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IMPACT OF SOWING DATES ON THE YIELD EFFICIENCY OF UPLAND RICE CULTIVARS

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Abstract
The choice of cultivars adapted to different regions and the determination of the best sowing dates are indispensable tools for crop development. This allows the installation of the crop in times favorable to its development, as well as cultivars that manage to reach their maximum yield potential. The objective of this study was to determine the best sowing dates and the cultivars that can adapt to the low-altitude Cerrado region and have the best development and yield efficiency. The experiment was conducted on a typical clayey dystrophic Red Latosol soil. The experimental design was in randomized blocks in a factorial scheme, comprised by four sowing dates during the spring/summer season (October, November, December, and February) and in each sowing date there were eight upland rice cultivars (BRS Esmeralda, ANa 6005, ANa 5015, IPR 117, IAC 203, IAC 500, ANa 7211 and BRSGO Serra Dourada) with four replicates. Sowing in October and November benefited the aerial dry mass and the spikelets fertility however, sowing in November provided higher plant height, which caused lodging in plants. Sowing in December caused the incidence of scald, mainly affecting the cultivar ANa 7211. For all cultivars, sowing in October favored the yield efficiency of upland rice in the low-altitude Cerrado, followed by sowing in November. The cultivars which demonstrated higher yield efficiency in the conditions of the region were BRS Esmeralda and ANa 5015.

Keywords: Cerrado. Global solar radiation. *Oryza sativa* L. Sprinkler irrigation.

1. Introduction

Forecasts indicate that by 2025 the world rice demand will increase by 8.4%, creating the need to increase rice production by 43,350.32 thousand tons compared to 2018 (OECD and FAO 2019); the increase in rice demand in underdeveloped countries will be 14% (11,860.74 thousand tons). Aggravating this is the estimated water scarcity of 2025, caused by climate change, which will affect rice produced in flooded systems, thus emphasizing the need for the use of alternatives in rice cultivation (IRRI 2018).

The production of upland rice with supplementary irrigation is a system that reduces water consumption for cultivation and results to yields similar to the average yields of flood-irrigated systems; this was observed by Vories et al. (2017) who cultivated rice under center pivot and obtained a productivity of 8,000 kg ha^{-1}.

The choice of cultivars with high yield potential, which adapt to each region, is fundamental for the increase of productivity and, consequently, of production. Although the cultivar's yield characteristics are important, other characteristics should also be considered when choosing the right cultivar; these characteristics include small size to avoid plant lodging, plant architecture with smaller and upright leaves, intensification of solar radiation use (Sher et al. 2017), and resistance to major pests and diseases (Wang and Peng 2017).

Plant biomass depends on the radiation intercepted by the leaves and on their ability to convert radiation energy into photoassimilates through photosynthesis (Behling et al. 2015). In addition, light is required for biochemical processes in the plant, promoting the regulation of Calvin-Benson cycle enzymes (Taiz et al. 2017).

Climatic aspects such as CO_2, rainfall, temperature, and solar radiation (Raoufi and Soufizadeh 2020) affect the development of each cultivar. Temperatures below 20 °C may lead to uneven maturity and spikelet sterility; temperatures above 35 °C can also cause spikelet sterility. Thus, cultivars differ in their response to temperature, with some being more tolerant during one stage of development but less tolerant during another (Yoshida 1981).

Since there are climatic variations during each cultivation period, the cultivation time of each cultivar is a factor that interferes in its development; therefore, the control of the cultivation time allows the farmer to expose the crop to more suitable conditions so that its maximum yield potential can be achieved. Ferrari et al. (2018) identified that the AN Cambará and ANa 5015 cultivars are the most suitable for cultivation in Vale do Ribeira (Brazil); sowing in November and December provide more favorable conditions for rice cultivation.

According to Arf et al. (2000), the recommended sowing date for rice cultivation in the low-altitude Cerrado region is November; however, this study was carried out over 20 years ago and, currently, there are new cultivars that have been made available by breeders.

The objective of the study was to identify the best sowing date and the cultivars that can adapt to the low-altitude Cerrado region and lead to better development and high yield efficiency.

2. Material and Methods

Characterization of the experimental area

The experiment carried out in the municipality of Selvíria, Mato Grosso do Sul, Brazil, during the 2016/17 season, at the experimental area of São Paulo State University (51º22' W 20º22' S), Ilha Solteira campus. The altitude was 335 m. The local soil is typical clayey dystrophic Red Latosol (Santos et al. 2018). In the 2015/16 harvest, the area was cultivated with soybean and then was left fallow until the time of the experiment.

The chemical characteristics of the soil were determined before the experiment, according to the methodology described by Raij et al. (2001), and were as follows: Organic Matter (O.M.) = 18 g dm^{-3}; P (resin) = 16 mg dm^{-3}; pH ($CaCl_2$) = 4.8; K^+, Ca^{2+}, Mg^{2+}, H + Al, and Al^{3+} = 8.4, 12, 12, 15, and 0 mmolc dm^{-3}, respectively; V = 68%.

Experimental design and climatic conditions

The experimental design was in randomized blocks with four sowing dates, each with eight upland rice cultivars and four replicates. Sowing took place on 10/13/16, 11/9/16, 12/15/16, and 2/16/17. It was not possible to sow in January due to the high rainfall that prevented soil tillage and sowing. The data for maximum and minimum temperature, rainfall and global radiation are shown in Figures 1A and B.

