit, and these leaves were properly dried and weighed to obtain the dry mass relationship with the area.

Root collection was performed during full flowering at the same time for all cultivars, three replicates per plot were collected. The collection was carried out through a monolith with a volume of 1485.2 cm^3, the dimensions of which were 20 cm deep, 15.8 cm wide (between lines) and 4.7 cm long, which was inserted so that the between line was in the centre of the width. The monoliths were submerged in dispersant (NaOH at 0.05 Mol L^{-1}) for 24h. They were then washed in running water with the aid of a 2 mm sieve, after which the samples were properly cleaned and kept in the refrigerator in solution with water and toluene (0.25 ml). Subsequently, root length measurement was performed using the method described by TENNANT (1975) and the estimated volume through wet weight and the Root Surface Area (RSA) by the ratio between volume and length.

For evaluation final grain yield, three repetitions per plot were used. The collections were carried out in a square meter and then traced, dried in a forced ventilation oven at a temperature of 60 ºC, cleaned in equipment for small and heavy samples on a precision scale. The obtained masses were corrected for the humidity of 13%. The correction in the moisture content allows uniform weight for the same moisture content in the grain, and the value of 13% was chosen because it is the moisture content in which the rice grain must be stored.

Calculation methodology and data analysis

Growth analysis was performed by adjusting sigmoid logistic equations with three parameters, for the accumulation of Dry Matter of the Aerial Part (DMAP) and Dry Matter of the Panicle (DMP) according to ALVAREZ, R. De C. F. et al. (2006); FELIX ALVAREZ; COSTA CRUSCIOL; STEPHAN NASCENTE (2012). So that the regression adjustment was performed using the SigmaPlot software with Equation 1, with f Dry Matter (DM) expressed in g m^{-2} and x the time in Days After Emergency (DAE).

$$DM = a/(1 + exp(-(x-x0)/b)) \quad (1)$$

Where: a is the parameter that delimits the maximum point of the curve; b is the parameter that defines the maximum slope of the curve; and parameter x0 establishes the value of x where y (DM) is equals to half of a.

Also evaluated were the Absolute Growth Rate (AGR), obtained through the derivative of the equation adjusted for DM and expressed in g m^{-2} day^{-1} shown in Equation 2 according to (ALVAREZ, Rita De Cassia Felix; CRUSCIOL; NASCENTE, 2012), and the Relative Growth Rate (RGR) obtained through the quotient of AGR and DMAP expressed in g g^{-1} day^{-1} as shown in Equation 3 according to (ALVAREZ, Rita De Cassia Felix; CRUSCIOL; NASCENTE, 2012). Where M is the mass in grams and T the time in days.

$$\text{AGR} = \frac{dM}{dT} \quad (2)$$

$$\text{RGR} = \frac{\text{AGR}}{DMAP} \quad (3)$$

Equation 1 was also used to analyze the accumulation of N in the aerial part and in the panicle, with f N accumulated in the DM in the unit of g m^{-2} and x the time in DAE. Through the derivative of the adjusted equation for the accumulation of N, the Absolute Absorption Rate (AAR) expressed in g N m^{-2} day^{-1}, Equation 4, proposed based on Equation 2 of AGR was obtained. And finally, the Specific Utilization Rate (SUR) was obtained through the ratio between AGR and the Total Accumulated Nitrogen (TAN) having as units g g^{-1} N Day^{-1} Equation 5. MN being the mass of N in grams and T the time in days.

$$\text{AAR} = \frac{dMN}{dT} \quad (4)$$

$$\text{SUR} = \frac{\text{AGR}}{TAN} \quad (5)$$

To analyze the efficiency of N, the following parameters were used, all estimated from the functions adjusted for the primary data: Apparent Nitrogen Recovery (ANR) obtained by the ratio between the difference of N accumulation with and without N application and the dose application of N fertilizer expressed as a percentage according to Equation 6 (FAGERIA; SANTOS; CUTRIM, 2007). Nitrogen Use Efficiency (NUE) obtained by the quotient between DMAP and TAN expressed in g g^{-1} of N described in Equation 7 (MARIOT et al., 2003). Physiological Nitrogen Use Efficiency (PNUE) obtained through the ratio between Grain Yield (GY) and TAN expressed in g g^{-1} of N described in Equation 8, according to BORIN et al (2013). Agronomic Assessment of Nitrogen Use Efficiency (AANUE) obtained because of the difference in grain yield with and without N application and the applied N dose expressed in g g^{-1} of N and described in Equation 9.

$$\text{ANR} = \frac{MN150 - MN0}{D150} \quad (6)$$

$$\text{NUE} = \frac{\text{DMAP}}{NAT} \quad (7)$$

$$\text{PNUE} = \frac{\text{GY}}{NAT} \quad (8)$$

$$\text{AANUE} = \frac{\text{P150} - \text{P0}}{D150} \quad (9)$$

Where: MN150 is the accumulated mass of N at a dose of 150 kg ha^{-1} of N in g m^2; MN0 is the accumulated N mass without application of N in g m^{-2}; D150 dose of 150 kg ha^{-1} of N; GP grain yield in g m^{-2}; P150 grain yield at the dose of 150 kg ha^{-1} of N in g m^{-2}; P0 grain yield without application of N in g m^{-2}.

