agrometeoros
REVISTA DA SOCIEDADE BRASILEIRA DE AGROMETEOROLOGIA

ISSN 2526-7043 www.sbagro.org.br DOI: http://dx.doi.org/10.31062/agrom.v32.e027668

Development stages of furrow-irrigated rice and their relationship with estimates from the App PlanejArroz

Silvio Steinmetz[1(*)], José Maria Barbat Parfitt[1], Walkyria Bueno Scivittaro[1], Giovani Theisen[1], Luan de Souza Dias[2] and Jéssica Goetzke Martin[2]

[1]Embrapa Clima Temperado. Rodovia BR 392, km 78, Cx. Postal 403, CEP 96001-970 Pelotas, RS. Brazil,
E-mails: silvio.steinmetz@embrapa.br, jose.parfitt@embrapa.br, walkyria.scivittaro@embrapa.br and giovani.theisen@embrapa.br
[2]Faculdade de Agronomia Eliseu Maciel - Universidade Federal de Pelotas. Campus Universitário s/n, CEP 96010-610 Capão do Leão, RS, Brazil.
E-mails: luansouza.engenheiroagronomo@gmail.com and goetzkejessica@gmail.com
[(*)]Corresponding author.

ARTICLE INFO

Article history:
Received 28 May 2024
Accepted 22 August 2024

Index terms:
Oryza sativa L.
phenological growth stages
soil water tension
crop management

ABSTRACT

The objectives of this study were to characterize how the water regime and the furrow and ridge environments affect the plant development stages (PDS) and how these stages relate to estimates of the App PlanejArroz. In the cropping season 1 – CS 1 (2021/2022), the PDS were obtained in three water regimes (water regime 1 – WR1; water regime 2 – WR2; water regime 3 – WR3). In the cropping season 2 – CS 2 (2022/2023), the water regime 4 - WR4 was included. The PDS were obtained through readings, twice a week, on the plants marked in the ridge and in the furrow. The results indicated that the number of days from emergence (ND) to reach the PDS was influenced by the water regime (WR), especially for stages R1 (panicle differentiation), R2 (booting) and R4 (anthesis), which showed differences between WR1 and WR3, respectively, of 7 , 6.3 and 7.9 days in the CS 1 and 4, 3.9 and 4.4 days in the CS 2. The results allow us to conclude that the irrigated rice PDS suffer delays in the furrow-ridge system and that the App PlanejArroz can be used to plan management practices in this system as long as corrections are made regarding the delay in the PDS.

Introduction

The State of Rio Grande do Sul (RS) is the largest producer of irrigated rice in Brazil, having contributed, in the last three growing seasons (from 2020/21 to 2022/23), with about 70% of the national production, occupying an area of 923 thousand hectares/year, with an average productivity of 8.2 $t.ha^{-1}$ (IBGE, 2024). It is estimated that in the state there are about three million hectares of lowland soils, which have drainage and irrigation infrastructure implemented for irrigated rice cultivation, and that around two million hectares of these soils have potential for soybean cultivation (Vedelago, 2014) or other dryland species in rotation or succession to rice.

The utilization of the furrow-ridge technology, which has shown good results in soybean and corn production in lowland soils of Rio Grande do Sul (Parfitt et al., 2017; Campos et al., 2021), may become an interesting option for irrigated rice cultivation in furrows, in rotation with soybean and corn (Concenço et al., 2020). The advantage is that rice cultivation would follow soybean and corn cultivated in the furrow-ridge system, without the need for soil preparation, meaning utilizing the remaining ridges, and thus irrigating the rice in furrows. However, for this, it is essential that management practices consider the variability in soil moisture resulting from furrow irrigation, which provides drained (upper portion), saturated (central portion), and flooded (lower portion) soil conditions in the field (Stevens et al., 2018). Therefore, it is important to evaluate how these different water regimes within the plot influence soil moisture content, as done by Della Lunga et al. (2020), and affect plant development considering that, in general, there is a delay in furrow-irrigated rice compared to the conventional soil flooding irrigation system (Ockerby & Fukai, 2001). In order to plan and execute the management practices according to plant development stages (PDS), as recommended for the conventional system (Reunião..., 2022), it is crucial to determine the delay in reaching the main PDS in the furrow-irrigated system. With this, it is possible to evaluate the possibility of carrying out crop management in this system using the App PlanejArroz (Steinmetz et al., 2021a, b), which was developed for the flooded system.

The objectives of this study were to characterize how the water regime, in three portions of the plot (upper, intermediate, and lower), and the furrow and ridge environments affect the main plant development stages and how these stages relate to estimates from the App PlanejArroz.

Material and methods

The study was carried out in the area of the Lowland Experimental Station of Embrapa Temperate Climate Research Center, in Capão do Leão, RS, Brazil (latitude 31°52' S; longitude 52°21' W; altitude 13 m), during two cropping seasons (2021/2022 and 2022/2023). The data were collected in a plot of approximately 300 m long of an experiment designed to generate multidisciplinary informations on the cultivation of furrow-irrigated rice, using one of the three available irrigation treatments, that is, irrigated every three days. The local climate, according to the Köppen´s climate classification, is Cfa type, which corresponds to the humid subtropical, with hot summers and no defined dry season (Wrege et al., 2011). The soil in the experimental area is classified as a typical Eutrophic Haplic Planosol (Santos et al., 2006).

In autumn 2021, a planialtimetric survey of the area and soil smoothing were carried out (systematization with varying slopes), establishing an average slope of 0.2% in the longitudinal direction of the plot. On this occasion, the soil in the experimental area was prepared using a conventional cultivation system, comprising plowing, harrowing, scarification (depth of 30 cm) of the soil and leveling the surface of the area. Concomitantly with the soil preparation, correction fertilization was carried out, applying 300 $kg.ha^{-1}$ of the 10-30-15 formulation, established based on the results of the chemical analysis of the soil and considering the nutritional demand of the succession of winter and summer crops scheduled for the first year of cultivation (Sociedade..., 2016). Next, the infrastructure of ridges measuring 90 cm wide (center to center) and approximately 20 cm high was implemented, using the SulcoSystem® ridge, from KLR Implementos. Also during autumn, Persian clover (*Trifolium resupinatum* L.) was sown as winter cover in the area, at a density of 5 $kg.ha^{-1}$ of seeds. This forage was cultivated until the beginning of October, when it was desiccated.

Rice sowing in the 2021/2022 cropping season (cropping season 1 – CS 1) was carried out on Persian clover stubble on 10/28/2021, at a seed density of 100 $kg.ha^{-1}$. Pre-sowing, basic fertilizer corresponding to 20 $kg.ha^{-1}$ of N and 80 $kg.ha^{-1}$ of P_2O_5 and K_2O was applied to the surface. In the 2022/2023 cropping season (cropping season 2 – CS 2), rice was sown in the same plot as the 2021/2022 cropping season, but in an adjacent area where soybeans were grown in a furrow-ridge system in the previous growing season and ryegrass during the autumn-winter period. Due to damage to the infrastructure of furrows and ridges caused by soybean management and harvesting operations, it was necessary to carry out surface preparation of the soil with a harrow and planer, taking advantage of the opportunity to incorporate the existing vegetation cover and basic fertilizer of rice sowing (14 $kg.ha^{-1}$ of N and 64 $kg.ha^{-1}$ of P_2O_5 and K_2O). Next, new ridges were prepared and immediately after the rice sowing took place. Due to the fact that the soil was quite dry and loose, this operation resulted in a reduction in the average height of the ridges.