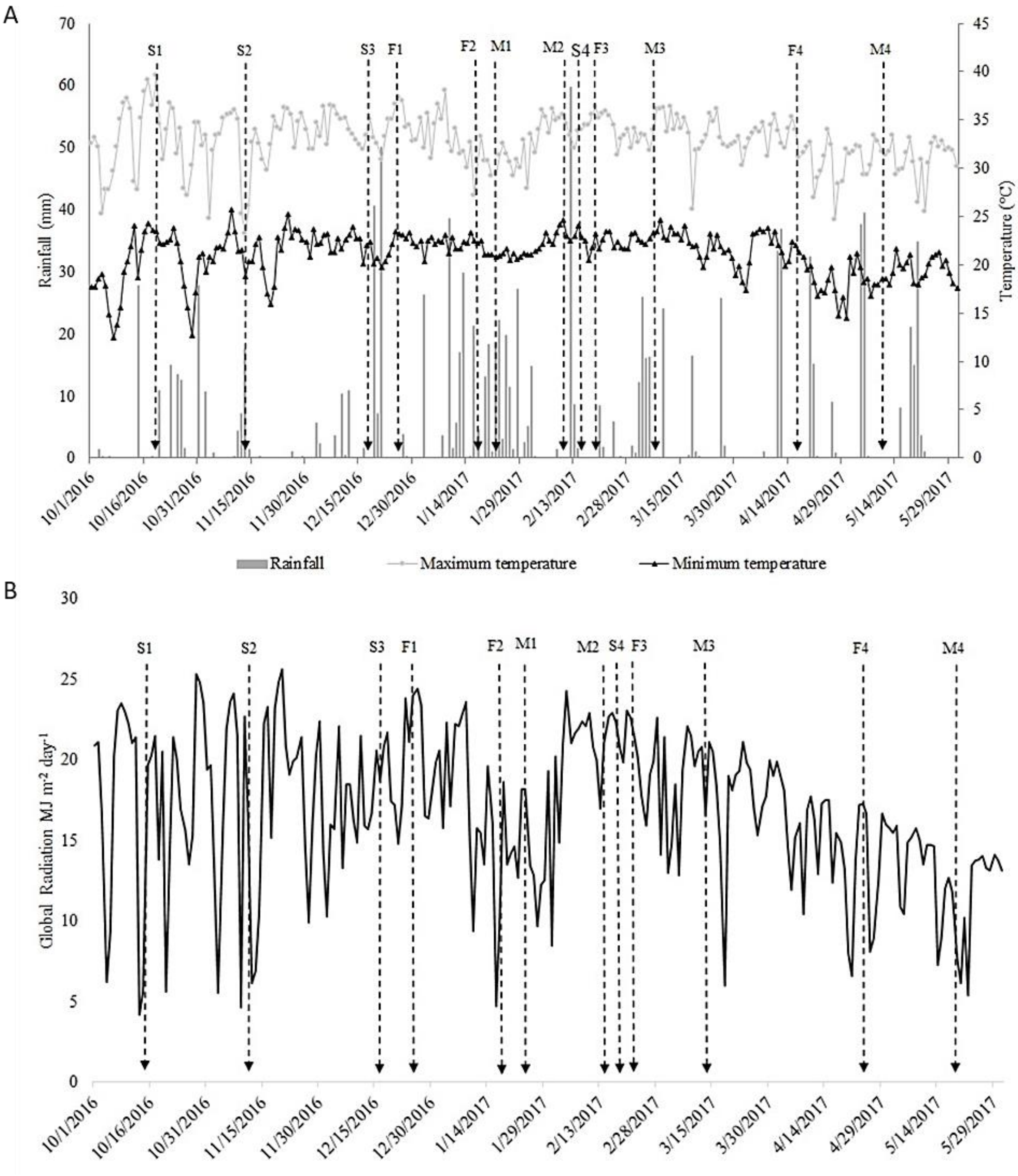

Figure 1. Data from daily rainfall daily, air minimum and maximum temperature (A). Global radiation (B) obtained in the experimental period, in season 2016/17. The sowing dates was represented by: S1, S2, S3, S4; the beginning of flowering was represented by: F1, F2, F3, F4; the beginning of maturation was represented by: M1, M2, M3, M4, in sowing times referring October, November, December and Feburary, respectively.

The rice cultivars were: BRS Esmeralda, ANa 6005, ANa 5015 and BRSGO Serra Dourada, which are classified as intermediate types; IPR 117, considered a traditional type; IAC 500, ANa 7211 and IAC 203, which fit the modern type.

Each plot consisted of six lines 4.5 m long, spaced 0.35 m between rows. The useful area was constituted by four central lines, considering the lateral lines as borders.

Set up and conduction of field experiments

The soil was managed with one plow and two harrows prior to the installation of the rice crops. Sowing fertilization was performed manually by using 250 kg ha^{-1} of the formulation 08-28-16, according to the recommendations of Cantarella et al. (1997). Seeds were treated with pyraclostrobin [5 g of active ingredient (a.i.) per 100 kg of seed], methyl thiophanate (45 g a.i. per 100 kg of seed), and fipronil (50 g of a.i. per 100 kg of seed), before sowing. Sowing was performed with 70 kg ha^{-1} seeds, manually.

To control weed, we used herbicides pendimethalin, 1,400 g ha^{-1} a.i. at pre-emergence, and metsulfuron-methyl, 2 g ha^{-1} a.i. after sowing, and at post-emergence [13 days after emergence (DAE)].

At 28 DAE, topdressing was performed with 60 kg ha^{-1} of nitrogen (N) in the form of ammonium sulfate. At the time of flowering, we applied trifloxystrobin + tebuconazole (75 + 150 g ha^{-1} a.i.) in order to prevent blast occurrence; and to control stink bugs we applied thiamethoxam (25 g ha^{-1} a.i.).

