agrometeoros
REVISTA DA SOCIEDADE BRASILEIRA DE AGROMETEOROLOGIA

ISSN 2526-7043 www.sbagro.org.br DOI: http://dx.doi.org/10.31062/agrom.v30.e027127

Number of days to reach the main plant developmental stages of irrigated rice cultivars

Silvio Steinmetz[1(*)], Ariano Martins de Magalhães Júnior[1], Paulo Ricardo Reis Fagundes[1], Santiago Vianna Cuadra[2] and Ivan Rodrigues de Almeida[2]

[1]Embrapa Clima Temperado. Rodovia BR 392, km 78, Caixa Postal 403, CEP 96.010-971 Pelotas, RS, Brazil.
E-mails: silvio.steinmetz@embrapa.br, ariano.martins@embrapa.br and paulo.fagundes@embrapa.br
[2]Embrapa Agricultura Digital. Av. Dr. André Tosello, 209 – Cidade Universitária, CEP 13083-866 Campinas, SP, Brazil.
E-mails: santiago.cuadra@embrapa.br and ivan.almeida@embrapa.br
[(*)]Correponding author.

ARTICLE INFO

Article history:
Received 2 September 2022
Accepted 29 November 2022

Index terms:
Oryza sativa L.
length of growth stages
phenology

ABSTRACT

The objective of this study was to determine the number of days (ND) to reach the main plant developmental stages (PDS) of irrigated rice cultivars. Field experiments were carried out at the Estação Experimental Terras Baixas (ETB) of Embrapa Clima Temperado, located in the municipality of Capão do Leão, State of Rio Grande do Sul, Brazil, during 12 crop seasons, using six sowing dates in each. Ten plants from each cultivar were tagged and had each of the PDS monitored throughout the crop cycle. The results indicated that the ND to reach each of the six PDS varied according to the cycle of the cultivars and that there was statistical difference between some of them. The ND to reach the stages R1 (panicle differentiation), R4 (anthesis) and R9 (complete panicle maturity) of the cultivar IRGA 424, for example, were 63, 96 and 125, respectively. The average number of days to reach the different plant developmental stages varies according to the cycle length of the cultivars, and the subperiod of longer duration is that between the four-leaf and panicle differentiation stages (V4-R1).

Introduction

The State of Rio Grande do Sul (RS) is the largest producer of irrigated rice in Brazil, having contributed, in the growing seasons 2017/18, 2018/19 and 2019/20 with about 70% of national production (IBGE, 2020). Although the average grain yield is relatively high (7.7 t ha^{-1}), it is believed that it may be even higher if some aspects related to crop management are improved, reducing the yield gap indicated by Ribas et al. (2020). For this, it is important that the execution of a particular cultural practice, such as topdressing nitrogen fertilization, water management, control of insect pests, diseases, or the time of harvest, is carried out at the right time, considering plant developmental stage, as recommended by the South-Brazilian Society of Irrigated Rice - Sosbai (Reunião, 2018).

Some cultural practices are related to critical subperiods of plant development. The subperiod between the flag leaf collar formation (R2) until the beginning of anthesis (R4), for example, can be useful to decrease the effect of

harmful low temperatures by raising the water depth or for controlling plant diseases such as blast (Pyricularia oryzae (Cavara); Magnaporthe oryzae B. Couch – forma perfeita) (Reunião, 2018).

In general, the date of occurrence of the main PDS is determined in field experiments, at different sowing times, using a phenological scale (Watson et al., 2004; Streck et al., 2006a; Steinmetz et al., 2017). Previous results have been presented either by groups (Steinmetz et al., 2017) or subgroups of cultivars (Steinmetz et al., 2021a) or for some stages of some cultivars (Streck et al., 2006a). The peculiarity of this study, in relation to the previous ones, is that it uses a series of experimental data, of several years, to characterize the occurrence of the main PDS of the cultivars individually, instead of groups or subgroups to which they belong to, involving the main genotypes released in recent years by public and private institutions.

The objective of this study was to determine the number of days to reach the main plant developmental stages of irrigated rice cultivars.