In both cropping seasons, top dressing nitrogen fertilization was divided into two applications at the three to four leaf stages (V3/V4 – 70 kg/ha of N) and panicle initiation (R0 – 40 $kg.ha^{-1}$ of N), both as urea. Weed control included the application of herbicides in pre- and post-emergence of rice. This and other cultural practices followed the technical indications of research for the crop in the South of Brazil (Reunião..., 2018).

In both cropping seasons, the irrigated rice cultivar BRS Pampa CL was used, considered as early cycle (around 118 days, according to Reunião..., 2022). In CS 1, irrigation was carried out every three days, applying an average depth of 23 mm, for 108 days. In CS 2, irrigation was also carried out every three days with an average depth of 23 mm, but for a period of 109 days. In CS 1, phenology data were obtained in three locations, chosen at random, from a plot approximately 300 m long, located in the center of the upper third (upper portion or water regime 1 –

WR1), in the center of the middle third (central portion or water regime 2 – WR2) and in the final part (lower portion or water regime 3 – WR3) of the plot. WR 1, 2 and 3 represented, respectively, the moisture levels of the drained, saturated and flooded soil, with the height of the water depth being variable in the latter. In CS 2, in addition to the three locations, chosen at random, water regime 4 - WR4 (flooded with water depth control) was included, which consisted of maintaining a water depth between 5 and 10 cm throughout the entire irrigation period, as recommended by research for this irrigation system (Reunião..., 2018). WR4 was included to serve as a reference for WR1, 2 and 3 and also because it was the irrigation system (flood) in which the phenology data used in the development of the App PlanejArroz were generated (Steinmetz et al., 2021a , b).

In CS 1, in each of the three locations, ten plants were marked in the ridge and ten in the furrow (five replications of two plants in both environments). In CS 2, twenty plants were marked in the ridge and twenty in the furrow (five repetitions of four plants in each environment). Each of the marked plants had their development monitored throughout the cycle, with each stage being characterized according to the scale of Counce et al. (2000). Two readings were taken per week and the average dates for each stage were obtained from observations on ten or twenty plants (main stem). The R1 stage (panicle differentiation) was determined by the method described by Stansel (1975), which consists of collecting and opening six main stems longitudinally and considering the date of R1 when at least two plants (one third of the sampled plants) had the panicle in the differentiation stage, that is, with approximately 1 mm to 2 mm in length. Therefore, for R1 a single value was obtained for each of the four WR and the two environments.

The six plant development stages (PDS) considered in this study were: V4: plant with four leaves; R1: panicle differentiation; R2: formation of the flag leaf collar (booting); R4: anthesis (one or more spikelets); R8: maturity of an isolated grain; R9: complete maturity of panicle grains. These stages are important because they are used as a reference for several rice crop management practices (Reunião..., 2022; Steinmetz et al., 2021a, b).

Statistical analysis was performed using SAS v. software. 9.04 (SAS Institute, 2022). The assessment of data normality was performed with proc. Univariate, the means and standard error calculated in the proc. Means and the analysis of variance performed in the proc. Mixed. The 95% criterion (F<0.05) was used to define the significance of the difference between treatments. The factors considered in the analysis were "Water Regime", with three levels (WR1, WR2, WR3) and "Environment", with two levels (Ridge and Furrow), with five replications per sample data. Data from each cropping season (CS 1 and CS 2) were analyzed separately.

Soil water tension (SWT) was measured using Watermark® sensors and data acquisition system. Two sensors were installed in the furrow at a depth of 10 cm, and a set of five sensors were installed in the ridge in order to obtain the average SWT content. Readings were taken every two or three days.

The meteorological data that occurred during the two CS were obtained using an automatic meteorological station (AMS), model "Davis Advantage Pro2", installed approximately 100 m from the location where the experimental data were obtained. In CS 1, due to a problem with the sensor, the air temperature data were replaced by those obtained at the Agroclimatological Station (EAPel) located in the headquarters area of the Lowland Experimental Station (Embrapa/ETB, Capão do Leão, RS), around six km from the experiment. The main meteorological data that occurred during the experiments are shown in figure 1, with the average maximum air temperature being 28.4 °C and 29.5 °C and the average minimum air temperature being 18.3 °C and 18.6 °C, respectively, in CS 1 and CS 2. The total rainfall during the crop cycle was 434.9 mm and 459.7 mm in CS 1 and CS 2, respectively.

Results and discussion

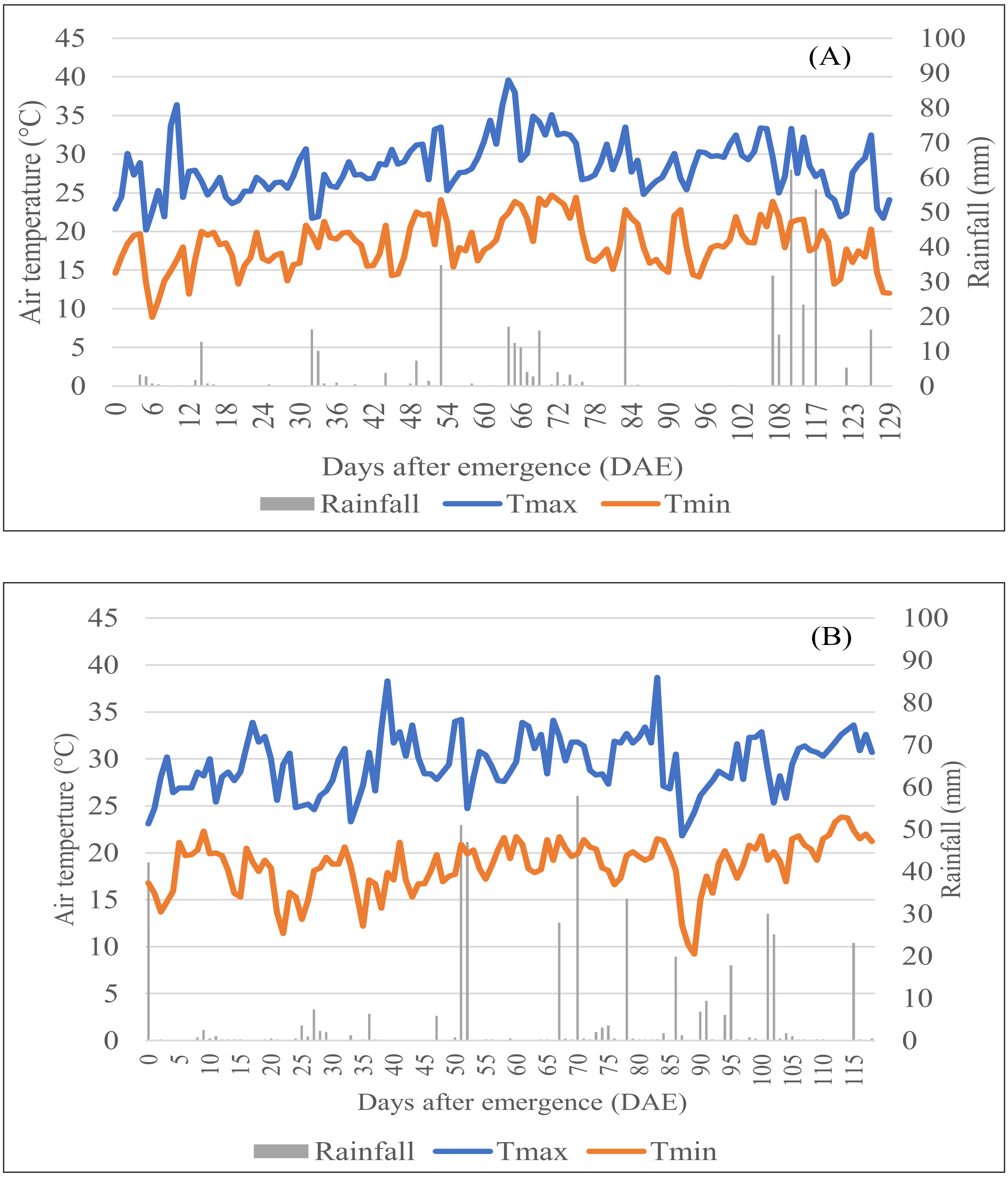
Influence of water regime on plant development

The number of days from emergence (ND) to reach the development stages of the rice cultivar BRS Pampa CL was influenced by the water regime (WR), especially for R1, R2 and R4 stages, which showed differences, respectively, of 7 days, 6.3 days and 7.9 days between WR1 and WR3 in CS 1 (Table 1A). In CS 2, these differences were smaller, corresponding to 4 days, 3.9 days and 4.4 days, respectively, for R1, R2 and R4 (Table 1B).