A conventional sprinkler irrigation system with an average precipitation of 3.3 mm h^{-1} was used for water supply. For water management, three coefficients were considered throughout the rice cycle. The value of 0.4 was considered during the vegetative phase of the plants. Two coefficients were considered during the reproductive phase, the initial value of 0.70 and the final of 1.00. These values were inverted during the rice maturation phase. When 90% of the panicles were mature, manual harvesting was performed.

Analysis

The following characteristics were evaluated:

Leaf N content, obtained by collecting leaf limbs of twenty flag leaves per plot, which were ground after having been dried and submitted to sulfuric digestion, according to the methodology proposed by Malavolta et al. (1997).

Aerial dry mass, determined by collecting 0.6 m of shoot line per plot. After being oven-dried to reach a constant weight, the dry mass was obtained.

Plant height (cm), being the distance between the soil surface and the upper end of the highest panicle at five points of each plot, in the grain filling stage.

Lodging, determined by visual observations at the maturation stage, by using the following rating scale: 0 - no lodging, 1 - up to 5%, 2 - 5 up to 25%, 3 - 25 up to 50%, 4-50 up to 75%, and 5-75 up to 100% of lodged plants.

Total number of spikelets $panicle^{-1}$, obtained by averaging the amount of grains of twenty panicles, which were collected at the harvest in each plot.

Leaf scald, estimated visually and based on the severity of the attack. A score was assigned to designate the severity of the disease by using the following rating scale (EMBRAPA, 1977): 0 - no infection; 1 - less than 1% of the leaf area was affected; 3 - 1% to 5% of the leaf area was affected; 5 - 6% to 25% of the leaf area was affected; 7 - 26% to 50% of the leaf area was affected; 9 - 51% to 100% of the leaf area was affected.

Spikelet fertility, determined by the ratio of the number of filled spikelets per panicle to the total number of spikelets per panicle and multiplied by 100.

Yield efficiency, determined by the ratio of grain yield (kg) to aerial dry mass obtained at flowering (kg).

Statistical analysis

An analysis of variance was performed for each sowing date. When homogeneity of residual mean squares (Banzatto and Kronka 2006) was found the experiments were analyzed jointly. The Tukey test (5% probability) was used for sowing dates and the Scott-Knott test (5% probability) was used for cultivars.

3. Results

There was a significant interaction between cultivars × sowing dates for leaf nitrogen content and aerial dry mass (Table 1). The BRS Esmeralda, ANa 6005, ANa 5015, and IPR 117 cultivars had higher N leaf contents in relation to the other cultivars in all sowing dates; their averages were approximately 19.8% higher than the averages of the other cultivars.

For cultivars ANa 6005, IPR 117, and IAC 203 there was no difference in leaf N content among sowing dates. In the cultivar BRS Esmeralda, the sowing performed in November stood out in relation to the October and February sowings, while the ANa 5015 cultivar sown in October had a higher N leaf content compared to the corresponding cultivar sown in February.

Table 1. Average values of leaf N content (g kg^{-1}) and aerial dry mass (kg ha^{-1}) at flowering of rice cultivars at different sowing dates. Selvíria - MS, Brazil (2016/17).

Cultivars	Sowing dates				
	October	November	December	February	Avarage
			Leaf N content (g kg^{-1})		
BRS Esmeralda	32.90^{aB}	37.19^{aA}	33.44^{aAB}	31.03^{aB}	33.64^{a}
ANa 5015	37.08^{aA}	35.89^{aAB}	33.88^{aAB}	32.55^{aB}	34.85^{a}
ANa 6005	34.18^{aA}	36.33^{aA}	33.95^{aA}	32.34^{aA}	34.20^{a}
IPR 117	34.14^{aA}	34.28^{aA}	32.46^{aA}	33.02^{aA}	33.47^{a}
IAC 500	30.36^{bA}	30.40^{bA}	29.84^{bA}	24.24^{bB}	28.71^{b}
IAC 203	29.33^{bA}	29.77^{bA}	26.88^{cA}	26.11^{bA}	28.02^{b}
Serra Dourada	30.78^{bAB}	31.64^{bA}	28.09^{cAB}	26.97^{bB}	29.37^{b}
ANa 7211	30.52^{bAB}	31.55^{bA}	21.21^{dC}	26.83^{bB}	27.53^{b}
Avarage	32.41^{A}	33.38^{A}	29.97^{B}	29.14^{B}	31.22
F test					
Cultivars (C)	29.83 **				
Dates (D)	25.08 **				
CxD	2.36 **				
CV(%)	6.26				
			Aerial dry mass (kg ha^{-1})		
BRS Esmeralda	$11{,}564^{aA}$	$10{,}313^{aA}$	$10{,}073^{aA}$	$7{,}607^{aB}$	$9{,}889^{a}$
ANa 5015	$9{,}527^{bAB}$	$10{,}695^{aA}$	$8{,}341^{bAB}$	$7{,}538^{aB}$	$9{,}025^{b}$
ANa 6005	$11{,}649^{aA}$	$11{,}808^{aA}$	$10{,}786^{aA}$	$8{,}002^{aB}$	$10{,}561^{a}$
IPR 117	$9{,}703^{bAB}$	$11{,}186^{aA}$	$9{,}005^{bAB}$	$8{,}769^{aB}$	$9{,}666^{a}$
IAC 500	$10{,}061^{bA}$	$9{,}969^{aA}$	$8{,}449^{bA}$	$5{,}283^{bB}$	$8{,}441^{b}$
IAC 203	$12{,}491^{aA}$	$9{,}689^{aB}$	$7{,}923^{bB}$	$7{,}710^{aB}$	$9{,}453^{a}$
Serra Dourada	$10{,}957^{aA}$	$9{,}120^{aA}$	$9{,}307^{bA}$	$6{,}726^{bB}$	$9{,}028^{b}$
ANa 7211	$7{,}941^{bBC}$	$10{,}495^{aA}$	$10{,}100^{aAB}$	$7{,}413^{aC}$	$8{,}987^{b}$
Avarage	$10{,}487^{A}$	$10{,}409^{A}$	$9{,}248^{B}$	$7{,}381^{C}$	9,381
F test					
Cultivars (C)	4.26 **				
Dates (D)	41.29 **				
CxD	2.60 **				
CV(%)	13.60				