Statistical analysis

To interpret the N dilution in the total dry matter (TDM), potential equations with two parameters were adjusted according to the function presented in Equation 10 (GASTAL; LEMAIRE, 2002), which was adjusted by the R software. Being f the level of N in percentage and x time in DAE (where x≥1); so that, a defines the highest point of the curve (greatest y) and b define the level at which y stops falling (where b < 0).

$$f = ax^b \quad (10)$$

Some attributes were submitted to ANOVA and when significant to the Tukey test ($P < 0.05$). The confidence interval assessed variables over time at a 95% significance level. A Pearson correlation was made between the attributes and parameters of the evaluated plants. All analysis of the data was conducted in the R statistical environment (R CORE TEAM, 2020) with particular use of the packages nlme and ggplot2 (PINHEIRO; BATES, 2022). Principal component analysis was carried out where all the attributes and parameters of the analyzed plants were vectored to understand better the variations observed concerning the cultivar cycle and the N dose. For PCA analysis, the statistical software R was used.

RESULTS

Grain yield and root surface area

The medium cycle cultivar was more productive than that of the short cycle, in both N levels (Figure 2). The medium cycle cultivar produced 9450 and 11640 kg ha^{-1}, at levels of zero N and 150 kg ha^{-1} of N respectively, whereas the short cycle cultivar showed a grain yield of 7100 kg ha^{-1} without N and 10110 kg ha^{-1} with N fertilization (Figure 2). The response in root growth occurred more pronounced in

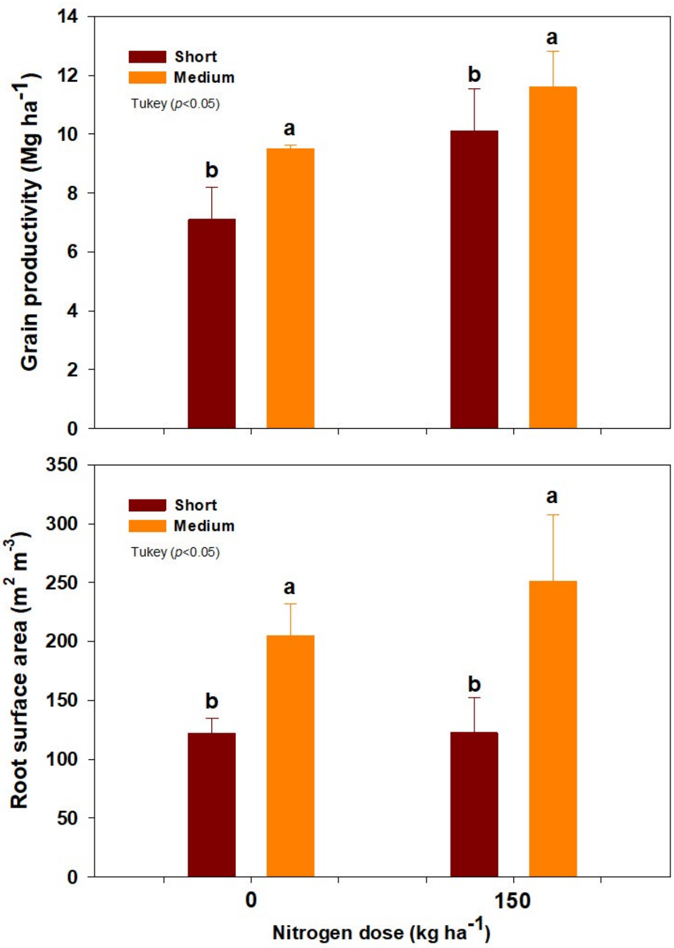

Figure 2 - Grain yield (A) and root surface area (B) of medium and short cycle cultivars submitted to two nitrogen levels, 0 kg N ha^{-1} and 150 kg N ha^{-1}. Vertical bar shows average data of 3 replicates. Error bars show standard deviation. Tukey ($P < 0.05$) compares the cultivars at the respective dose.

the medium cycle cultivar, which had an increase of 46 m^2 m^{-3} in the area explored by the roots by volume of soil, increasing from 205 m^2 m^{-3} to 251 m^2 m^{-3}. The short cycle cultivar showed no increase in the area explored by the roots, exploring 122 m^2 m^{-3} of soil with and without application of N fertilization (Figure 2).