Similar behavior was observed between WR1 and WR3 in the average ND for the six stages, as the differences between them were 5.2 days in CS 1 (Table 1A) and 3 days in CS 2 (Table 1B). It is likely that the smaller differences observed between WR1 and WR3 in CS 2 are due to lower soil water tension (SWT) (Table 2 and Figure 2B). For R4 stage (anthesis), the results are in accordance with those found by McClung et al. (2020), who observed a shorter delay in the occurrence of this stage for several cultivars, under higher values of volumetric soil moisture. These results can also be explained by the lower height of the ridges in CS 2 compared to CS 1, providing more effective and faster wetting.

Data analysis indicated that in CS 1 there was a significant interaction (F<0.05) between the factors "Water Regime" and "Environment" for stages V4 and R8, and that some of the other stages showed statistical differences

Figure 1. Maximum (Tmax) and minimum (Tmin) daily air temperature (°C) and daily rainfall (mm), in days after emergence (DAE), in the 2021/2022 (A) and 2022/2023 (B) cropping seasons, recorded during the field experiments, in Capão do Leão, RS.



for the aforementioned factors. Using the R4 stage as an example, it can be seen that in CS 1 the average of WR1 (92.6 days) was statistically different from the average of WR2 (86.3 days) and the average of WR3 (84.7 days) , but these last two were not different from each other (Table 1A). In CS 2, the average of WR3 (87.1 days) was different from the average of WR2 (91.0 days) and the average of WR1 (91.5 days), but these last two did not show differences between them (Table 1B).

In the conventional irrigation system (soil flooding), the duration of the subperiod from emergence to the R1 stage (vegetative subperiod) is the most variable, as it is influenced by several factors associated with crop management (Stansel, 1975; Steinmetz et al., 2013). In this study, the difference in the rice cultivation water regime, especially in the SWT, may have been the main reason for this response (Tables 1 and 2 and Figure 2).

In CS 2, the maximum deviations in the ND to reach each of the six PDS were in the range of – 3 to + 3 days when individually comparing the water regimes WR1, 2 and 3 with the flooded regime (WR4). These deviations are even smaller when comparing the average values of the three water regimes (Average WR) with WR4, being - 1 day in R1, - 0.5 day in R4 and 0.1 day in R9 (Table 1B). This response may be associated with adequate water supply in WR 1, 2 and 3, characterized by low SWT levels, below

Table 1. Number of days (ND) from emergence to six development stages of the cultivar BRS Pampa CL as a function of water regime (WR1=drained soil: upper 205 portion; WR2=saturated soil: central portion; WR3=flooded soil: lower portion) and the environment (Ridge and Furrow), in the 2021/2022 (A) and 2022/2023 (B) cropping seasons, and its relationship with estimates from the App Planej-Arroz, in Capão do Leão, RS.

(A)							
Water Regime (WR)/Environment	Number of days (ND) from emergence to the stage						Average ND
	V4	R1	R2	R4	R8	R9	
WR1 Ridge	12.6 ab	61	80.6	93.6	109.8 a	116.0	78.9
WR1 Furrow	15.6 a	61	77.6	91.6	109.2 a	114.0	78.2
Average WR1	14.1	61	79.1 a	92.6 a	109.5	115.0 a	78.5
WR2 Ridge	12.2 b	58	76.2	89.4	107.4 a	114.0	76.2
WR2 Furrow	11.4 b	56	73.2	83.2	100.8 c	111.6	72.7
Average WR2	11.8	57	74.7 b	86.3 b	104.1	112.8 a	74.4
WR3 Ridge	12.8 ab	55	74.8	87.8	106.2 ab	111.8	74.7
WR3 Furrow	12.2 b	53	70.8	81.6	102.0 bc	111.4	71.8
Average WR3	12.5	54	72.8 b	84.7 b	104.1	111.6 ab	73.3
Average WR	12.8	57	75.5	87.9	105.9	113.1	75.4
PlanejArroz							
Average (30 years)	16	51	65	79	103	111	71
Cropping season 2021/2022	16	52	65	79	103	111	71
(B)							
Water Regime (WR)/Environment	Number of days (ND) from emergence to the stage						Average ND
	V4	R1	R2	R4	R8	R9	
WR1 Ridge	12.6	62	79.2	92.4	110.4	118.8	79.2
WR1 Furrow	13.8	60	78.2	90.6	107.8	116.6	77.8
Average WR1	13.2	61	78.7 a	91.5 a	109.1 a	117.7 a	78.5
WR2 Ridge	12 .6	61	79.8	90.6	108.2	116.2	78.1
WR2 Furrow	15.6	60	79.8	91.4	108.6	117.0	78.7
Average WR2	14.1	60	79.8 a	91.0 a	108 .4 a	116.6 a	78.3
WR3 Ridge	12.2	58	74.2	87.2	106.4	114.4	75.4
WR3 Furrow	15.6	57	75.4	87.0	105 .6	113.6	75.7
Average WR3	13.9	57	74.8 b	87.1 b	106.0 b	114.0 b	75.5
Average WR	13.7	59	77.8	89.9	107.8	116.1	77.4
WR4 (Flooded)	15.4	58	77.6	90.4	107.9	116.0	77.5
PlanejArroz							
Average (30 years)	15	49	62	77	101	109	69
Cropping season 2022/2023	18	55	69	80	99	105	71

V4=plant with 4 leaves; R1=panicle differentiation; R2=formation of the flag leaf collar (booting); R4=anthesis (one or more spikelets); R8=maturity of an isolated grain; R9=complete maturity of the panicle grains.
For each cropping season and stage, letters compare the correspondent values according to the Tukey test ($p<0.05$).

20 kPa, throughout the rice cultivation cycle, except in DAE 45, when it reached 26.5 kPa in WR1 and 23.6 kPa in WR2 (Figure 2B). For the R4 stage (anthesis), the results of this study are different from those of Ockerby & Fukai (2001), who observed a delay between 11 and 15 days in the furrow-irrigated system in relation to the conventional one, although they considered the "sowing – anthesis" instead of "emergence – anthesis". These authors suggest that this delay may have been caused by the occurrence of lower temperatures in the furrow-irrigated system.

The influence of the water regime (WR) on the ND to reach three subperiods of plant development (E-R1, E-R4 and E-R9) and its relationship with the ND estimated by the App PlanejArroz is illustrated in figure 3 and indicates that the its impact was more pronounced, especially in subperiods E-R1 and E-R4, in CS 1 (Figure 3A) than in CS 2 (Figure 3B), for the reasons previously discussed.

Influence of the Furrow and Ridge environments on plant development

The most significant influence of the furrow and ridge environments on the phenology of rice plants occurred in WR2 of CS 1, as the R4 stage occurred 6.2 days earlier in the furrow compared to the ridge. The R8 stage also occurred

Table 2. Soil water tension, in ridge and furrow, in WR1=drained soil (upper portion), in WR2=saturated soil (central portion) and in WR3=flooded soil (lower portion), in cropping seasons 2021/2022 and 2022/2023, in Capão do Leão, RS.

