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Performance of upland rice cultivars at different sowing times: an alternative for crop rotation in low altitude Cerrado region, Brazil

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Abstract

The adequacy of the best sowing times and the choice of rice cultivars is determinant for greater investment and return in upland rice cultivation. Thus, this study identified the best sowing time and the cultivar that expresses its yield potential, being adaptable and stable, in a low altitude Cerrado region. The study was conducted during the agricultural year 2016/17. The soil of the site is a typical clayey dystrophic Red Latosol. The experimental design was in randomized blocks, in factorial scheme with four sowing times in spring/summer season (October, November, December and February), each with eight upland rice cultivars (BRS Esmeralda, ANa 5015, ANa 6005, IPR 117, IAC 500, IAC 203, BRSGO Serra Dourada and ANa 7211) and four replicates. The following parameters were evaluated: days elapsed from emergence to flowering and harvesting, number of panicles m^{-2}, number of filled spikelets per panicle, thousand grain weight and yield. Analyzes of adaptability and stability were performed as well as the principal components analysis. Except for the hundred grains weight, sowing times and cultivars interacted significantly for all characteristics evaluated. The cultivar BRS Esmeralda was adapted and stable to the different sowing times, being the most productive mainly when sown in October. The high yields were correlated with better grain filling, according principal components analysis.

Keywords: sprinkler irrigation, solar radiation, photosynthesis, *Oryza sativa* L.

Abbreviations: a.i._ active ingrediente; DAE_ days after emergence; Kc_ crop coefficients

Introduction

The crop rotation practice has become increasingly necessary for agricultural sustainability, and rice is an interesting option for the production system. According to Nascente et al. (2013), rice/soybean rotation provides higher rice yield compared to monoculture.

Upland rice accounts for 26.5% of the total rice grown in Brazil. However, yield is lower than expected (average of 2,347 kg ha^{-1} in the 2016/17 harvest) when compared to the irrigated rice system: 7,619 kg ha^{-1} (Conab, 2018). Among the factors that contribute to low yield is the occurrence of drought periods in the cultivation sites.

Aiming to minimize the effects of drought periods, sprinkler irrigation has become a viable alternative (Vories et al., 2013), in addition to contributing to increased rice yield and quality. Furthermore, the amount of water supplied to upland rice crop is lower in comparison to flooded rice, promoting greater rice cultivation sustainability (López-Piñeiro et al., 2016). Under conditions favored for rice development, such as the use of sprinkler irrigation, high yields can be achieved, as observed by Vories et al. (2017), which obtained yield of up to 8,000 kg ha^{-1} under pivot irrigation.

Rice, like other crops, is sensitive to climatic variation, water availability and other factors such as temperature, atmospheric CO_2 concentration, and solar radiation (Yoshida et al., 2015).

Wang et al. (2016), studying rice cultivation in subtropical and tropical environments, found that there was less solar radiation use efficiency due to the high temperatures in tropical environment; that is, lower conversion of radiation to biomass and, consequently, lower grain yield. Therefore, the crop cultivation time should coincide with the climatic conditions suitable for rice development.

The architecture of each rice cultivar may be related to the rate of photosynthesis. Burges et al. (2017) observed a positive correlation between photosynthesis rate, leaf quantity and width, and plant height. The authors state that higher plants may provide a greater photoassimilates supply to the drains, favoring yield. Thus, it is fundamental to study cultivars adapted to the edaphoclimatic conditions of each region. Oliveira et al. (2017) developed an experiment in Brazil, evaluating three cultivars of upland rice (BRSMG Curinga, Douradão and BRS Primavera) in five sowing times in spring/summer season (September, October, November, December and February). The authors verified that cultivars BRSMG Curinga and Douradão were more productive than cultivar BRS Primavera. Regarding the sowing dates, which provided the highest yields were carried out in October, November and December.

The crop development depends on the genotype-environment relationship, with each cultivar development determined according to the local conditions (Colombari Filho et al., 2013). Therefore, it is important to evaluate each material in the aspects of yield, adaptability and stability in each environment. According to Mariotti et al. (1976), adaptability is the material ability to respond positively to environmental change, and stability is the material ability to be productive in different environments. In this way, Reginato Neto et al. (2013) observed different behavior in 16 upland rice cultivars in Mococa and Capão Bonito (São Paulo State, Brazil), observed general adaptability in 12 genotypes, adaptation to favorable environments for IAC 2010 and IAC 2011 genotypes and adaptation to unfavorable environments for genotypes BRS Curinga and IAC 2012. The authors observed stability for cultivars IAC 201, BRS Curinga, IAC 1945, IAC 2006 and IAC 2009.

This study identified the best sowing time and the cultivar that expressed its yield potential, being more adapted and stable, in order to provide a crop rotation alternative that is profitable to the producer in a low altitude Cerrado region.

Results and discussion

Development of rice

Table 1 shows the days elapsed from emergence to flowering (f) and maturation (m) of rice cultivars at each sowing time. The cultivar IPR 117 showed the shortest cycle in relation to the other cultivars in all times: 80 to 93 days. The largest cycles occurred in the cultivars ANa 7211 and IAC 500: 90 up to 111 days. In the other cultivars, the values were intermediate.