Leaf area index (LAI)

The cultivars studied when cultivated without N fertilization had low leaf area indexes, 3.6 m^2 m^{-2} in the medium cycle cultivar and 2.8 in the short cycle cultivar, both below the critical LAI. When grown with the application of 150 kg N ha^{-1}, these showed a considerable increase in the LAI, with 2.8 m² of photosynthetically active leaf per m² of cultivation in the medium cycle and 2.7 in the short cycle (Figure 3). Thus, the precocious reached 5.5 LAI being within the ideal range, and cultivar with a medium cycle 6.4 above the critical LAI. Thus, in the medium cycle, the ideal LAI could be achieved with a lower N fertilization.

Dry matter of the aerial part (DMAP) and absolute growth rate (AGR)

The adjustments obtained for DMAP showed a high degree of significance for both models,

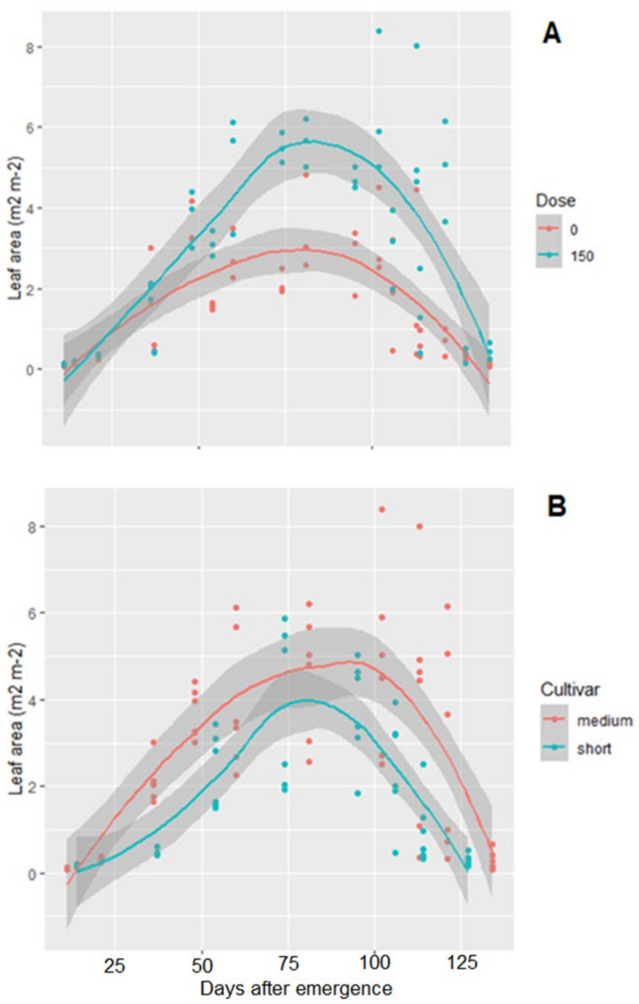

Figure 3 - Temporal variation of the leaf area index (LAI) for nitrogen dose (A) and cultivar cycle (B) in irrigated rice submitted to two nitrogen levels: 0 kg N ha^{-1} and 150 kg N ha^{-1}. Shaded areas represent 95% confidence bands of model fits.

with a significance level of less than 0.01% by the F test. It was observed that the higher doses reflected in higher DMAP and that, regardless of the dose, the medium cycle cultivar showed higher DMAP than short cycle cultivar (Figure 4). Responses to the application of N fertilizer in the production of DMAP in the medium cycle cultivar represented an increase from 1899 g m^{-2} to 2588 g m^{-2} with an increase of 689 g m^{-2} equivalent to 27%, according to the model estimate for the end of the cycle. In the short cycle cultivar, the increase, estimated by the model for the end of the cycle, went from 1727 g m^{-2} to 2232 g m^{-2}, increasing 505 g m^{-2} in DMAP, representing a 23% increase. The medium cycle cultivar showed a greater response in the production of biomass to N applied, because, in addition to having developed more DMAP, and it obtained an absolutely and proportionally greater increase in the accumulation of biomass. However, this greater response in biomass did not result in a greater response in grain production, since the increase in grain yield was greater in the short cycle cultivar (Figure 2). Regarding the absolute growth rate, a higher growth rate was observed at the 150 N dose and in the early cycle cultivar close to 80-90 DAE (Figure 5). Figure 6 shows the difference in growth of rice plants of cultivar IRGA 417 in the