Water regime (WR)/Environment	Soil water tension (kPa)		Average Cropping season
	Cropping season 2021/2022	Cropping season 2022/2023	
WR1 Ridge	41.1	18.2	29.7
WR1 Furrow	17.2	7.6	12.4
Average WR1	29.2	12.9	21.0
WR2 Ridge	32.4	6.8	19.6
WR2 Furrow	21.7	4.1	12.9
Average WR2	27.0	5.5	16.3
WR3 Ridge	15.8	3.5	9.7
WR3 Furrow	10.3	2.4	6.4
Average WR3	13.1	3,0	8.0
Average WR	23.1	7.1	15.1
Average Ridge	29.8	9.5	19.7
Average Furrow	16.4	4.7	10.6

Figure 2. Evolution of soil water tension, average between ridge and furrow, in WR1=drained soil (upper portion), in WR2=saturated soil (central portion) and in WR3=flooded soil (lower portion), in the 2021/2022 (A) and 2022/2023 (B) cropping seasons, in Capão do Leão, RS.

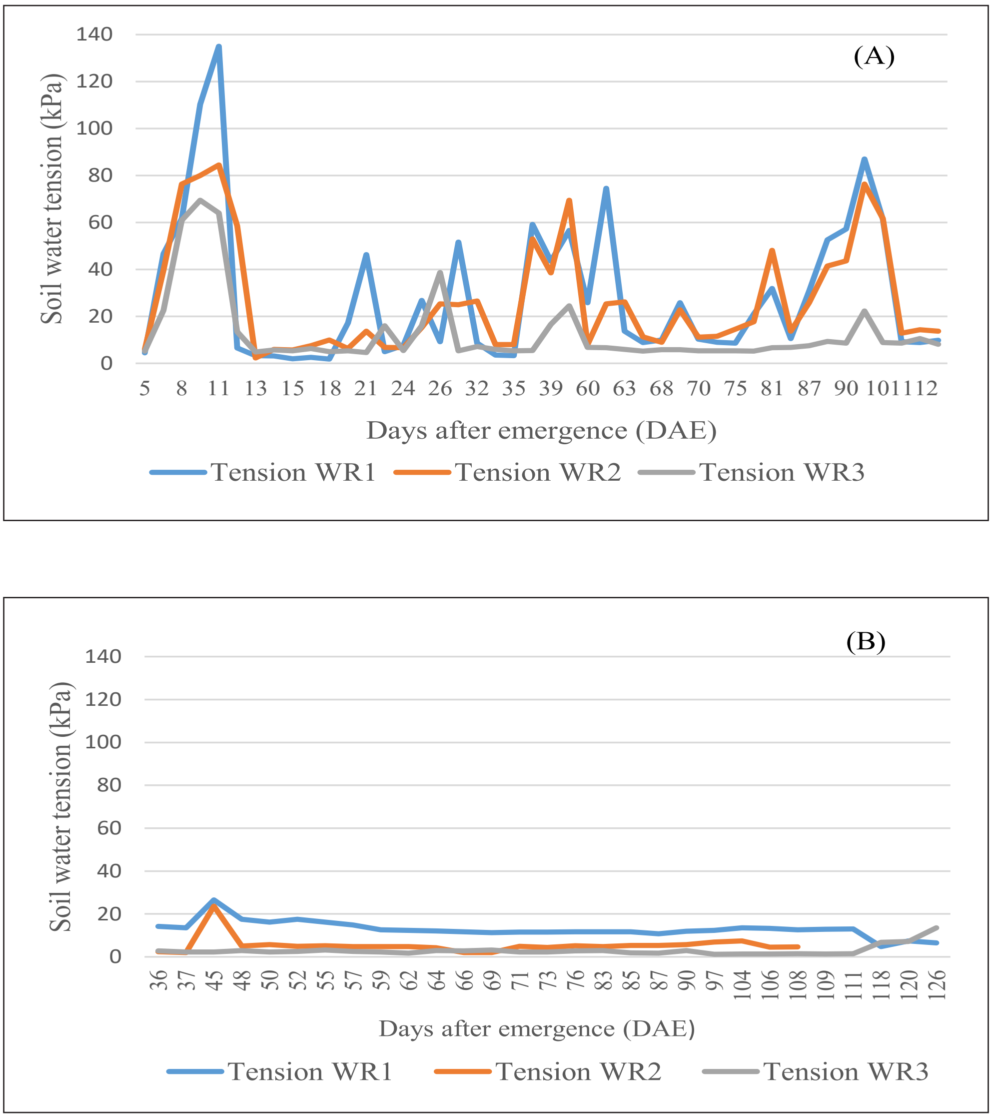
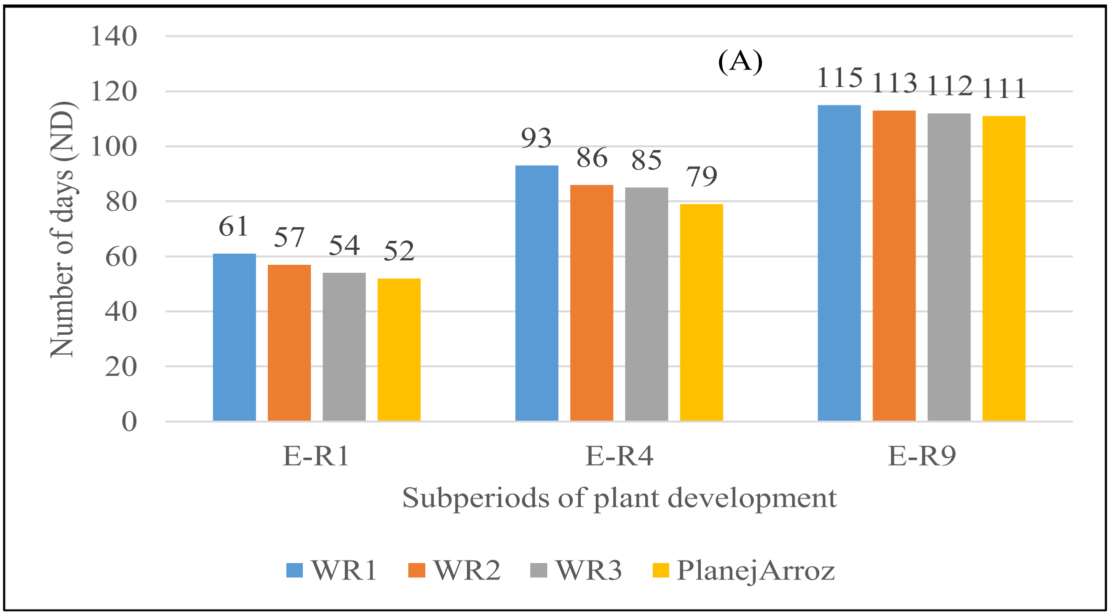
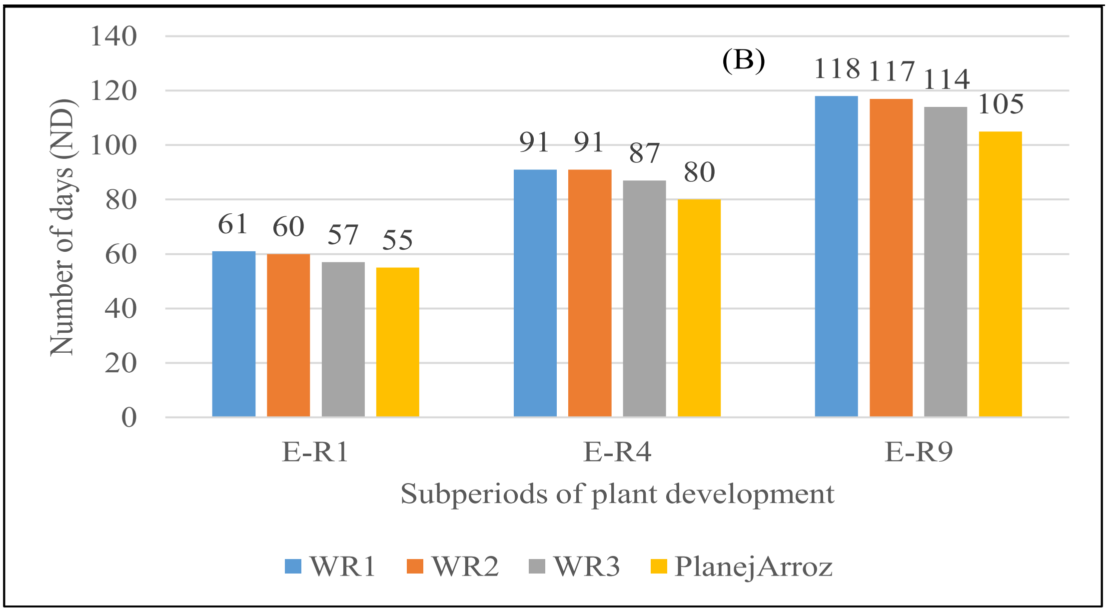