Production components and yield

From the unfolding of the interaction times x cultivars, for all cultivars, the lowest amounts of panicles m^{-2} occurred when sowing was performed in February, compared to the other times (Table 2). Regarding the development of cultivars within each time, when sown in October, the cultivar ANa 7211 presented a greater number of panicles m^{-2} in relation to the others.

In November, panicle amounts increased in the cultivars IAC 500, BRS Serra Dourada, and ANa 7211, being this production component affected by both the genotype of each cultivar and the environment (Shrestha et al., 2012). Therefore, as the vegetative period of rice cultivars was prolonged in the sowings of October and November, the amount of panicles m^{-2} was favored.

Wang et al. (2016), evaluating rice cultivated in the dry and rainy seasons, verified that the dry season stood out with greater amount of panicles m^{-2}, because there was a higher incidence of solar radiation in that period. Our study showed total solar radiation of 2,091.8 in October; 2,032.6 in November; 1,887.4 in December; and 1,575.2 MJ m^{-2} in February. Thus, the amount of panicles m^{-2} was reduced with the decrease of the sum of the solar radiation in each time. Therefore, a higher light intensity promotes the increase of the fixed CO_2 (Wang et al., 2012), in addition to favoring the photosynthetic process and, consequently, the number of panicles m^{-2}.

In the unfolding of the interaction times x cultivars, the largest numbers of filled spikelets occurred for all cultivars sown in October, being influenced by the solar radiation in the cultivation period (Table 3).

Regarding the cultivars within each sowing time, there was no difference for the October sowing. In November, the cultivars BRS Esmeralda, ANa 6005, and ANa 7211 stood out in relation to the others. High temperatures during the flowering period result in lower fertility of spikelets, and there may be 50% sterility of spikelets when the temperatures are 32.6, 38.5, and 40.8 °C for cultivars of early, medium, and late cycle, respectively (Nguyen et al., 2014).

The temperature at flowering did not exceed 36 °C. Although the temperature was high at the time of flowering, irrigation may have contributed to the formation of filled spikelets, since the availability of water is essential for translocation of photosynthates from the source to the drain, in this case, to the spikelets (Hidayati et al., 2016). According to He and Serraj (2012), sprinkler irrigation provides higher amounts of filled spikelets per panicle in relation to rainfed cultivation.

For the hundred grains weight, the October sowing provided higher values in comparison to the other times, emphasizing the higher rate of solar radiation at that time, resulting in a higher rate of photosynthesis, and, consequently, increased grain filling (Table 4). The highest value of hundred grains weight occurred in the cultivar IPR 117, which has long grains, being its mass greater in relation to the other cultivars that present long/thin grains.

The hundred grains weight of the cultivars ANa 5015 and ANa 6005 was lower than that of IPR 117, but higher than the values observed for the other cultivars. The lowest value of hundred grains weight occurred in ANa 7211. According to Fidelis et al. (2016), this is an intrinsic characteristic of each cultivar, corroborating the results of the authors who observed a greater hundred grains weight in the cultivars BRS Bonança and BRS Conai when under conditions of water stress in the 2011/12 crop. These cultivars have long and long/thin grains, respectively, compared to the cultivar BRS Primavera, which has long/thin grains.

The cultivars BRS Esmeralda, IAC 500, and IAC 203 sown in October presented higher grain yield in comparison to the other sowing times. In the other cultivars, the sowings of October and November stood out in relation to the sowings of December and February (Table 5).

The grain yield reflected the production components, in which the figures of panicles m^{-2}, filled spikelets per panicle, and hundred grains weight were higher in the sowing of October. Thus, there was a longer period of development of rice cultivars and higher solar radiation in the sowing of October. Pal et al. (2017) argue that the increase in the rice development period and solar radiation increases photosynthesis in plants, thus interfering with yield.

In the sowing of October, there was a higher grain yield for the cultivar BRS Esmeralda, followed by IAC 500. Pinheiro et al. (2016), evaluating different upland rice cultivars in a

Table 1. Days elapsed between the emergence and flowering (f) and maturation (m) of upland rice cultivars at different sowing times. Selvíria - MS, Brazil (2016/17).

Cultivar	Sowing time								Average	
	October		November		December		February			
	f	m	f	m	f	m	f	m	f	m
BRS Esmeralda	71	95	72	94	67	90	66	92	69	93
ANa 5015	66	95	63	89	61	82	61	83	63	87
ANa 6005	73	95	73	94	70	90	69	92	71	93
IPR 117	64	93	59	87	61	80	59	83	61	86
IAC 500	79	103	76	96	70	90	75	92	75	95
IAC 203	75	95	69	89	63	82	61	83	67	87
Serra Dourada	71	97	67	94	65	82	61	83	66	89
ANa 7211	78	111	79	103	72	96	75	92	76	100
Average	72	98	70	93	66	87	66	88	-	-