Material and Methods

The field experiments were carried out in the area of the Estação Experimental Terras Baixas (ETB) of Embrapa Clima Temperado, in the municipality of Capão do Leão, RS, Brazil (latitude 31° 52 'S; longitude 52° 21' W and altitude 13 m), during a period of twelve crop seasons (2004/2005 - 2015/2016). The local climate, according to the Köppen classification, is of the Cfa type, which corresponds to the humid subtropical, with hot summers and without a defined dry season (Wrege et al., 2011). The soil in the experimental area is classified as a typical eutrophic Haplossolo Haplico (Santos et al., 2006). The plots were 5m long and 1.58m wide, consisting of 9 lines spaced by 17.5cm. The basic and topdressing fertilizations and other cultural treatments followed the recommendations of Sosbai (Reunião, 2003) for the 2004/05 crop season, and the current Sosbai indications for the other crop seasons. The date of emergence was considered when around 50% of the seedlings in the plot were visible above ground level.

In general, twelve cultivars and six sowing dates (from early September to mid-December) were used in each crop season. However, throughout the years, some cultivars were replaced by others, making variable the number of crop seasons for each cultivar. In this work, 34 cultivars were evaluated, involving the four cycles indicated by Sosbai (Reunião, 2018).

In order to facilitate the interpretation of the results, the cultivars were classified, according to their cycles, into seven subgroups. The numbers between parenthesis indicate the average cycle lenght, in days, according to Sosbai (Reunião, 2018) while those between brackets correspond to the number of years in which data were collected for that cultivar. The cultivars evaluated were one of Very Short cycle 1 (VS1): IRGA 421 (95) [7]; two of Very Short cycle 2 (VS2): BRS Atalanta (100) [12]; BRS Ligeirinho (95) [2]; two of Short cycle 1 (S1): BRS 6 "Chuí" (110) [5]; BRS Querência (110) [12]; eleven of Short cycle 2 (S2): BRS Pampa (118) [8]; BRS Firmeza (120) [5]; IRGA 417 (115) [9]; IRGA 422 CL (120) [3]; IRGA 423 (120) [3]; IRGA 430 (120) [1]; Avaxi CL (120) [7]; Inov CL (120) [7]; Titan CL (120) [1]; Guri Inta CL (120) [3]; Puitá Inta CL (120) [5]; nine of Medium cycle 1 (M1): BRS Pelota (125) [6]; BRSCIRAD 302 (128) [3]; BRS Sinuelo CL (130) [7]; BR-IRGA 410 (123) [4]; BR-IRGA 409 (126) [5]; IRGA 429 (124) [1]; IRGA 426 (125) [3]; IRGA 428 CL (125) [2]; Lexus CL (128) [3]; seven of Medium cycle 2 (M2): BRS 7 "Taim (130) [5]; BRS Bojuru (135) [2]; BRS Fronteira (135) [8]; IRGA 424 (132) [8]; IRGA 424 IR (133) [1]; IRGA 425 (132) [3]; IRGA 427 (136) [2]; and two of Long cycle (L): SCS BRS Tio Taka (141) [6]; Epagri 109 (142) [4]. Of the 34 cultivars evaluated in this work, 28, that is 70%, are on the list of all cultivars (40) recommended by Sosbai (Reunião, 2018) for cultivation in the states of Rio Grande do Sul and Santa Catarina.

Ten plants (main stem) of each cultivar were marked and had their development monitored throughout the cycle, each stage being characterized according to the scale proposed by Counce et al. (2000). Two to three readings were taken per week. Average dates for each stage were obtained from the observations in the 10 plants. The stage R1 (panicle differentiation) was determined by the method described by Steinmetz et al. (2009a).

The six stages considered in this work were: V4: plant with four leaves; R1: panicle differentiation; R2: flag leaf collar formation (booting); R4: anthesis (one or more florets); R8: maturity of an isolated grain; R9: complete maturity of the panicle grains. In order to better characterize the phenological behavior of the cultivars, six subsequent subperiods of plant development were established (E-V4; V4-R1; R1-R2; R2-R4; R4-R8 and R8-R9). Three larger periods were also established, namely, vegetative period (E-R1), reproductive period 1 (R1-R4) and reproductive period 2 (R4-R9), respectively. The reason for this is that, before the study of Counce et al. (2000), the periods E-R1, R1-R4 and R4-R9 were considered, respectively, as vegetative phase, reproductive phase and maturation phase (Yoshida, 1981). On the scale of Counce et al. (2000), the first subperiod corresponds to the vegetative phase and the other two are part of the reproductive phase. In this study, the beginning of the reproductive period will be considered as the R1 stage and not the R0 (panicle initiation), as indicated in Counce et al. (2000).