Figure 3. Number of days (ND) from emergence (E) to stages R1 (Panicle differentiation), R4 (Anthesis) and R9 (complete grain maturation) of the cultivar BRS Pampa CL as a function of water regime (WR1=drained soil : upper portion; WR2=saturated soil: central portion; WR3=flooded soil: lower portion), in the 2021/2022 (A) and 2022/2023 (B) cropping seasons, in Capão do Leão, RS, and its relationship with estimates from the App PlanejArroz.





6.6 days earlier in the furrow than in the ridge. Similar, but less pronounced, responses also occurred in WR1 and WR3 (Table 3A).

These results indicate that the plants located in the furrow had better water supply, or lower SWT values, than those located on the ridge, as shown in figure 4 (A, B, C) and Table 2. In CS 2, the influence of the furrow and ridge environments on plant development was less pronounced, probably due to the lower TAS values, both in the average of these two environments for the three water regimes (Figure 2B and Table 2), and individually in the furrow and in the ridge (Figure 4 D, E, F and Table 2).

Data analysis indicated that some PDS showed statistical differences depending on the water regime or environment. For the R2 stage, for example, the average for ND Ridge (77.2 days) was statistically different from the average for ND Furrow (73.9 days) (Table 3 A) in CS 1. Similar behavior occurred with the R4 stage. For the R8 stage, due to the fact that there was a significant interaction between the factors in the respective CS, it is possible to compare the ND responses of the two environments (ridge and furrow) in the three water regimes. Thus, for example, the ND of WR2 furrow (100.8 days) was statistically different from the ND of four combinations of factors x environments, that is, WR1, 2, 3 ridge and WR1 furrow, but that these are not different from each other (Table 3 A).

Table 3. Number of days (ND) from emergence to six development stages of the cultivar BRS Pampa CL as a function of water regime (WR1=drained soil: upper portion; WR2=saturated soil: central portion; WR3=flooded soil: lower portion) and the environment (ridge and furrow), in the 2021/2022 (A) and 2022/2023 (B) cropping seasons, in Capão do Leão, RS, and its relationship with estimates from the App PlanejArroz.

(A)							
Walter Regime (WR)/Environment	Number of days (ND) from emergence to the stage						Average ND
	V4	R1	R2	R4	R8	R9	
WR1 Ridge	12.6 ab	61	80.6	93.6	109.8 a	116.0	78.9
WR2 Ridge	12.2 b	58	76.2	89.4	107.4 a	114.0	76.2
WR3 Ridge	12.8 ab	55	74.8	87.8	106.2 ab	111.8	74.7
Average Ridge	12.5	58	77.2 a	90.3 a	107.8	113.9	76.6
WR1 Furrow	15.6 a	61	77.6	91.6	109.2 a	114.0	78.2
WR2 Furrow	11.4 b	56	73.2	83.2	100.8 c	111.6	72.7
WR3 Furrow	12.2 b	53	70.8	81.6	102.0 bc	111.4	71.8
Average Furrow	13.1	57	73.9 b	85.5 b	104.0	112.3	74.3
Average Environment	12.8	57	75.5	87.9	105.9	113.1	75.4
PlanejArroz							
Average (30 years)	16	51	65	79	103	111	71
Cropping season 2021/2022	16	52	65	79	103	111	71
(B)							
Water Regime (WR)/Environment	Number of days (ND) from emergence to the stage						Average ND
	V4	R1	R2	R4	R8	R9	
WR1 Ridge	12.6	62	79.2	92.4	110.4	118.8	79.2
WR2 Ridge	12.6	61	79.8	90.6	108.2	116.2	78.1
WR3 Ridge	12.2	58	74.2	87.2	106.4	114.4	75.4
Average Ridge	12.5 a	60	77.7	90.1	108.3	116.5	77.5
WR1 Furrow	13.8	60	78.2	90.6	107.8	116.6	77.8
WR2 Furrow	15.6	60	79.8	91.4	108.6	117.0	78.7
WR3 Furrow	15.6	57	75.4	87.0	105.6	113.6	75.7
Average Furrow	15.0 b	59	77.8	89.7	107.3	115.7	77.4
Average Environment	13.7	59	77.8	89.9	107.8	116.1	77.4
WR4 (Flooded)	15.4	58	77.6	90.4	107.9	116.0	77.5
PlanejArroz							
Average (30 years)	15	49	62	77	101	109	69
Cropping season 2022/2023	18	55	69	80	99	105	71

V4=plant with 4 leaves; R1=panicle differentiation; R2=formation of the flag leaf collar (booting); R4=anthesis (one or more spikelets); R8=maturity of an isolated grain; R9=complete maturity of the panicle grains.
For each cropping season and rice stage, letters compare the correspondent values according to the Tukey test ($p<0.05$)