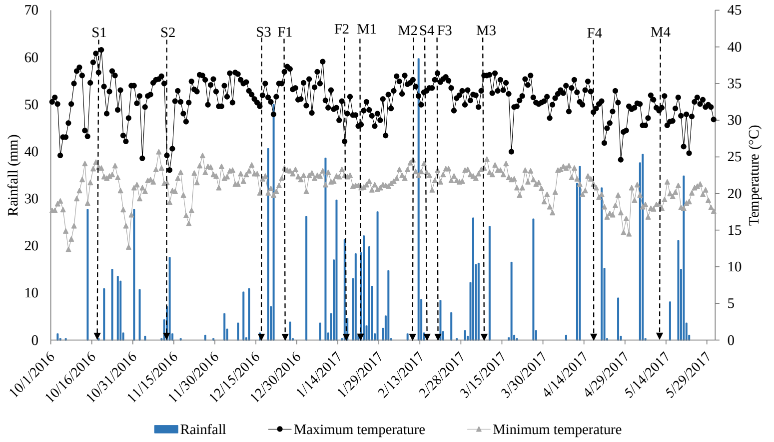

Fig 1. Rainfall daily data, air minimum and maximum temperature during the experimental period, in harvest 2016/17. S1, S2, S3, S4 represent the sowing; F1, F2, F3, F4 represent the start of flowering; C1, C2, C3, C4, represent the start of maturation, in sowing times referring October, November, December and Feburary, respectively.

Table 2. Average values of the number of panicles m^{-2} of upland rice cultivars at different sowing times. Selvíria - MS, Brazil (2016/17).

Cultivar	Sowing time				
	October	November	December	February	Average
BRS Esmeralda	337 bA	317 bA	315 bA	197 bB	292 c
ANa 5015	314 bA	266 bA	266 cA	175 bB	255 c
ANa 6005	306 bA	303 bA	282 cA	211 bB	276 c
IPR 117	323 bA	280 bA	318 bA	197 bB	279 c
IAC 500	367 bA	351 aA	340 bA	204 bB	316 b
IAC 203	303 bA	290 bA	321 bA	208 bB	280 c
Serra Dourada	361 bA	376 aA	411 aA	278 aB	356 a
ANa 7211	446 aA	384 aAB	372 aB	198 bC	350 a
Average	345 A	321 A	328 A	209 B	301
F test					
Cultivar (C)	15.57 **				
Sowing time (S)	88.92 **				
C x S	1.87 *				
VC(%)	12.39				

*p≤0.05, **p≤0.01, by the F test. VC: variation coefficient. 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 time in each cultivar 69.07.

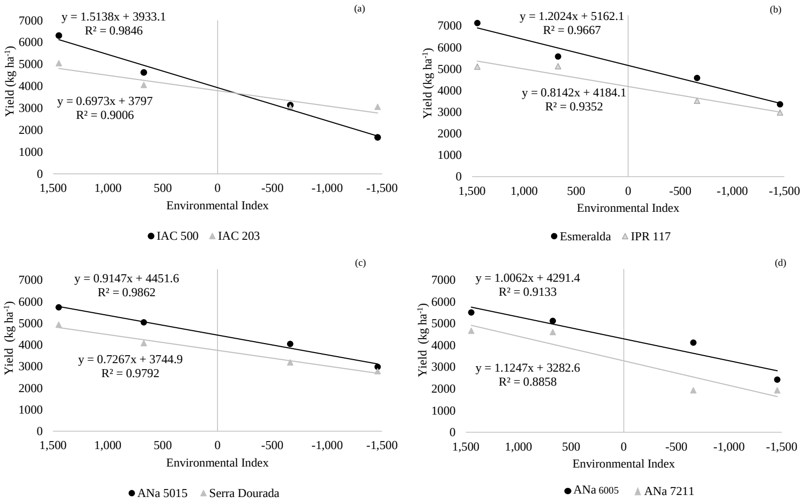

Fig 2. Regression curves adjusted for grain yield of upland rice cultivars at different sowing times. Selvíria - MS, Brazil (2016/17), by Eberhart and Russell (1966) method.

Table 3. Average values of number of filled spikelets per panicle of upland rice cultivars at different sowing times. Selvíria - MS, Brazil (2016/17).

Cultivar	Sowing time				
	October	November	December	February	Average
BRS Esmeralda	117 aA	101 aAB	94 aB	96 aB	102 a
ANa 5015	114 aA	92 bB	98 aAB	83 aB	97 a
ANa 6005	116 aA	103 aA	99 aA	77 bB	98 a
IPR 117	104 aA	86 bAB	76 bB	82 aB	87 b
IAC 500	112 aA	86 bB	68 bBC	65 bC	83 b
IAC 203	110 aA	89 bB	72 bB	75 bB	86 b
Serra Dourada	105 aA	85 bB	77 bB	70 bB	84 b
ANa 7211	119 aA	101 aA	62 bB	75 bB	89 b
Average	112 A	93 B	81 C	78 C	91
F test					
Cultivar (C)	7.28 **				
Sowing time (S)	68.16 **				
C x S	2.03 *				
VC(%)	11.66				

*p≤0.05, **p≤0.01, by the F test. VC: variation coefficient. 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 time in each cultivar 19.63.