*p≤0.05, **p≤0.01 by the F test. CV: coefficient of variation. Averages followed by the same letter, lowercase in the column and uppercase in the row, do not differ from each other by the Scott-Knott and Tukey test at 5% significance, respectively. Minimum significant difference (MSD) for sowing dates 4.23 and 2,364.60 for leaf N content and aerial dry mass, respectively.

In cultivar IAC 500, the leaf N content was lower during the February sowing compared to the other sowing dates. The cultivar ANa 7211 presented higher leaf N content in the November sowing compared to the December and February sowings.

The studied factors (cultivars and sowing dates) also influenced significantly the aerial dry mass. The BRS Esmeralda, ANa 6005, BRSGO Serra Dourada and IAC 500 cultivars had the lowest dry matter mass in the February sowing compared to the other sowing dates (Table 1).

For the ANa 5015 and IPR 117 cultivars, the values were higher in the November sowing compared to the February one. The dry matter mass in cultivar IAC 203 was higher in the October sowing when compared to other sowing dates. The cultivar ANa 7211 had a higher value in the November sowing than in the October and February sowings.

In the sowing carried out in October, the BRS Esmeralda, IAC 203, BRSGO Serra Dourada and ANa 6005 cultivars stood out in relation to the others. There was no difference in aerial dry mass among the evaluated cultivars sown in November. The BRS Esmeralda, ANa 7211 and ANa 6005 cultivars had higher values in relation to the others during the December sowing. However, during the February sowing, only the IAC 500 and BRSGO Serra Dourada cultivars had a low dry mass.

From the interaction of cultivars × sowing dates, it was observed that the plant height of the cultivars BRS Esmeralda, IAC 500, ANa 5015, IAC 203, ANa 7211 and BRSGO Serra Dourada was higher in the October and November than in the December and February sowings (Table 2). For the cultivars ANa 6005 and IPR 117, the November sowing stood out from the others sowing dates.

Table 2. Average values of plant height (cm) of rice cultivars at different sowing dates. Selvíria - MS. Brazil (2016/17).

Cultivars	Sowing dates				
	October	November	December	February	Avarage
BRS Esmeralda	106.30^{bA}	112.25^{bA}	95.20^{bB}	88.20^{bC}	100.49^{b}
ANa 5015	109.70^{bA}	110.90^{bA}	96.25^{bB}	89.75^{bB}	101.65^{b}
ANa 6005	103.05^{cB}	112.00^{bA}	97.10^{bB}	84.70^{cC}	99.21^{b}
IPR 117	115.80^{aB}	123.70^{aA}	104.60^{aC}	102.25^{aC}	111.59^{a}
IAC 500	81.10^{eA}	74.90^{fA}	61.65^{eB}	47.95^{fC}	66.40^{f}
IAC 203	101.05^{cA}	106.40^{cA}	79.45^{cB}	74.60^{dB}	90.38^{c}
Serra Dourada	96.40^{dA}	97.80^{dA}	78.95^{cB}	76.60^{dB}	87.44^{d}
ANa 7211	82.65^{eA}	82.05^{eA}	71.80^{dB}	64.50^{eC}	75.25^{e}
Avarage	99.51^{B}	102.50^{A}	85.62^{C}	78.57^{D}	91.55
F test					
Cultivars (C)	253.43**				
Dates (D)	293.52**				
CxD	3.62**				
CV(%)	4.10				

*p≤0.05. **p≤0.01 by the F test. CV: coefficient of variation. Averages followed by the same letter, lowercase in the column and uppercase in the row, do not differ from each other by the Scott-Knott and Tukey test at 5% significance, respectively. Minimum significant difference (MSD) for sowing dates 2.46.

The IPR 117 cultivar showed greater height in all the sowing dates compared to other cultivars, while the IAC 500 and Ana 7211 cultivars had smaller height. In the BRS Esmeralda, ANa 5015, and ANa 6005 cultivars, height was lower than in the IPR 117 but higher than the other cultivars.

Lodging was observed in cultivar IPR 117 at all sowing dates (Figure 2). In the sowing carried out in November there was lodging in most of the evaluated cultivars, except for the IAC 500 and ANa 7211 cultivars, which had height lower than 0.85 m.