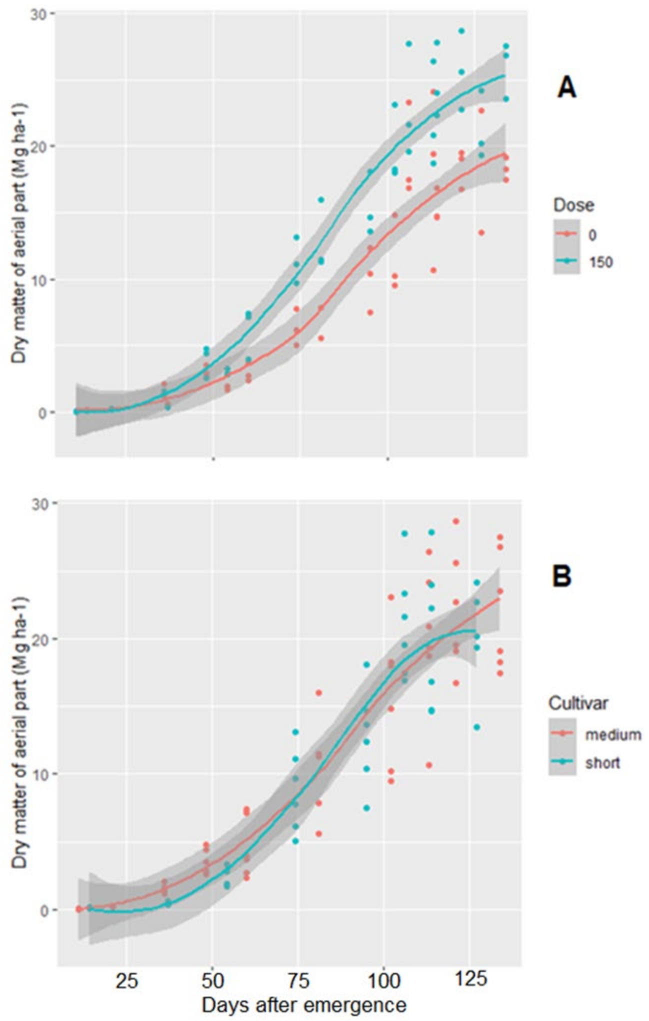

Figure 4 - Temporal variation of dry matter of aerial part (DMAP) for nitrogen dose (A) and cultivar cycle (B) in irrigated rice submitted to two nitrogen levels: 0 kg N ha^{-1} and 150 kg N ha^{-1}. Shaded areas represent 95% confidence bands of model fits.

tillering phase, with and without nitrogen fertilization, in addition to the chlorosis symptoms characteristic of N deficiency in plants without nitrogen fertilization.

Nitrogen accumulated in the aerial part and N use efficiency

As in the other variables analyzed, the accumulation of N was faster in the dose 150 N (Figure 7). When comparing cultivars, there was no greater N accumulation in the medium or short cycle cultivars (Figure 7). Note that the short cultivar has parameters b and x0 lower than the average cycle indicating that the accumulation of N in the biomass occurs more quickly in the short cultivar (Figure 7). The increase in TAN caused by N fertilization was much greater in the medium cycle cultivar (Figure 7), which for this reason obtained an Apparent Nitrogen Recovery (ANR) of 93%, while the short cultivar reached a RAN of 57% (Table 2). The Nitrogen Use Efficiency (NUE) and the Physiological Nitrogen Use Efficiency (PNUE) were higher in treatments that did not receive N. The Agronomic Assessment of Nitrogen Use Efficiency (AANUE) was higher in the short cultivar, being 20 g of grains per g of N and 14.6