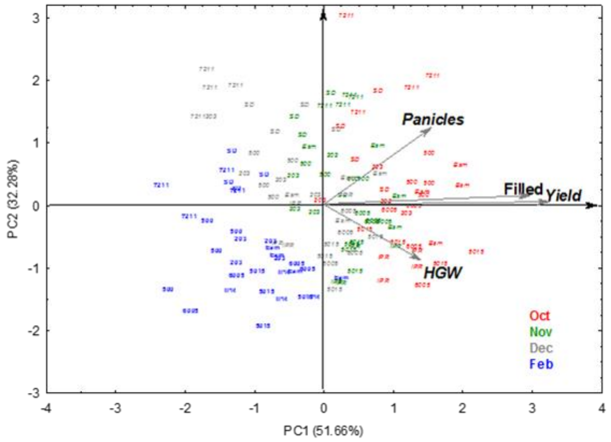

Fig 3. Biplot graph for the principal components PC1 and PC2 in the principal component analysis with cultivars of upland rice and different sowing dates. PC1= principal component one; PC2= principal component two; Panicles= number of panicles m^{-2}; Filled= filled spikelets $panicle^{-1}$; HGW= hundred grains weight; Oct= October; Nov= November; Dec= December; Feb= February. Esm= BRS Esmeralda, 5015= ANa 5015, 6005= ANa 6005, IPR= IPR 117, 500= IAC 500, 203= IAC 203, SD= BRSGO Serra Dourada, 7211= ANa 7211.

Table 4. Average values of hundred grains weight (g) of upland rice cultivars at different sowing times. Selvíria - MS, Brazil (2016/17).

Cultivar	Sowing time				
	October	November	December	February	Average
BRS Esmeralda	2.58	2.40	2.48	2.53	2.50 c
ANa 5015	2.83	2.69	2.72	2.67	2.73 b
ANa 6005	2.74	2.62	2.67	2.68	2.68 b
IPR 117	2.96	2.82	2.67	2.70	2.79 a
IAC 500	2.57	2.48	2.44	2.45	2.48 c
IAC 203	2.46	2.36	2.32	2.48	2.40 d
Serra Dourada	2.31	2.31	2.31	2.23	2.29 e
ANa 7211	2.16	2.12	2.00	2.06	2.08 f
Average	2.58 A	2.48 B	2.45 B	2.48 B	2.49
F test					
Cultivar (C)	92.79 **				
Sowing time (S)	10.23 **				
C x S	1.35 ^{ns}				
VC(%)	3.94				

^{ns} not significant, *p≤0.05, **p≤0.01, by the F test. VC: variation coefficient. 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 time 0.18.

Table 5. Average values of grain yield (kg ha^{-1}) of upland rice cultivars at different sowing times. Selvíria - MS, Brazil (2016/17).

Cultivar	Sowing time				
	October	November	December	February	Average
BRS Esmeralda	7,133 aA	5,579 aB	4,580 aC	3,356 aD	5,162 a
ANa 5015	5,740 cA	5,044 aA	4,044 aB	2,980 aC	4,452 b
ANa 6005	5,503 cA	5,118 aA	4,123 aB	2,422 bC	4,291 b
IPR 117	5,108 dA	5,126 aA	3,523 aB	2,980 aB	4,184 b
IAC 500	6,308 bA	4,628 bB	3,134 bC	1,662 bD	3,934 c
IAC 203	5,047 dA	4,054 bB	3,029 bC	3,058 aC	3,797 c
Serra Dourada	4,932 dA	4,080 bAB	3,186 bBC	2,782 aC	3,745 c
ANa 7211	4,664 dA	4,605 bA	1,929 cB	1,932 bB	3,282 d
Average	5,554 A	4,779 B	3,444 C	2,646 D	4,106
F test					
Cultivar (C)	18.66 **				
Sowing time (S)	201.84 **				
C x S	3.59 **				
VC(%)	12.67				

*p≤0.05, **p≤0.01, by the F test. VC: variation coefficient. 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 time in each cultivar 964.32.

Table 6. Estimates of adaptability and stability parameters of upland rice cultivars at different sowing times. Selvíria - MS, Brazil (2016/17).

Cultivar	β_1 (1)	$\sigma^2 d$ (2)
Esmeralda	1.20 ^{ns}	59,935.09 ^{ns}
ANa 5015	0.91 ^{ns}	-37,715.02 ^{ns}
ANa 6005	1.01 ^{ns}	178,271.04 *
IPR 117	0.81 ^{ns}	49,858.76 ^{ns}
IAC 500	1.51 **	24,150.15 ^{ns}
IAC 203	0.70 **	69,691.59 ^{ns}
Serra Dourada	0.73 *	-38,991.18 ^{ns}
ANa 7211	1.12 ^{ns}	350,006.50 **

^{ns} not significant, *p≤0.05, **p≤0.01, by t test (1) H_0: $\beta_1 = 1$, and by F test (2) H_0: $\sigma^2 d = 0$.

Table 7. Eigenvalues, amount of explained variance, correlation coefficients and eigenvectors, and the two first principal components.