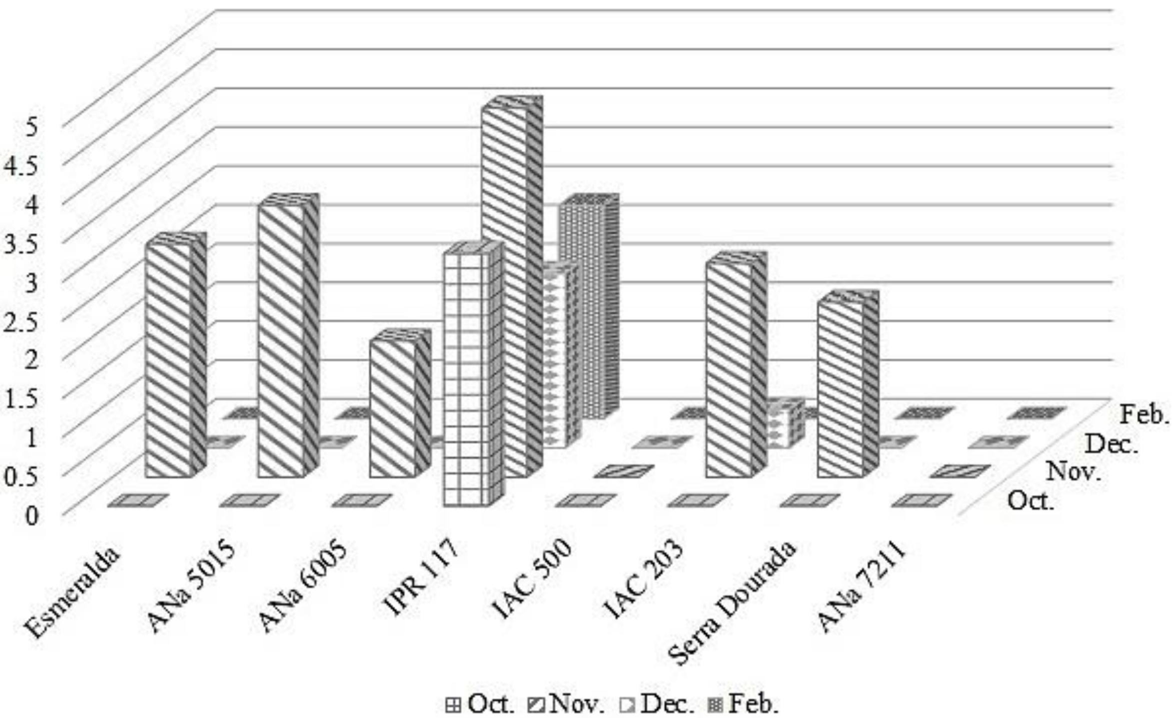

Figure 2. Lodging notes of rice plants of eight cultivars at different sowing dates. Selvíria - MS, Brazil (2016/17).

The effect of the studied factors on the number of total spikelets per panicle was examined; there was no difference in the number of total spikelets per panicles for the BRS Esmeralda and IPR 117 cultivars among the studied dates (Table 3).

Table 3. Average values of total spikelets panicle^{-1} of rice cultivars at different sowing dates. Selvíria - MS. Brazil (2016/17).

Cultivars	Sowing dates				
	October	November	December	February	Avarage
BRS Esmeralda	148^{bA}	130^{bA}	131^{bA}	128^{aA}	134^{b}
ANa 5015	134^{bA}	112^{cAB}	131^{bA}	103^{bB}	120^{c}
ANa 6005	130^{bA}	128^{bAB}	118^{bAB}	106^{bB}	120^{c}
IPR 117	123^{bA}	106^{cA}	106^{cA}	110^{bA}	111^{c}
IAC 500	128^{bA}	96^{dB}	84^{cB}	80^{cB}	97^{d}
IAC 203	137^{bA}	113^{cAB}	104^{cB}	102^{bB}	114^{c}
Serra Dourada	116^{bA}	91^{dB}	96^{cAB}	79^{cB}	96^{d}
ANa 7211	188^{aA}	170^{aAB}	148^{aB}	118^{aC}	156^{a}
Avarage	138^{A}	118^{B}	115^{B}	103^{C}	118
F test					
Cultivars (C)	36.95**				
Dates (D)	40.15**				
CxD	2.37**				
CV(%)	10.95				

*p≤0.05. **p≤0.01 by the F test. CV: coefficient of variation. Averages followed by the same letter, lowercase in the column and uppercase in the row, do not differ from each other by the Scott-Knott and Tukey test at 5% significance, respectively. Minimum significant difference (MSD) for sowing dates 24.06.

For the ANa 5015 and ANa 6005 cultivars, the number of total spikelets was higher in the October sowing compared to the February sowing. In general, the numbers of total spikelets were higher in the October sowing for the IAC 500, IAC 203, and BRS Serra Dourada cultivars. For cultivar ANa 7211, the number of spikelets decreased with late sowing (December and February).

The unfolding of cultivars in each sowing season, revealed that the ANa 7211 cultivar stood out from the others in the October, November, and December sowings. In the February sowing the highest values were observed in the BRS Esmeralda and ANa 7211 cultivars.

Regarding the evaluation of leaf scald, there was an incidence on plants sown in December (Figure 3). The greatest incidence occurred in cultivar ANa 7211, followed by cultivar ANa 6005. The occurrence of this disease was favored by the high precipitation in January. In addition, average temperatures in this period ranged from 22 to 32 °C, being ideal for disease development that has been observed to occur between 24 and 28 °C (Filipi et al. 2005).