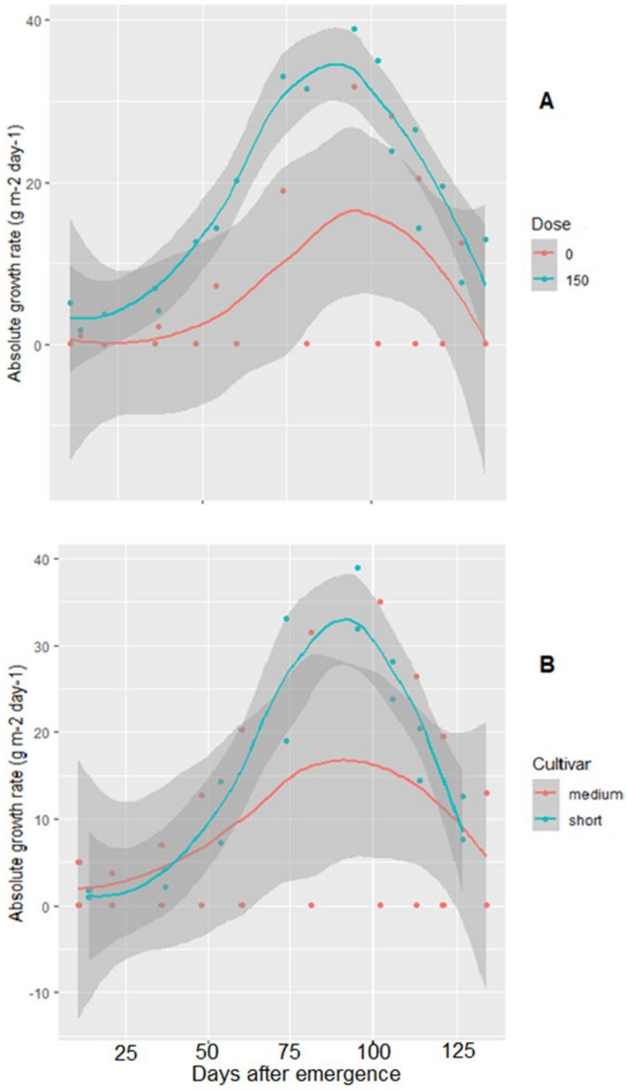

Figure 5 - Absolute growth rate for nitrogen dose (A) and cultivar cycle (B) in irrigated rice submitted to two nitrogen levels: 0 kg N ha^{-1} and 150 kg N ha^{-1}. Shaded areas represent 95% confidence bands of model fits.

g g^{-1} in the medium cycle (Table 2). Regarding the N level, the initial levels were relatively low, being 3.55 and 3.15% in the short cultivar with and without N, respectively (Figure 8). And in the medium cycle cultivar, the initial contents were 4.33 and 4.13% with and without N application, respectively. The treatments without N had a faster decay and reached very low levels of N in the tissue, according to the adjusted curve. The cultivar medium cycle reached a concentration of 0.75% and the short reached 0.81% at the end of the cycle.

Pearson correlation and and principal component analysis between the different attributes of rice plants evaluated

Regarding the Pearson correlation it was observed that the yield had a positive relationship with LAI, RSA, DMAP, DMP, TAN and N (Figure 9). And the NUE had a negative relationship with the LAI and DMP.

Figure 6 - Aspect of the plants in the tillering phase - in the foreground a plot of cultivar IRGA 417 with N application and in the background on the left the same cultivar without N application.

The sum of PC1 and PC2, 87.2% of all observed variations were obtained (Figure 10). In the PCA it is also observed that both in the cultivar cycle (medium and short) and in the doses (0N and 150N) there is a clear grouping. Regarding the grouping by cultivar cycle, it is observed that there are a large number of variables (nue, nue, agr, rsa, yield, dmap, tan) that converge to the medium cycle cultivar (Figure 10). Thus, the medium cycle cultivar has a greater N use efficiency and greater grain yield.

DISCUSSION

The medium cycle cultivar is able to exploit the resources of the environment and transform into grain production, as it presents a larger leaf area and a higher biomass production per cultivation area, in addition to a larger root area per volume of soil, these characteristics revert to production. However, the short cultivar showed a greater increase in grain yield, even with an increase in LAI equal to the average cultivar, indicating that it is a genotype more responsive to N fertilization. Recent research observed that longer-cycle rice "indica" varieties had higher N utilization efficiency and higher yields than shorter cycle rice varieties (SHARMA et al., 2018).

If the growth pattern of a cultivar is well known, DMAP can be a useful tool to estimate its growth, thus assisting in deciding the amount of N to be applied. The greatest increase in the mass of panicles in the medium cycle cultivar may be because this cultivar continues tilling practically until the end of the cycle in the treatment with the application of N, always generating new panicles. (HUANG, M. et al., 2016). HUANG et al. (2019) also observed greater grain yield when there is greater biomass production, the greater relative efficiency of N uptake and N accumulation after flowering. Dry matter production is directly influenced by solar radiation captured by plants. In addition, the DMAP is an attribute that is related to greater N utilization efficiencies and that is related to higher grain yield (HUANG, M. et al., 2016).