Components	PC1	PC2
Eigenvalues	2.07	1.29
Explained variance	51.66	32.28
Accumulated variance	51.66	83.94
Correlation (eigenvectors)		
Number of panicles m^{-2}	0.43 (0.30)	0.81* (0.72)
Yield	0.94* (0.65)	0.01 (0.01)
Hundred grains weight	0.46 (0.32)	-0.79* (-0.70)
Filled spikelets panicle^{-1}	0.89* (0.62)	0.01 (0.01)
Interpretation	joint action of two variables, yield and filled spikelets panicle^{-1}	Contrast between number of panicles m^{-2} and hundred grains weight

conventional soil tillage system, observed that the cultivars BRS Esmeralda and BRS Primavera were more productive than BRS Sertaneja, BRS Serra Dourada, and BRS Caçula. The cultivar BRS Esmeralda features long/thin grains of greater acceptability in the market in relation to the other types of grains, being a great option for the producer to obtain good economic return. Regarding the cultivar IAC 500, the grain type is also long/thin, but stands out mainly for being aromatic and, therefore, with greater market value, increasing profitability.In the sowings done in November and December, the cultivars BRS Esmeralda, ANa 5015, ANa 6005, and IPR 117 stood out in relation to the others. This reflects the highest amount of filled spikelets per panicle of the cultivars BRS Esmeralda, ANa 6005, and IPR 117 in the sowing of November, and in December, including the cultivar ANa 5015. Although the cultivar ANa 7211 presented a larger number of panicles m^{-2}, the hundred grains weight was inferior in relation to all the cultivars, leading to low grain yield. In the February sowing, the cultivars BRS Esmeralda, ANa 5015, IPR 117, IAC 203, and BRS Serra Dourada were more productive in relation to the others, and in the first two cultivars, a greater number of filled spikelets $panicle^{-1}$ was observed, while for BRS Serra Dourada, there was a higher number of panicles m^{-2} at this sowing time.

Rice cultivars adaptability and stability

It was observed that the conditions at each sowing time influenced the yield of the cultivars, and there was instability in the environmental conditions at the different sowing times, with the sowings of October and November being considered favorable, due to the higher environmental indexes observed (1,448 and 673, respectively), and the sowings of December and February being considered unfavorable (environmental indexes of -662 and -1459, respectively).

There was general adaptability for the cultivars BRS Esmeralda, ANa 5015, ANa 6005, IPR 117, and ANa 7211 ($\beta_1 = 1$ and means above the general average), except for the cultivar ANa 7211 (Table 6), being also verified an intermediate slope of the lines adjusted to linear regression (Figure 2b, c, d). The cultivar IAC 500 is considered adaptive for favorable conditions, since $\beta_1 > 1$, with a greater slope in the line adjusted to linear regression (Figure 2a), and being responsive under environmental conditions adequate to its development. For the cultivars IAC 203 and BRS Serra Dourada, $\beta_1 < 1$ was verified (Figure 2a, c), indicating adaptability to unfavorable environments, but with means below the general average of yield. The cultivars BRS Esmeralda, ANa 5015, IPR 117, IAC 500, IAC 203, and BRS Serra Dourada presented stability (σ^2d was not significant) (Table 6). For the cultivars ANa 6005 and ANa 7211, there was significance for σ^2d, indicating instability. Hardly ever one cultivar will be superior to the others at all cultivation times, due to the instability of environmental conditions (Cargnin et al., 2008).

Principal components analysis

Only two eigenvalues were higher than the unity (Table 7), 2.07 for the component with greater initial variability retention (component 1), and 1.29 the second largest (component 2). This allowed the biplot graph construction (Figure 3). The principal components retained 83.94% of the total original information, being 51.66% and 32.28% for the first main component (PC1) and second component (PC2), respectively.

For PC1 (Table 7), the variables that presented the highest correlation coefficients were productivity and filled spikelets $panicle^{-1}$ (0.94 and 0.89, respectively), whereas for PC2 the variables were panicles m^{-2} and hundred grains weight (0.81 and -0.79, respectively).

Through graphical representation and the variables correlation of principal components, it was possible to verify which variables acted in the separation of groups, according to the sowing time. In the Figure 3, the sowing time was displaced in October to the right of PC1, a result of higher yield and greater amount of filled spikelets $panicle^{-1}$. As sowing times are moving to the right, there is a reduction in yield and quantity of filled spikelets $panicle^{-1}$.

The sowing in February provided a displacement of this time below PC2, distancing itself from the number of panicles m^{-2}, being this variable reduced in relation to the other sowing times. The other sowing times (October, November and December) are similarly distributed to PC2, with a similarity in the number of panicles m^{-2}.

It was observed that cultivars ANa 7211, BRSGO Serra Dourada show a displacement above PC2 in all sowing seasons, indicating a higher number of panicles m^{-2} in these cultivars. While the cultivars IPR 117, ANa 6005 and ANa 5015 are below PC2, suggesting that these cultivars have a greater hundred grains weight in relation to the others.

Materials and methods

Description of plants materials

The cultivar BRS Esmeralda is able to reach productivity 7,500 kg ha^{-1}. It has moderate resistance to major diseases and a certain tolerance to water stress. Your lodging risk is reduced by good stay green (Castro et al., 2014).

The cultivar ANa 5015 has a productive potential of 5,000 kg ha^{-1}, presents moderate resistance to the principal diseases and plants lodging, with medium size. The cultivar ANa 6005 has a productive potential of 6,000 kg ha^{-1}, has medium size and resistance to lodging, and is moderately resistant to the principal diseases of the crop (Agronorte, 2017).