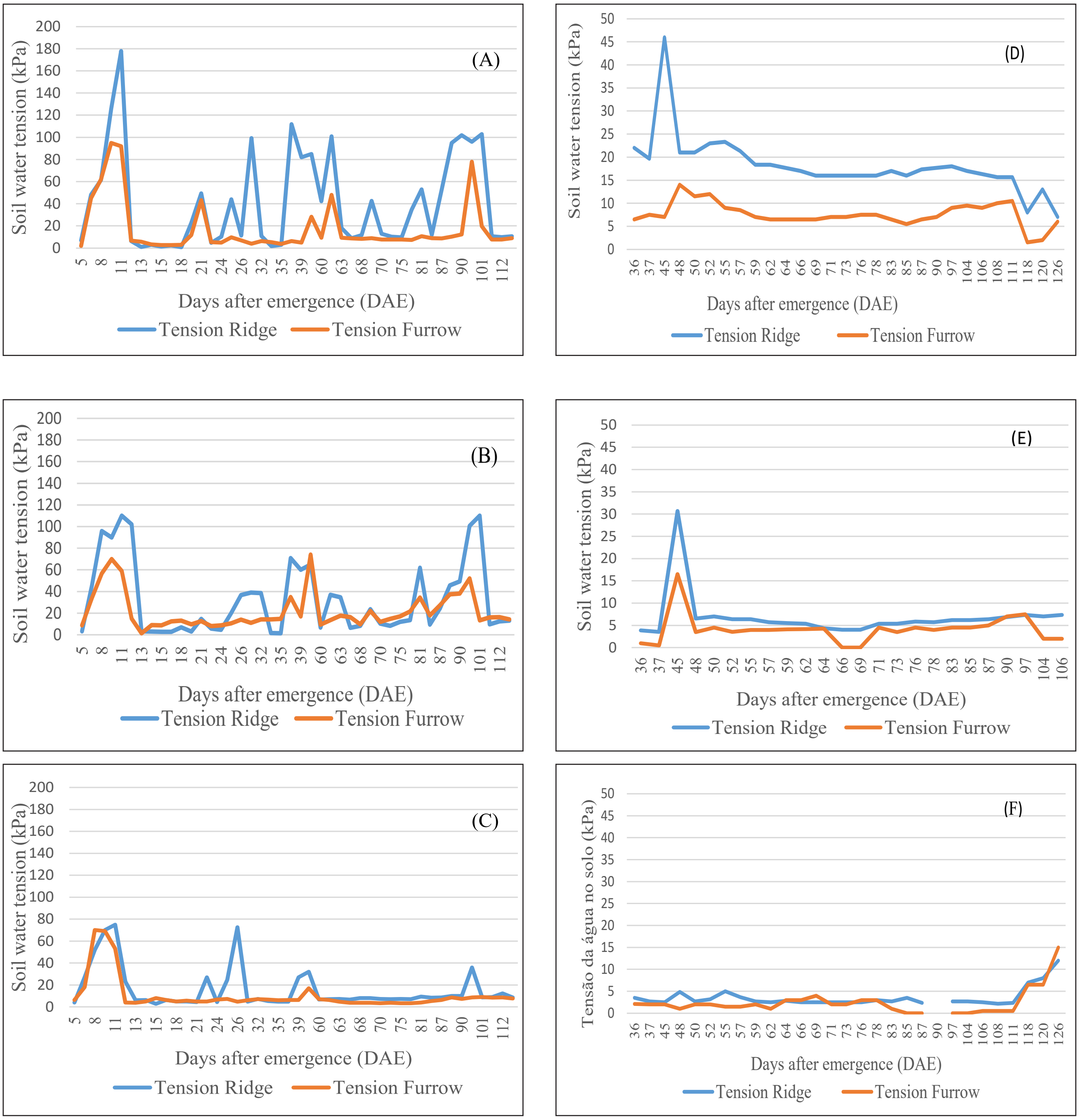
The results in Table 3B indicate that the difference in ND to reach the different stages of plant development is small when comparing the values obtained in the two environments (ridge and furrow) with WR4 (flooded). For the R1 stage, for example, it is + 2 days, for the ridge, and + 1 day for the furrow. This response is attributed to the adequate water supply in both the ridge and the furrow, as indicated by the low levels of water tension in the soil (Figure 4 D, E, F and Table 2).

The influence of the furrow and ridge environments on the ND to reach three subperiods of plant development (E-R1, E-R4 and E-R9) and its relationship with the ND estimated by the App PlanejArroz is illustrated in figure 5 and indicates that its impact was more pronounced, especially in the E-R4 subperiod, in CS 1 (Figure 5A) than in CS 2 (Figure 5B), for reasons previously discussed.

Relationship between phenology in the furrow-ridge system and in the App PlanejArroz

The comparison of the average ND for the six stages, considering the average of the three water regimes (Average WR), with those estimated by the App PlanejArroz – Cropping season, indicates that the delay provided by the furrow-irrigated system was 4.4 days (Table 1A) and 6.4 days (Table 1B), respectively, in CS 1 and 2. This delay is more significant when considering, individually, each of the six stages, reaching a maximum value of 10.5 days for the R2 stage in CS 1 (Table 1A) and 11.1 days for the R9

Figure 4. Evolution of soil water tension, in ridge and furrow, in the 2021/2022 cropping season, in WR1=drained soil (upper portion) (A), in WR2=saturated soil (central portion) (B), in WR3=flooded soil (lower portion) (C) and in the 2022/2023 cropping season, in WR1 (D), in WR2 (E) and in WR3 (F) in Capão do Leão, RS.

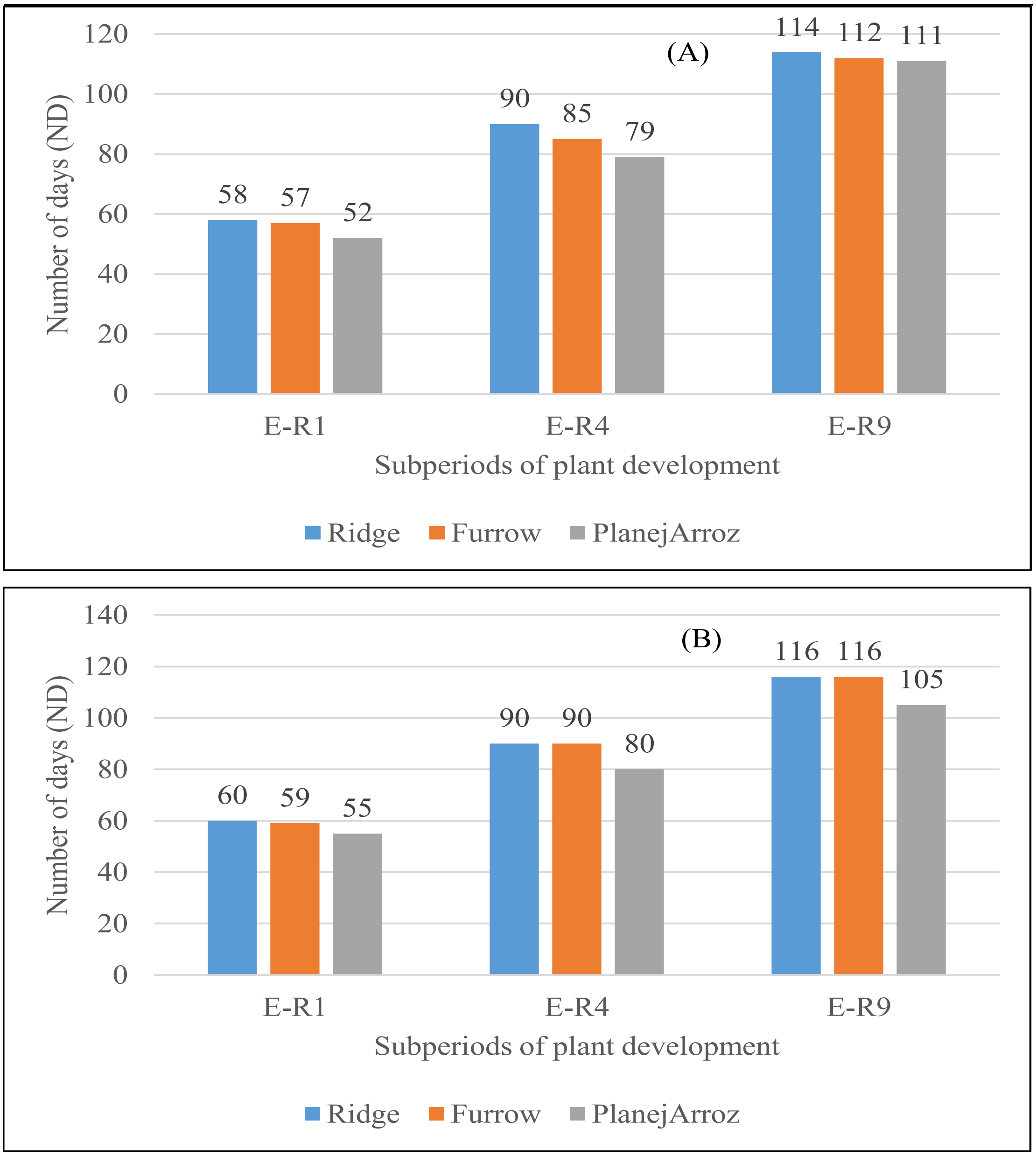


stage in CS 2 (Table 1B). For stage R4, the delay was 8.9 days in CS 1 (Table 1A) and 9.9 days in CS 2 (Table 1B), being , therefore, lower than the delay in the range of 11 – 15 days found by Ockerby & Fukai (2001).