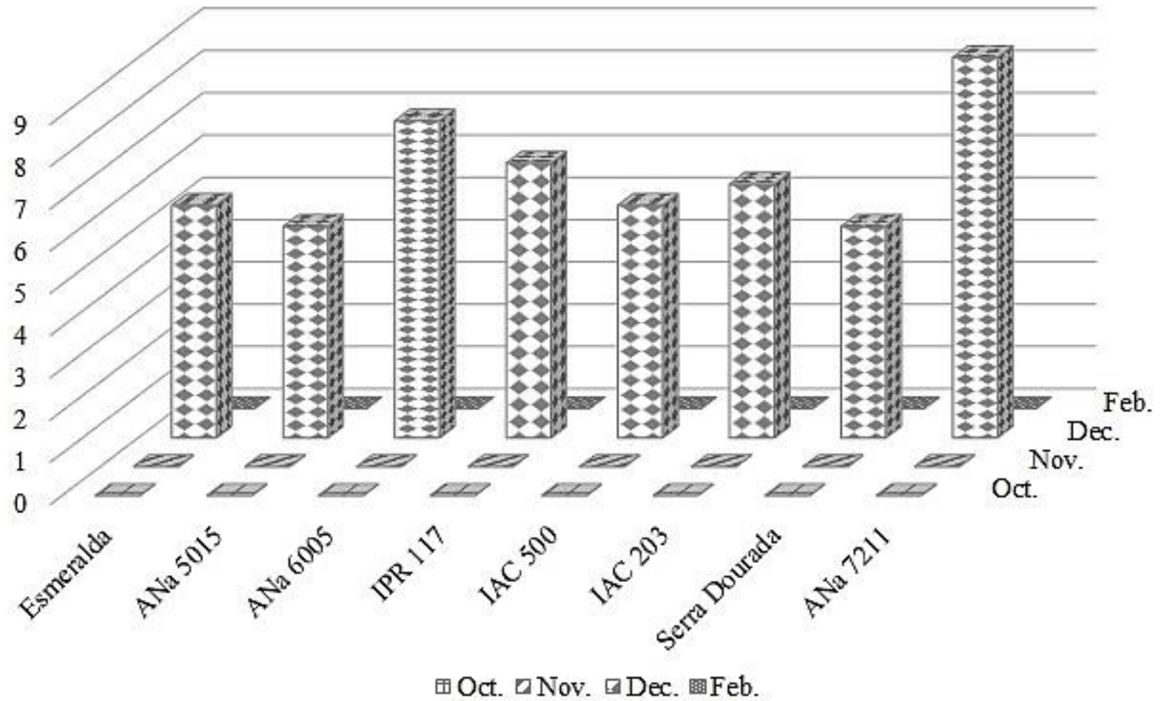

Figure 3. Scald notes on rice leaves of eight cultivars at different sowing dates. Selvíria - MS, Brazil (2016/17).

In the December sowing, spikelet fertility was lower for the ANa 5015, IAC 203, BRS Serra Dourada, and ANa 7211 cultivars (Table 4), while for cultivar ANa 6005, this value was lower in the February sowing compared to the other dates. For the IAC 500 and IPR 117 cultivars, the highest values were obtained from the October and November sowings.

Table 4. Average values of spikelets fertility (%) and yield efficiency of rice cultivars in different sowing dates. Selvíria - MS. Brazil (2016/17).

Cultivars	Sowing dates				
	October	November	December	February	Avarage
			Spikelets fertility (%)		
BRS Esmeralda	78.83^{aA}	77.69^{bA}	71.36^{bA}	74.44^{cA}	75.58^{d}
ANa 5015	84.98^{aA}	82.67^{bAB}	75.09^{bB}	80.67^{bAB}	80.85^{c}
ANa 6005	88.62^{aA}	80.65^{bA}	84.10^{aA}	72.08^{cB}	81.36^{c}
IPR 117	84.56^{aA}	82.05^{bAB}	71.38^{bC}	74.52^{cBC}	78.13^{d}
IAC 500	86.66^{aAB}	89.55^{aA}	82.17^{aAB}	81.28^{bB}	84.91^{b}
IAC 203	80.67^{aA}	78.32^{bA}	69.27^{bB}	74.28^{cAB}	75.64^{d}
Serra Dourada	90.50^{aA}	93.93^{aA}	80.00^{aB}	88.40^{aA}	88.21^{a}
ANa 7211	63.14^{bA}	58.95^{cA}	42.00^{cB}	63.67^{dA}	56.94^{e}
Avarage	82.24^{A}	80.48^{A}	71.92^{C}	76.17^{B}	78
F test					
Cultivars (C)	74.83 **				
Dates (D)	35.77 **				
CxD	3.72 **				
CV(%)	5.63				
			Yield efficiency		
Esmeralda	0.65aA	0.54^{aAB}	0.46^{aB}	0.44^{aB}	0.52^{a}
ANa 5015	0.60aA	0.48^{aBC}	0.50^{aBC}	0.40^{aC}	0.49^{a}
ANa 6005	0.48bA	0.44^{aA}	0.38^{aAB}	0.30^{bB}	0.40^{b}
IPR 117	0.53bA	0.46^{aAB}	0.40^{aAB}	0.36^{aB}	0.44^{b}
IAC 500	0.63aA	0.46^{aB}	0.40^{aB}	0.32^{bB}	0.45^{b}
IAC 203	0.41bA	0.42^{aA}	0.40^{aA}	0.40^{aA}	0.41^{b}
Serra Dourada	0.46bA	0.45^{aA}	0.34^{aA}	0.42^{aA}	0.42^{b}
ANa 7211	0.59aA	0.44^{aB}	0.19^{bC}	0.26^{bC}	0.37^{b}
Avarage	0.54A	0.46^{B}	0.38^{C}	0.36^{C}	0.44

F test	
Cultivars (C)	6.43**
Dates (D)	34.18**
CxD	2.37**
CV(%)	18.22

**p≤0.01 by the F test. CV: coefficient of variation. Averages followed by the same letter, lowercase in the column and uppercase in the row, do not differ from each other by the Scott-Knott and Tukey test at 5% significance, respectively. Minimum significant difference (MSD) for sowing dates 8.10 and 0.15 for spikelets fertility and yield efficiency, respectively.