The cultivar BRSGO Serra Dourada was developed for small farmers using fewer amounts of agricultural inputs, its yield can reach 4,500 kg ha^{-1}, it is moderately resistant to diseases (Melo et al., 2012). The cultivar IPR 117 is the traditional type, has an average yield of 3,500 kg ha^{-1}, is moderately susceptible to lodging and moderately resistant to major diseases (Iapar, 2017).

The IAC 500 is an aromatic cultivar, of the modern type, producing up to 6,000 kg ha^{-1}, has a high lodging tolerance because of its small size and is moderately susceptible to blast. This cultivar can be grown in both the flooded system and the sprinkler irrigated upland system (Bastos, 2001). The cultivar IAC 203 is of the modern type, has good tolerance to lodging by the small size. Its average productivity is 4,380 kg ha^{-1}, presenting good tolerance to blast (Regitano Neto et al., 2013).

The ANa 7211 has an average size and yield potential 7,500 kg ha^{-1} and can be grown in both flooded system as in upland system (Agronorte, 2017). All cultivars have long/fine grains, with the exception of cultivar IPR 117, which has long grains.

Description of the area: location, climate and soil

The experiment was conducted at experimental area of the Faculty of Engineering (UNESP), Ilha Solteira campus, located in the municipality of Selvíria, MS, at approximately 51º22' W and 20º22' S. The altitude was 335 meters, during the agricultural year 2016/17.

According to Köppen's classification, the climate of the region is Aw, with annual average rainfall of 1,313 mm, minimum and maximum annual temperature of 19 and 31 °C, respectively, and annual relative air humidity between 70 and 80%. The rainfall daily data, air minimum and maximum temperature during the experimental period are shown in Fig 1. Precipitation was intense at the end of December 2016 and throughout January 2017, rendering sowing unfeasible in January. Temperatures decreased from April until the end of the experiment. Temperature peaks occurred in the second week of October.

The local soil is a typical clayey dystrophic Red Latosol (Santos et al., 2013). The chemical characteristics of the soil were determined before the installation of the experiment, with the following results: 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; and V = 68%.

Experimental design and treatments

The experimental design was in randomized blocks, in factorial scheme 4 x 8, with four sowing times, each time with eight cultivars and four replicates. Sowing times in spring/summer season, which is warm and rainy, were: 10/13/16, 11/09/16, 12/15/16 and 02/16/17.

Rice cultivars were: BRS Esmeralda, ANa 5015, ANa 6005, and BRSGO Serra Dourada, classified as intermediate type; IPR117, classified as traditional type; and IAC 500, IAC 203, ANa 7211, classified as modern type.

For intermediate cultivars, the stature is intermediate in relation to the traditional and modern types, the leaves are short and narrow, semi-erect and smooth, the cycle ranges from early to medium, and the grains are characterized as long/thin (Fornasieri Filho and Fornasieri, 2006). The cultivars of the traditional type have low yield potential, high size, broad and decumbent leaves, and are photoperiod sensitive. The cycle varies from medium to long, and the grains can be short or long. The cultivars of the modern type are of high yield potential, the leaves are erect, the plants are photoperiod insensitive, with lodging tolerance due to the low size, and there is a better nutrient use efficiency (Borém and Rangel, 2015).

Set up and conduction of field experiment

Each plot was composed of six rows of 4.5 m in length, with spacing between rows of 0.35 m. The useful area was composed of four central rows, considering the lateral rows as border. Before the installation of the experiment, the area was cultivated with soybean in the 2015/16 crop. The soil was prepared prior to the installation of the rice crop with one plowing and two harrowing operations.

Sowing fertilization was performed using 250 kg·ha^{-1} of the formulation 08-28-16. Preceding sowing, seeds were treated with pyraclostrobin, methyl thiophanate and fipronil at doses of 5, 45 and 50 g of the active ingredient (a.i.) per 100 kg of seed, respectively. Sowing was done manually, with 70 kg ha^{-1} seeds. Weed management was carried out using herbicides at pre-emergence (pendimethalin, 1,400 g ha^{-1} a.i.), soon after sowing, and at post-emergence (metsulfuron-methyl, 2 g ha^{-1} a.i.), approximately at 13 days after emergence (DAE).

Cover fertilization was done at approximately 28 DAE, using ammonium sulfate as a source, at the dose of 60 kg ha^{-1} N. Trifloxystrobin + tebuconazole (75 + 150 g ha^{-1} a.i.) was applied with the objective of preventing a possible blast occurrence; thiamethoxam (25 g ha^{-1} a.i.) was also applied for the control of stink bug at the time of flowering.

Water was supplied by means of a fixed conventional sprinkler irrigation system, presenting average precipitation of 3.3 mm $hour^{-1}$. Three crop coefficients (Kc) were used in the water management of the rice crop, distributed during the period between emergence and harvest.

For the vegetative phase, the value of 0.4 was used; for the reproductive phase, two Kc took place: the initial, of 0.70, and the final, of 1.00; and for the maturation phase, these values were inverted, that is, the initial, of 1.00, and the final, of 0.70. Harvesting was done manually when the rice plants had 90% of mature panicles.