The influence of the water regime (WR) and the furrow and ridge environments on the ND to reach three subperiods of plant development (E-R1, E-R4 and E-R9) and its relationship with the ND estimated by the App PlanejArroz is illustrated in Figures 3 and 5, respectively, indicating a more pronounced delay in ND due to WR in CS 1 (Figure 3A) than in CS 2 (Figure 3B), due to differences in soil water tension. In general, delays in ND are more significant due to WR (Figure 3) than to the environment (Figure 5).

The results that indicate a greater ND to achieve the different PDS in furrow-irrigated rice in relation to the App PlanejArroz can be considered as expected, considering that the basic data and estimates of the main PDS of this software were generated for the conventional system (flood irrigation) (Steinmetz et al., 2021a, b). The six PDS used in this study are important, as each of them is associated with one or more rice crop management

Figure 5. Number of days (ND) from emergence (E) to stages R1 (panicle differentiation), R4 (anthesis) and R9 (complete grain maturation) of the cultivar BRS Pampa CL according to the environment (ridge and furrow), in the 2021/2022 (A) and 2022/2023 (B) cropping seasons, in Capão do Leão, RS, and its relationship with estimates from the App PlanejArroz.



practices, as indicated by the technical recommendations of the Sociedade Sul-Brasileira de Arroz Irrigado – Sosbai, but the R1 stage is especially important, because it is used as a reference for nitrogen top dressing (NTD) (Reunião..., 2022). For this stage, the delay in relation to PlanejArroz was 5 days and 4 days, respectively, in CS 1 (Table 1A) and 2 (Table 1B).

These results suggest that PlanejArroz can be used as a reference to estimate the date of occurrence of the R1 stage and, consequently, to plan the date to perform NTD on rice in furrow-irrigated cultivation, as long as a 5-day correction is made for the delay in reaching R1 in this system, corresponding to the average of CS 1 (5 days) and CS 2 (4 days).

It should be noted that it is recommended to use NTD at the R0 stage (panicle initiation) (Reunião..., 2022) and that this stage, in flood-irrigated rice, occurs around 4 days before the R1 stage (De Carli, et al., 2016). Thus, assuming that R0 also occurs around 4 days before R1 in the furrow-irrigated system, the date of occurrence of R0 can be estimated through the PlanejArroz using the R1 stage as reference. To the estimated date of R1 it shoud be subtracted 4 days to reach the R0 stage, and then adding 5 days relative to the delay associated with the furrow irrigated system.

The same principle can be used to plan other management practices associated with each of the other five stages of plant development, that is, the date of occurrence of the desired stage is estimated by PlanejArroz and then corrected according to the average delay of furrow irrigated system determined in this study. However, for greater security in the use of this information, it is recommended that additional studies be carried out involving different cultivars, sowing times and rice producing regions in the state of Rio Grande do Sul.

Conclusions

The development stages of irrigated rice are delayed in the furrow-irrigated system in comparison to the flood-irrigated system and these delays are more pronounced in water regime 1 (drained soil: upper portion of the field) and in the ridge environment compared to the furrow.

The App PlanejArroz can be used to plan management practices for furrow-irrigated rice, as long as corrections are made regarding the delay in plant development in that system, but additional studies are recommended.

Authors´contribution

S. STEINMETZ designed and conducted the experiments, analysed the data and wrote the manuscript. J. M. B. PARFITT and J. G. MARTIN obtained and analysed the soil water tension data. W. B. SCIVITTARO collaborated in writting tha manuscript. G. THEISEN performed the statistical analysis. L. de S. DIAS helped to obtain the phenological data.

References

CAMPOS, A.S. de; CENTENO, A.; ANDRES, A.; PARFITT, J.M.B.; MELLO-ARAUJO, L.B.; BUENO, M.V.; PINTO, M.A.B.; MARTINS, M.B.; VEBER, P.M.; SCIVITTARO, W.B. **Utilização da tecnologia sulco-camalhão na produção de soja e milho em Terras Baixas do Rio Grande do Sul.** Pelotas: Embrapa Clima Temperado, 2021. 30p. (Embrapa Clima Temperado. Documentos, 506).

CONCENÇO, G.; PARFITT, J.M.B.; SINNEMANN, C.S.; VEIGA, A.B.; BERGMANN, H.M.; MELO,T.S.; SILVA, L.B.X. Semeadura direta de arroz em resteva de soja cultivada no Sistema sulco-camalhão. **Brazilian Journal of Development**, Curitiba, v.6, n.3, p. 13221-13231 mar. 2020. DOI: 10.34117/bjdv6n3-258

COUNCE, P.A.; KEISLING, T.C.; MITCHELL, A.J. A uniform, objective, and adaptive system for expressing rice development. **Crop Science**, Madison, v. 40, n. 2, p. 436-443, 2000.

De CARLI, C.; STEINMETZ, S.; STRECK, N. A.; MARCHESAN, E.; SILVA, M. R. da. Número de dias e de graus-dia entre a iniciação e a diferenciação da panícula de cultivares de arroz irrigado. **Ciência Rural**, Santa Maria, v. 46, n. 3, p. 428-433, mar., 2016. DOI: https://doi.org/10.1590/0103-8478cr20141057

DELLA LUNGA, D.; BRYE, K. R.; SLAYDEN, J. M. HENRY, C. G.; WOOD, L. S. Soil moisture, temperature, and oxidation-reduction potential fluctuations across a furrow-irrigated rice field on a silt-loam soil. **Journal of Rice Research and Developments**. v. 3, v. 1, p. 103-114, 2020. DOI: 10.36959/973/427

IBGE. Instituto Brasileiro de Geografia e Estatística. Sistema IBGE de Recuperação Automática – SIDRA. **Levantamento sistemático da produção Agrícola. Tabela 6588 - 2024.** Available at: <http://www.sidra.ibge.gov.br/tabela/6588#resultado>. Accessed on: Apr. 12 2024.

McCLUNG, A., M.; ROHILA, J. S.; HENRY, C. G.; LORENCE, A. Response of U.S. rice cultivars grown under non-flooded irrigation management. **Agronomy,** v. 10, n. 55, 2020. DOI:10.3390/agronomy10010055

OCKERBY, S. E.; FUKAI, S. The management of rice grown on raised beds with continuous furrow irrigation. **Field Crops Research**. v. 69, p. 215-226, 2001.

PARFITT, J.M.B.; WINKLER, A.S.; PINTO, M.A.B.; SILVA, J.T.; TIMM, L.C. Irrigação e drenagem para cultivo de soja e milho. In: EMYGDIO, B.M.; ROSA, A.P.S.A.; OLIVEIRA, A.C.B. (Eds.) **Cultivo de soja e milho em terras baixas do Rio Grande do Sul**. Brasília: Embrapa, 2017. Cap. 3, p. 44-78.

REUNIÃO TÉCNICA DA CULTURA DO ARROZ IRRIGADO, 32., Farroupilha-RS. **Arroz irrigado**: recomendações técnicas da pesquisa para o Sul do Brasil. Cachoeirinha: Sociedade Sul-Brasileira de Arroz Irrigado, 2018, 205 p.