The unfolding of cultivars in each sowing date, revealed lower fertility only in cultivar ANa 7211 compared to the other cultivars in all sowing dates. In the November and December sowings the highest fertility levels occurred in cultivars BRSGO Serra Dourada and IAC 500.

Yield efficiency indicates the amount of grain the plant produces for each kg of aerial dry mass. A significant interaction was observed between cultivars × sowing dates (Table 4). The cultivars IAC 203 and BRSGO Serra Dourada had similar values at different sowing dates.

For the ANa 5015, IAC 500, and ANa 7211 cultivars, the highest values were verified in October among all the sowing dates. The BRS Esmeralda cultivar had greater yield efficiency in the October sowing compared to the December and February ones. In the ANa 6005 and IPR 117 cultivars, these values were lower in the February than the October sowing.

In the unfolding of cultivars in each sowing date, we highlighted the BRS Esmeralda, ANa 5015, IAC 500, and ANa 7211 cultivars in relation to the other cultivars in the October sowing. In November, there was no difference among the cultivars. In December, only the ANa 7211 cultivar had a lower value compared to the others. In the February sowing, lower values were observed in cultivars ANa 6005, IAC 500, and ANa 7211.

4. Discussion

The present work showed that the response of each cultivar varied according to the sowing date. Regarding the leaf N content (Table 1), we identified two cultivar groups (BRS Esmeralda, ANa 5015, ANa 6005, and IPR 117 had higher values and IAC 500, IAC 203, BRS Serra Dourada, and ANa 7211 had lower values). This characteristic may be attributed to genotypic differences. The leaf N content of cultivars sown in October and November was higher due to the climatic conditions during these months.

Mauad et al. (2011) observed a difference in leaf N content between two rice cultivars; cultivar Caiapó (traditional type) had a higher leaf N content than the Maravilha cultivar (modern type). Reis et al. (2019) evaluated three rice cultivars and found different leaf N contents in each; the highest value was observed in the ANa 7007, followed by AN Cambará, and the ANa 5015 showed the lowest value.

Nitrogen is a very important nutrient for plants as it is a component of chlorophyll molecules, nucleic acids, proteins, and cytochromes. In rice crops, the application of this nutrient affects crop productivity directly by causing increases in yield components such as number of panicles per square meter, number of spikelets per panicle, and even grain mass; this is because N leads to an increased leaf area, thus resulting in increased photosynthesis (Fornasieri Filho and Fornasieri 2006). There is a strong correlation between the leaf N content and the photosynthetic capacity of the plant (Zhong et al. 2019); therefore, the development of cultivars with higher leaf N content is sought.

Aerial dry mass affects the characteristics of each cultivar, varying with plant architecture and its adaptation to each environment. In the evaluated environment, the BRS Esmeralda, ANa 6005, IPR 117, and IAC 203 cultivars had the highest mass, and the October and November sowings were the most prominent (Table 1).

The lower aerial dry mass values observed in the February sowing were due to the shorter cultivar cycles and the lower incidence of global radiation. In the present study, the total solar radiation values observed throughout the cultivar cycles were 2,091.8 in October, 2,032.6 in November, 1,887.4 in December, and 1,575.2 MJ m^{-2} day^{-1} in February (Figure 1B). Although the cultivars belonged to different groups (traditional, intermediate, and modern), no relationship was observed between the group each cultivar belonged to and the amount of dry mass produced. Thus, nitrogen topdressing at 28 DAE at a dose of 60 kg ha^{-1} in the form of ammonium sulfate may have contributed to this effect in aerial dry mass, as nitrogen may also influence the tillering of rice plants (Wang et al. 2017), which will consequently affect plant mass. Each cultivar's nitrogen acquisition and use efficiency are affected by various factors such as the activity of enzymes of assimilation, nitrate accumulation and redistribution in reserve organs, N uptake kinetics, low nitrate reductase content in plants during the vegetative period, nitrate accumulation occurrence in plant tissues, and subsequent movement of nitrate for synthesis of protein reserves in the grain.

Environmental factors, mainly solar radiation and temperature also influenced the crops response to nitrogen application. Fifteen days before and after flowering, high solar radiation, and temperatures between 25 and 30 °C favor the application of N because the cereal plant responds better (Fornasieri Filho and Fornasieri 2006).

Mauad et al. (2011) observed a higher amount of dry mass in the Maravilha cultivar (modern group) compared to the Caiapó cultivar (traditional group). Crusciol et al. (2019) observed a higher dry mass in the modern cultivar (Maravilha) than in the traditional type (Caiapó) when fertilizing with 160 mg dm^{-3} of phosphorus, while in the other doses (0 and 40 mg dm^{-3}) there was no difference. According to Carmeis Filho et al. (2017) modern group cultivars show greater tillering compared to traditional group cultivars and this can affect on their aerial dry mass.

Pal et al. (2017) found a reduction in the dry mass of rice plants when sowing was performed during the late in relation to the early season of different rice cultivars. They attributed this characteristic to the shortening of the rice development period. Similar results were obtained in the present work; late sowing decreased the rice cultivar's cycle and affected the amount of dry mass produced.