The increase in leaf area benefited photosynthesis, accumulating more photoassimilates that is reversed in grain production. The increase in LAI also causes greater transpiration of the plant, due to the greater surface area of transpiration, consequently the absorption of nutrients increase through a greater mass flow. The increase in the root surface area allowed a greater absorptions of nutrients, ensuring better plant nutrition. In this way, the average

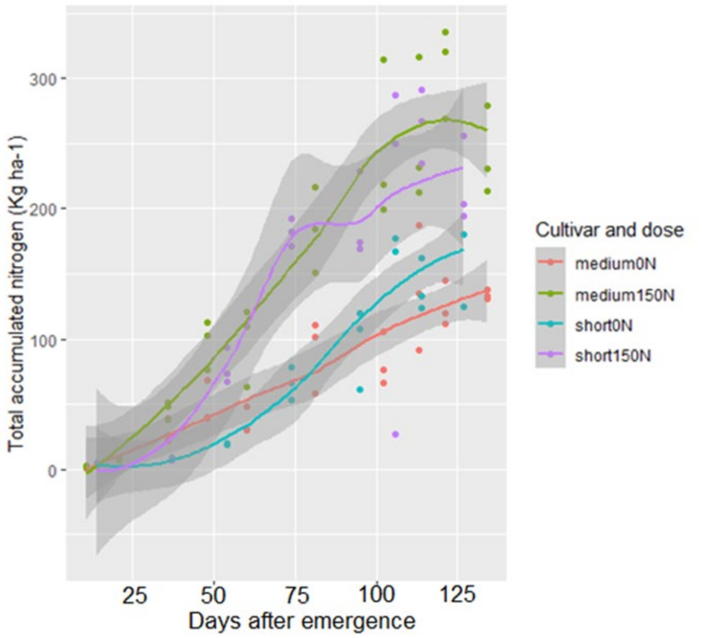

Figure 7 - Total accumulated N (TAN) for nitrogen dose and medium and short cycle cultivars of irrigated rice submitted to two N levels: 0 kg N ha^{-1} and 150 kg N ha^{-1}. Shaded areas represent 95% confidence bands of model fits.

cultivar increased the capacity to exploit the nutrients made available by the soil, together with the demands for nutrients to achieve greater grain yield. The short cultivar, on the other hand, increased grain yield and consequently demand with N fertilization but did not increase its capacity to absorb nutrients through the increase in RSA. This may be one of the factors that prevent the precocious one from reaching grain yield levels as high as medium cycle cultivars. So that the short cultivar has a higher AGR in the two doses of N when compared to the cultivar medium cycle. When comparing the growth rates obtained with those presented by other authors (ALVAREZ; CRUSCIOL; NASCENTE, 2012) it is noted that the two cultivars have a higher AGR, with early cycle cultivar reaching double the value presented by this author. Possibly

Table 2 - Dry matter of the Aerial Part (DMAP), Total Accumulated Nitrogen (TAN), Apparent Nitrogen Recovery (ANR), Nitrogen Utilization Efficiency (NUE), Physiological Nitrogen Utilization Efficiency (PNUE), and Agronomic Assessment of Nitrogen Use Efficiency (AANUE) for medium and early cycle irrigated rice cultivars submitted to two levels of nitrogen: 0 kg N ha^{-1} and 150 kg N ha^{-1}. The values of DMAP, TAN, N%, ANR, NUE and PNUE were estimated at physiological maturation from the previously adjusted models. Tukey (P < 0,05).

Cultivar	Dose of N	DMAP	TAN	N%	ANR	NUE	PNUE	AANUE
	kg ha^{-1}	--------------kg ha^{-1}-------------				-------------------------g g^{-1}-------------------------		
Short	0	17270 b	16.2 b	0.81 b	--	106 a	44^{ns}	--
	150	22320 a	24.8 a	1.26 a	57	90 b	41	20.1
Medium	0	18990 b	13.3 b	0.76 b	--	143 a	71 a	--
	150	25880 a	27.3 a	1.19 a	93	95 b	43 b	14.6