REUNIÃO TÉCNICA DA CULTURA DO ARROZ IRRIGADO, 33., Restinga Seca-RS. **Arroz irrigado**: recomendações técnicas da pesquisa para o Sul do Brasil. Restinga Seca: Sociedade Sul-Brasileira de Arroz Irrigado, 2022, 198 p.

SANTOS, H. G.; JACOMINE, P. K. T.; ANJOS, L. H. C.; OLIVEIRA, V. A. de; OLIVEIRA, J. B. De; COELHO, M. R.; LUMBRERAS, J. F.; CUNHA, T. J. F. (Ed.) **Sistema brasileiro de classificação de solos**. 2. ed. Rio de Janeiro: Embrapa Solos, 2006. 306 p.

SAS Institute, 2022. **The SAS system for windows**. Version 9.4. Cary, NC.

SOCIEDADE BRASILEIRA DE CIÊNCIA DO SOLO. NÚCLEO REGIONAL SUL. COMISSÃO DE QUÍMICA E FERTILIDADE DO SOLO – RS/SC. **Manual de calagem e adubação para os Estados do Rio Grande do Sul e de Santa Catarina**. [s. l.]: CQFS – RS/SC, 2016. 376 p.

STANSEL, J.W. **The rice plant – its development and yield.** In: SIX DECADES OF RICE RESEARCH IN TEXAS. Beaumont: Texas Agricultural Experiment Station, 1975. p. 9-21.

STEINMETZ, S.; PETRINI, J. A.; ALMEIDA, I. R. de; MAGALHÃES JÚNIOR, A. M.; FAGUNDES, P. R. R.; DEIBLER, A. N.; RADIN, B.; PRESTES, S. D.; SILVA, M. F.; BERMUDEZ, D. A. **Uso do método de graus-dia para estimar a data de ocorrência dos principais estádios de desenvolvimento de subgrupos de cultivares de arroz irrigado no Rio Grande do Sul (Versão Resumida)**. Pelotas: Embrapa Clima Temperado, 2013. 108p. (Embrapa Clima Temperado. Boletim de Pesquisa e Desenvolvimento, 205).

STEINMETZ, S.; CUADRA, S. V.; ALMEIDA, I. R., MAGALHÃES Jr., A. M.; FAGUNDES, P. R. R. Estádios de desenvolvimento da planta de subgrupos de cultivares de arroz irrigado por inundação**. Agrometeoros**, Passo Fundo, v.29, e026814, 2021a. DOI: http://dx.doi.org/10.31062/agrom.v29.e026814

STEINMETZ, S.; PEREIRA, C. B.; SANTOS, E. L.; CUADRA, S. V.; ALMEIDA, I. R., STRECK, N. A.; BENEDETTI, R. P.; DUARTE Jr., A. J.; ZANON, A. J.; RIBAS, G. G.; SILVA, M. R.; KROEFF, R. M.; PRESTES, S. D. Fundamentals and applications of PlanejArroz, a software for irrigated rice management and yield estimation. **Agrometeoros**, Passo Fundo, v.29, e026847, 2021b. DOI: http://dx.doi.org/10.31062/agrom.v29.e026847

STEVENS, G.; RHINE, M.; HEISER, J. **Rice production with furrow irrigation in the Mississippi River Delta Region of the USA**. 2018. DOI: 10.5772/intechopen.74820. Accessed on: Jul. 02 2020.

VEDELAGO, A. **Adubação para a soja em terras baixas drenadas no Rio Grande do Sul.** 2014. 83 f. Dissertação (Mestrado em Ciência do Solo), Universidade Federal do Rio Grande do Sul, Porto Alegre, 2014.

WREGE, M. S.; STEINMETZ, S.; REISSER JÚNIOR, C.; ALMEIDA I. R. de (Editores técnicos). **Atlas climático da Região Sul do Brasil:** Estados do Paraná, Santa Catarina e Rio Grande do Sul. Pelotas: Embrapa Clima Temperado; Colombo: Embrapa Florestas, 2011. 211p.

CITATION

STEINMETZ, S.; PARFITT, J. M. B.; SCIVITTARO, W. B.; THEISEN, G.; DIAS, L. de S.; L. S.; MARTIN, J. G. Development stages of furrow-irrigated rice and their relationship with estimates from the App PlanejArroz. **Agrometeoros**, Passo Fundo, v.32, e027668, 2024.

agrometeoros
REVISTA DA SOCIEDADE BRASILEIRA DE AGROMETEOROLOGIA

ISSN 2526-7043 www.sbagro.org.br DOI: http://dx.doi.org/10.31062/agrom.v32.e027668

Estádios de desenvolvimento do arroz irrigado por sulco e sua relação com as estimativas do aplicativo PlanejArroz

Silvio Steinmetz[1(*)], José Maria Barbat Parfitt[1], Walkyria Bueno Scivittaro[1], Giovani Theisen[1], Luan de Souza Dias[2] e Jéssica Goetzke Martin[2]

[1]Embrapa Clima Temperado. Rodovia BR 392, km 78, Cx. Postal 403, CEP 96001-970 Pelotas, RS.
E-mails: silvio.steinmetz@embrapa.br, jose.parfitt@embrapa.br, walkyria.scivittaro@embrapa.br e giovani.theisen@embrapa.br
[2]Faculdade de Agronomia Eliseu Maciel - Universidade Federal de Pelotas. Campus Universitário s/n, CEP 96010-610 Capão do Leão, RS.
E-mails: luansouza.engenheiroagronomo@gmail.com e goetzkejessica@gmail.com
[(*)]Autor para correspondência.

INFORMAÇÕES

História do artigo:
Recebido em 28 de maio de 2024
Aceito em 22 de agosto de 2024

Termos para indexação:
Oryza sativa L.
estádios fenológicos
tensão de água no solo
manejo da cultura

RESUMO

Os objetivos deste trabalho foram caracterizar como o regime hídrico e os ambientes sulco e camalhão afetam os estádios de desenvolvimento da planta (EDP) e como esses estádios se relacionam com as estimativas do aplicativo PlanejArroz. Na safra 2021/2022 os EDP foram obtidos em três regimes hídricos (regime hídrico 1 – RH1; regime hídrico 2 – RH2; regime hídrico 3 – RH3). Na safra 2022/2023, foi incluído o regime hídrico 4 - RH4. Os EDP foram obtidos por meio de leituras, duas vezes por semana, nas plantas marcadas no camalhão e no sulco. Os resultados indicaram que o número de dias da emergência (ND) para atingir os EDP foi influenciado pelo regime hídrico (RH), especialmente para os estádios R1 (diferenciação da panícula), R2 (emborrachamento) e R4 (antese), que apresentaram diferenças entre o RH1 e o RH3, respectivamente, de 7, 6,3 e 7,9 dias na safra 2021/2022 e de 4, 3,9 e 4,4 dias na safra 2022/2023. Os resultados permitem concluir que os EDP de arroz irrigado sofrem atraso no sistema sulco-camalhão e que o aplicativo PlanejArroz pode ser utilizado para o planejamento das práticas de manejo do arroz irrigado no sistema sulco-camalhão desde que sejam feitas as correções relativas ao atraso no desenvolvimento das plantas no referido sistema.

REFERENCIAÇÃO

STEINMETZ, S.; PARFITT, J. M. B.; SCIVITTARO, W. B.; THEISEN, G.; DIAS, L. de S.; L. S.; MARTIN, J. G. Development stages of furrow-irrigated rice and their relationship with estimates from the App PlanejArroz. **Agrometeoros**, Passo Fundo, v.32, e027668, 2024.