Variables analyzed in rice

The following characteristics were evaluated: flowering and maturation, that is, number of days elapsed between the emergence and flowering of 50% of the plants and between the emergence and maturation of 90% of the panicles of the plots; number of panicles m^{-2}, obtained by counting the panicles in one meter, and, afterwards, calculating the conversion to the number of panicles m^{-2}; filled spikelets per panicle, determined by the average count of full spikelets in twenty panicles; hundred grains weight, performed by random sampling and weighing two 100 g samples per each plot, corrected to 13% wet basis; and grain yield, obtained by weighing the shell grains from the plot area, correcting the moisture to 13% and converting to kg ha^{-1}. The adaptability and stability analysis was performed according to Eberhart and Russell (1966) following the model $Y_{ij} = \mu_i + \beta_i I_j + \delta_{ij} + \varepsilon_{ij}$, which μ_i represents the mean of genotype, β_i indicates the linear regression coefficient, I_j refers to the environmental index, δ_{ij} is regression deviance and ε_{ij} corresponds to the mean experimental error. The regression coefficient (β) indicates the linear component, suggesting adaptability, whereas the regression deviances ($\sigma^2 d$) refer to stability. The adaptability and stability are the ability of a genotype to be positively responsive to an environmental stimulus and to have predictable behavior according to the environmental stimulus, respectively.

Prior to principal component analysis, the standardization of the variables was performed, with the mean values 0 and variance 1. This analysis allowed reducing the amount of information of four variables (panicles m^{-2}, yield, filled spikelets $panicle^{-1}$ and hundred grains weight) in two orthogonal latent variables, the principal components. These components are the results of linear combinations of orthogonal variables from the two largest eigenvalues of the data correlation matrix (Hair, 2005). Thus, the four variables were summarized in two new latent ones, making possible the construction in two-dimensional figure (biplots). The analysis was made from the data of the original variables retained by the main components that have eigenvalues greater than unity (Kaiser, 1958). The coefficients of the linear functions for interpretation were considered, the weight of each variable being attributed by means of the coefficients (> | 0.7 |).

Statistical analysis

The data were submitted to analysis of individual variance for each sowing time. The ratio between the largest and smallest mean residual square was lower than seven for all characteristics, indicating homogeneity between them (Banzatto and Kronka, 2006) and allowing the joint analysis of the experiments. For sowing times, the Tukey test ($p \leq 0.05$) was used; and for cultivars, the Scott-Knott test was used, at 5% probability. The statistical program used was SISVAR (Ferreira, 2014). For the analyses of adaptability and stability, the methodology of Eberhart and Russel (1966) using the GENES program (Cruz, 2001) for analysis. Statistical analysis for principal component was performed in Statistica software version 7.0 (Statsoft, 2004).

Conclusion

The cultivar BRS Esmeralda was shown to be adapted and stable to the different sowing times, being the most productive mainly when sown in October, and this high yield is correlated with the better grain filling, as indicated in the analysis of main components.

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References

Agronorte (2017) Arroz. http://www.agronorte.com.br/br/Produtos/ARROZ (Accessed September 19, 2017).

Banzato DA, Kronka SN (2006) Experimentação agrícola. 4th edn. Funep, Jaboticabal. 237 p.

Bastos CR (2001) IAC-500: arroz aromático para o Estado de São Paulo. O Agronômico. 53 (1): 23-29.

Burges AJ, Retkute R, Herman T, Murcie EH (2017) Exploring Relationships between Canopy Architecture, Light Distribution, and Photosynthesis in Contrasting Rice Genotypes Using 3D Canopy Reconstruction. Front Plant Sci. 8: 1-15.

Cargnin, A, Souza MA, Pimentel AJB, Fogaça CM (2008) Interação genótipos e ambientes e implicações na adaptabilidade e estabilidade de arroz sequeiro. R Bras Agrociênc. 14 (3-4): 49-57.

Castro AP, Morais OP, Breseghello F, Lobo VLS, Guimarães CM, Bassinello PZ, Colombari Filho JM, Santiago CM, Furtini IV, Torga PP, Utumi MM, Pereira JA, Cordeiro ACC, Azevedo R, Sousa NRG, Soares AA, Radmann V, Peters VJ (2014) BRS Esmeralda: cultivar de arroz de terras altas com elevada produtividade e maior tolerância à seca. Santo Antônio de Goiás (Brazil): Embrapa Arroz e Feijão. 4 p. (Technical Notice, 215).

Colombari Filho JM, Resende MDV, Morais OP, Castro AP, Guimarães EP, Pereira JA, Utumi MM, Breseghello F (2013) Upland rice breeding in Brazil: a simultaneous genotypic evaluation of stability, adaptability and grain yield. Euphytica. 192 (1): 117–129.

Conab - Companhia Nacional de Abastecimento. Acompanhamento da safra brasileira de grãos - v. 5 (Safra 2017/18) - n.4 (Quarto levantamento). Conab, Brasília. 132p.

Cruz CD (2001) Programa GENES: versão windows: aplicativo computacional em genética e estatística. UFV, Viçosa. 648p.

Eberhart SA, Russell WA (1996) Stability parameters for comparing varieties. Crop Sci. 6: 36-40.