Plant height is the result of the architecture of each cultivar. The small or intermediate size of rice plants in the sprinkler irrigation system is desirable as it has a certain tolerance to lodging (Fornasieri Filho and Fornasieri 2006). The shortest cultivars were IAC 500 and ANa 7211, which belong to the modern type of group, while the IPR 117 cultivar had the greatest height because it belonged to the traditional type group (Table 2).

According to Streck et al. (2018) with the advancement of genetic breeding there was a reduction in the height of rice plants from the years 1972 to 2016, showing that modern cultivars have a lower height, with a reduction of approximately 14 cm over 45 years. Arf et al. (2000) evaluated nine upland rice cultivars sown at different dates and also observed a significant effect for plant height. The authors found greater heights in the November and December sowing in the first year of cultivation, while in the second year of cultivation the November sowing resulted in higher values. These results are similar to those obtained in the present study since the evaluated cultivars had the greatest heights in the November sowing. Sowing in February resulted in shorter heights due to the cultivars having less time to grow and a lower incidence of solar radiation.

According to Fornasieri Filho and Foransieri (2006) higher rice plants have some advantages such as easier manual harvesting, greater ability to compete with weeds, and better water and nutrient absorption capacity owing to a deeper root system. On the other hand, greater heights are detrimental to rice plants because they favor lodging.

In this work, lodging was intense in the IPR 117 cultivar (Figure 2) of the traditional type, which reached a height of up to 123 cm. The severity of lodging depends on the plant's height, the stem's diameter and resistance, and the adhesion of the sheaths to the internodes; it is also affected by productivity and environmental factors such as water availability and wind intensity (Shah et a. 2019). The occurrence of lodging, mainly during the November sowing, was due to the intense winds in the ripening phase of the cultivars.

Severe damage is caused when lodging occurs; this involves a reduction in productivity, caused by a lower amount of photoassimilates and nutrients absorbed by the grains during formation as a consequence of the decreased cross section of the vascular bundles. This phenomenon leads to an increase in spikelet sterility, in addition to causing self-shading in plants (Liu et al. 2019). Lodging also leads to a reduced crop yield, loss of grain in the soil, lower grain quality (Liu et al. 2020), dirty grains that may be stained by fungal attacks, and a decreased head grain amount during milling.

The number of spikelets was also variable with cultivars and sowing dates, with the greatest number found in cultivar ANa 7211, followed by BRS Esmeralda (Table 3). The October sowing resulted in the greatest number of spikelets, probably due to the longer cycle of the cultivars and the high incidence of solar radiation, which resulted in a higher dry mass. These factors contributed to a higher photosynthetic rate in plants during this period, favoring the number of spikelets produced.

The number of spikelets panicle^{-1} is a factor strongly affected by genotype and, at the same time, by environmental conditions (Razafindrazaka et al. 2020). The authors evaluated rice cultivation at different altitudes and also found that there are distinct responses among cultivars in each environment.

Spikelet fertility is influenced by environmental conditions and carbohydrate translocation to grains (Lawas et al. 2018) and is reflected by the percentage of spikelets that have been converted to grain.

The ANa 7211 cultivar had the lowest spikelet fertility, even when sowing in October and November, when spikelet fertility was higher for the other cultivars (Table 4). This was due to the high temperatures during the flowering of cultivar ANa 7211, which occurred after the flowering of the other cultivars. According to Razafindrazaka et al. (2020) and Wu et al. (2019), cultivars interact with temperature during flowering and some cultivars may be more sensitive to high temperatures than others, thus having lower spikelet fertility.

Guimarães et al. (2018) found a higher percentage of spikelet fertility in the IAC 202 cultivar (77.1%) compared to the Primavera cultivar (75.2%). Cheabu et al. (2018) observed that high temperatures (40-45 °C) affect the seed-setting rate in rice accessions at both vegetative and booting stages. For Brazilian rice accessions, they found two materials which are tolerant to high temperatures, one moderately tolerant and one susceptible.

The lower spikelet fertility observed in the December sowing was due to the incidence of scald in rice, which was more severe in cultivar ANa 7211 (Figure 4). The symptoms of leaf disease begin with a brown-colored necrotic lesion that can cause the affected leaf to die. In grains, necrotic scores are initially detected as patches of reddish-brown color, which, consequently, cause sterility or miscarriage of the grains (Fornasieri Filho and Fornasieri 2006).

Yield efficiency was higher in the BRS Esmeralda and ANa 5015 cultivars. Overall, yield efficiency was lower in the October than in the February sowing (Table 4). The same result was observed for leaf N content, plant height, and total spikelets per panicle. This reduction could be attributed to the decrease in solar radiation and temperatures, especially during the sowing carried out in February.

Light is an indispensable factor in the photosynthetic process, providing energy for conversion of CO_2 and H_2O into organic compounds and activating enzymes such as rubisco (Taiz et al. 2017). According to Gautam et al. (2019), the incidence of solar radiation, its absorption, and its use efficiency interfere in the production of biomass by the crop. There is a positive correlation between yield and the incidence of solar radiation, enhancing the photosynthetic characteristics of the leaves by increasing radiation use efficiency (Gautam et al. 2019; Gong et al. 2020).

5. Conclusions

Each cultivar has a variable response to the different sowing dates, thus demonstrating adaptation to climatic conditions. Sowing in October is the most suitable sowing dates for rice development in the low-altitude Cerrado region. Under the use of supplemental irrigation, BRS Esmeralda and ANa 5015 performed best among the studied cultivars in the region. Studies in this area should be encouraged in order to help increase food supply in a more sustainable manner and allow the application of other technologies that will help increase production.

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