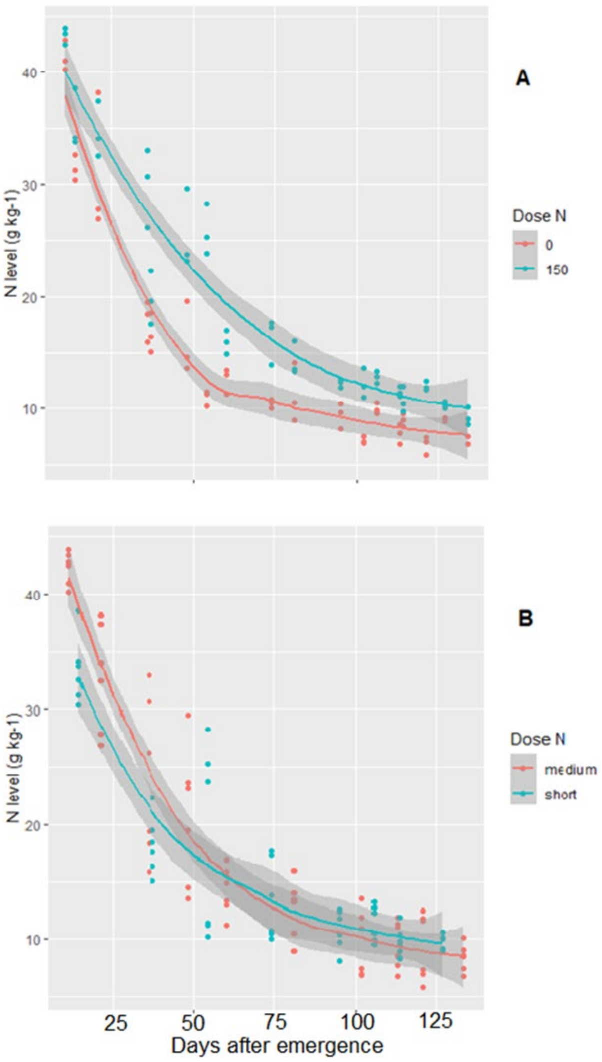

Figure 8 - Nitrogen level for N dose (A) and cultivar cycle (B) in irrigated rice submitted to two N levels: 0 kg N ha^{-1} and 150 kg N ha^{-1}. Shaded areas represent 95% confidence bands of model fits.

since the cultivars in the present study are cultivated under flood irrigation, which, in general, results in a more favourable condition for rice development. In work carried out by ALVAREZ et al 2012, upland rice was carried out only with supplementary irrigation and with older cultivars, which in general have less productive potential.

When we compare the ANRs obtained in this resarch with those presented by BORIN et al. (2013), using the medium cycle cultivar, we found similar results that have an average of 80%, varying between 49 and 138%. However, FAGERIA et al (2007) reached lower ANR in rainfed rice ranging between 23 and 37%, with an average of 29%. One of the factors that can contribute to high apparent N recovery by the medium cycle cultivar is its larger root surface area. In this way, the N absorbed more by the treatment with N fertilization comes not only from the absorption of the applied N, but also from the N made available by the soil. Since the higher RSA allows the medium cultivar to exploit the resources better available in the soil, consequently absorbing

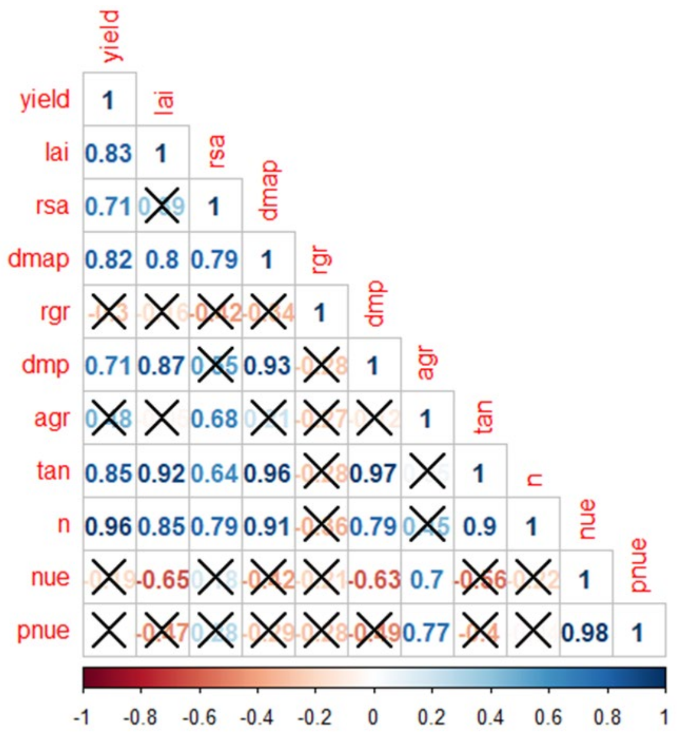

Figure 9 - Pearson correlation between the different attributes of rice plants evaluated in two doses of N and cultivars of short and medium cycle. lai: leaf area index, rsa: root surface area, dmap: dry matter of the aerial part, rgr: relative growth rate, dmp: dry matter of panicle, agr: Absolute Growth Rate, tan: total accumulated N, n: level of N, nue: N use efficiency and pnue: physiological N use efficiency. Significant at $P < 0.05$.

more N. In addition to the roots, the increase in the leaf area (Figure 3) can also contribute to the increase in N absorption because with its addition, the plant has greater transpiration, generating a greater mass flow of the nutrient.