Ferreira DF (2014) Sisvar: A Guide for Its Bootstrap Procedures in Multiple Comparisons. Ciênc Agrotec. 38 (2): 109-112.

Fidelis RR, Tonello LP, Veloso DA, Santos VB, Barros HB (2016) Rice cultivars development in low input agriculture conditions. Appl Res Agrotec. 9 (2): 07-17.

Hair JF, Anderson RE, Tatham RL, Black W (2005) Análise multivariada de dados. 5th edn Bookman, Porto Alegre, 593p.

He H, Serraj R (2012) Involvement of peduncle elongation, anther dehiscence and spikelet sterility in upland rice response to reproductive-stage drought stress. Environ Exp Bot. 75: 120-127.

Hidayati N, Triadiati, Anas I (2016) Photosynthesis and transpiration rates of rice cultivated under the system of rice intensification and the effects on growth and yield. Hayati J Biosci. 23 (2): 67-72.

Iapar. Instituto agronômico do Paraná (2017) IPR 117. (Technical Notice). http://www.iapar.br/arquivos/File/folhetos/arroz/arroz117.html (Accessed September 17, 2017).

Kaiser HF (1958) The varimax criterion for analytic rotation in factor analysis. Psychometrika, 23:187-200.

López-Piñeiro A, Sánchez-Llerena J, Peña D, Albarrán A, Ramírez M (2016) Transition from flooding to sprinkler irrigation in Mediterranean rice growing ecosystems: Effect on behaviour of bispyribac sodium. Agric Ecosyst Environ. 223(1): 99–107.

Mariotti IA, Oyarzabal ES, Osa JM, Bulacio ANR, Almada GH (1976) Análisis de estabilidad y adaptabilidad de genotipos de caña de azúcar. Interacciones dentro de una localidad experimental. Rev Agron Noroeste Arg. 13 (14): 105-127.

Melo PGS, Morais OP, Diniz JÁ, Lobo VLS, Fonseca JR, Castro AP, Bassinello PZ (2012) BRSGO Serra Dourada: upland rice cultivar for family agriculture in the State of Goiás. Crop Breed Appl Biotechnol. 12: 227-229.

Nascente AS, Crusciol CAC, Stone LF, Cobucci T (2013) Upland rice yield as affected by previous summer crop rotation (soybean or upland rice) and glyphosate management on cover crops. Planta Daninha. 31 (1): 147-155.

Nguyen DN, Lee KJ, Kim DI, Anh NT, Lee BW (2014) Modeling and validation of high-temperature induced spikelet sterility in rice. Field Crops Res. 156: 293-302.

Oliveira JAP, Nascente AS, Stone LF, Lanna AC, Heinemann AB (2017) Épocas de semeadura afetando índices morfofisiológicos de cultivares de arroz de terras altas. Rev Cienc Agrar. 60 (2): 131-140.

Pal R, Mahajan G, Sardana V, Chauhan BS (2017) Impact of sowing date on yield, dry matter and nitrogen accumulation,and nitrogen translocation in dry-seeded rice in North-West India. Field Crops Res. 206: 138-148.

Pinheiro V, Nascente AS, Stone LF, Lacerda MC (2016) Seed treatment, soil compaction and nitrogen management affect upland rice. Pesqui Agropecu Trop. 46 (1): 72-79.

Regitano Neto A, Ramos Junior EU, Gallo PB, Freitas JG, Azzini LE (2013) Comportamento de genótipos de arroz de terras altas no estado de São Paulo. Rev Ciênc Agron. 44 (3): 512-519.

Santos HG, Jacomine PKT, Oliveira VA, Lumbreras JF, Coelho MR, Almeida JA, Cunha TJF, Oliveira JB (2013) Sistema brasileiro de classificação de solos. 3rh edn. Embrapa, Brasília. 353 p.

Shrestha S, Asch F, Dusserre J, Ramanantsoaniria A, Brueck H (2012) Climate effects on yield components as affected by genotypic responses to variable environmental conditions in upland rice systems at different altitudes. Field Crops Res. 134, 216–228.

Statsoft, Inc. (2004). Statistica (data analysis software system), version 7. www.statsoft.com

Vories ED, Stevens WE, Tacker PL, Griffin TW, Counce PA (2013) Rice production with center pivot irrigation. Appl Eng Agric. 29 (1): 51-60.

Vories E, Stevens W, Rhune M, Straatmann Z (2017) Investigating irrigation scheduling for rice using variable rate irrigation. Agric Water Manag. 179: 314–323.

Wang C, Guo L, Li Y, Wang Z (2012) Systematic comparison of C3 and C4 plants based on metabolic network analysis. BMC Syst Biol. 6 (2): 1-14.

Wang D, Laza MRC, Cassman KG, Huang J, Nie L, Ling X, Centeno GS, Cui K, Wang F, Li Y, Peng S (2016) Temperature explains the yield difference of double-season rice between tropical and subtropical environments. Field Crops Res. 198, 303-311.

Yoshida R, Fukui S, Shimada T, Hasegawa T, Ishigooka Y, Takayabu I, Iwasaki T (2015) Adaptation of rice to climate change through a cultivar-based simulation: a possible cultivar shift in eastern Japan. Clim Res. 64 (3): 275-290