The NUE of this research are superior to those presented by LOPES (1996) and LOPES (2000), which were respectively 11.8, 4.68 and 9, 99 grams of grains per gram of N. The results reported in these two works have lower NUE because they have older cultivars that are less responsive to N. In addition, there has recently been the adoption of new management practices that increase the use of N in the fertilizer by the crop, such as the application of the first N fertilization before flood irrigation and anticipation of the sowing time, which is favourable to an adequate development of the crop, and, consequently, use of Nitrogen from fertilization. They are similar to those reported by FAGERIA et al. (2007) and BORIN et al. (2013). When there was an adequate supply of N, the concentrations according to the adjusted functions were 1.18 and 1.26% of N for the medium and short cycle cultivars, respectively, very similar to the values reported in WITT et al. (1999) in Asia, FAGERIA; PRABHU (2004) in Central Brazil and MUELLER (1980) in South Brazil for maximum grain yield. There is a small difference between the levels of the cultivars, with the short cultivar having a slightly higher content in the two levels of N.

Cultivars that are more efficient in absorbing N have higher yields and dry matter gain as they have higher root oxidation activity and active root uptake surface area for N uptake and higher abscisic acid and cytokinin content in the medium and late growth stages (XIN et al., 2021).

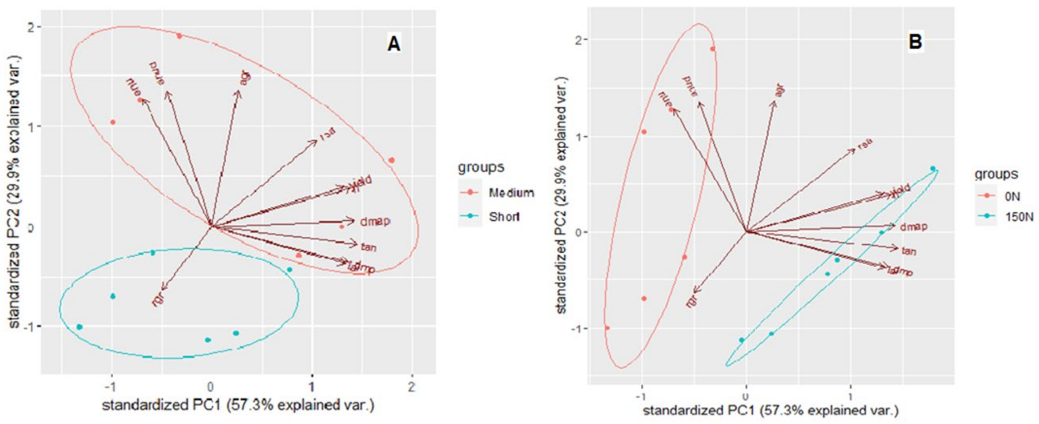

Figure 10 - Principal component analysis comparing medium and short cycle cultivars (A) and N doses (B). lai: leaf area index, rsa: root surface area, dmap: dry matter of the aerial part, rgr: relative growth rate, dmp: dry matter of panicle, agr: Absolute Growth Rate, tan: total accumulated N, n: level of N, nue: N use efficiency and pnue: physiological N use efficiency. Significant at $P < 0.05$.

The NUE for irrigated rice cultivars is the target of studies in several places in the world, the genetic improvement, aims to explore genes of interest that contribute to the expression of the best use of N (ISLAM, 2019; WANG et al., 2018). Contrary to what was observed in this study, short maturation varieties can have rapid initial development and, under appropriate conditions of sowing time, can result in better yields (AKTER et al., 2019). In general, NUE and grain yield can be affected by several factors inherent to cultivars, such as application rate, plant density and light interception, which is also influenced by the plant's morphological structure and irrigation (HOU et al., 2019).

Thus, this research makes possible to have a greater knowledge of the dynamics and response of short and medium cycle cultivars to nitrogen fertilization, thus assisting in a more efficient management of nitrogen with greater economic return and less potential damage to the environment.

CONCLUSION

The medium cycle cultivar has a greater capacity to explore the environment due to the larger area of the root system and greater leaf area, which gives the greater capacity to explore the resources of the environment. Under N fertilization, the increase in leaf area and root system of the medium cycle cultivar is even greater than that of the short cycle cultivar.

The medium cycle cultivar demands less N per unit of total dry matter and impacts on greater Nitrogen Utilization Efficiency and Nitrogen Utilization Physiological Efficiency. Grain yield is similar in both cultivars with the expected increases in N. However, in absolute numbers the productivity in the medium cycle cultivar is higher because it has a greater capacity to exploit the resources of the environment.

DECLARATION OF CONFLICT OF INTEREST

The authors declare no conflict of interest in this article.

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AUTHORS' CONTRIBUTIONS

All authors contributed equally for the conception and writing of the manuscript. All authors critically revised the manuscript and approved of the final version.

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