The number of days to reach each PDS represents the average of the six sowing dates, in each crop season, and of

the various years in which the cultivar was evaluated. The mean values of the subgroups were calculated to serve as reference for the cultivars that belong to the subgroups.

The statistical comparison of the cultivars regarding the number of days to reach the six stages, the six subperiods and the three periods of plant development was made using the Mood test, a non-parametric method, since the data (residues) do not present normal distribution in the linear model fitting (Siegel & Castellan Jr., 1988).

Results and Discussion

The average number of days (ND) to reach each of the six PDS varied according to the cultivar´s cycle (Figure 1). For some stages, except for V4, there was statistical difference (SD) between some cultivars, especially for those belonging to different subgroups. Thus, to reach the R9 stage, for example, the ND (142) of the cultivar Epagri 109 (L) was statistically different from the ND of 125, 115 and 91, respectively, of the cultivars IRGA 424 (M2), BRS Pampa (S2) and IRGA 421 (VS1). However, there was no SD between the cultivars IRGA 424 (M2) and BRS Pampa (S2) (Table 1).

Considering only the cultivars belonging to the subgroups S1, S2, M1 and M2, which represent the cycle of the main cultivars sown in the State of Rio Grande do Sul, one can verify that the ND to reach the R9 stage varied from 104 days for the cultivar BRS 6 "Chuí" (S1) to 129 days for cultivar BRSCIRAD 302 (M1) (Table 1).

When considering the average values of the ND to reach the R9 stage of these four subgroups, but represented by only two subgroups, that is, 112 and 121 days, which would correspond, respectively, to the Short and Medium groups, it appears that these were within, or very close to, the cycle length ranges indicated in Sosbai (Reunião, 2018).

The ND to reach the R4 stage indicated that there was SD between some cultivars, especially for those belonging to different subgroups (Table 1). Thus, for example, the ND (115) of the cultivar SCSBRS Tio Taka (L) was statistically different from the ND of 95, 86 and 82, respectively, of the cultivars BRS 7 "Taim" (M2), Guri Inta CL (S2) and BRS 6 "Chuí" (S1). There was also SD between the last three cultivars (Table 1).

The results in Table 1, for stage R4, are similar to those obtained in experiments using cultivars of different cycles and conducted at different sowing times such as those by Freitas et al. (2006). These authors indicated that the average ND to reach the R4 stage, of the three sowing times (early, preferential and late), of the cultivar BR-IRGA 409, was 98 days, which is close to the value of 92 obtained in this work for this cultivar. The results are also close when comparing the ND of the cultivar IRGA 417, which was 95 days in Freitas et al. (2006) and 88 days in this work (Table 1).

The E-R1 subperiod represented about 49% of the total cycle (E-R9) on the average of all cultivars, ranging from 47% for the cultivar IRGA 421 (43 over 91 days) to 54% for the cultivar Epagri 109 (76 over 142 days) (Table 1). For the subperiod E-R2, the values of 60% and 71% of the total cycle, respectively, for cultivars IRGA 421 (55 over 91 days) and Epagri 109 (101 over 142 days) are similar to 55% for cultivar IRGA 421 and 75% for the cultivar Epagri 109, obtained by Streck et al. (2006a).

The evaluation of the ND between the main stages indicated that there was no statistical significance between cultivars for the subperiods from the emergence to the four-leaf stage (E-V4), from the booting to the beginning of the anthesis (R2-R4) and from the beginning to the end

Figure 1. Average number of days from emergence to the plant developmental stages V4 (plant with four leaves), R1 (panicle differentiation), R2 (booting), R4 (anthesis), R8 (beginning of ripening) and R9 (complete ripening of grains), of four irrigated rice cultivars, of Very short (IRGA 421), Short (BRS Pampa), Medium (IRGA 424 RI) and Long (Epagri 109) cycles, obtained during twelve crop seasons (2004/2005 - 2015/2016), in Capão do Leão, RS, Brazil.

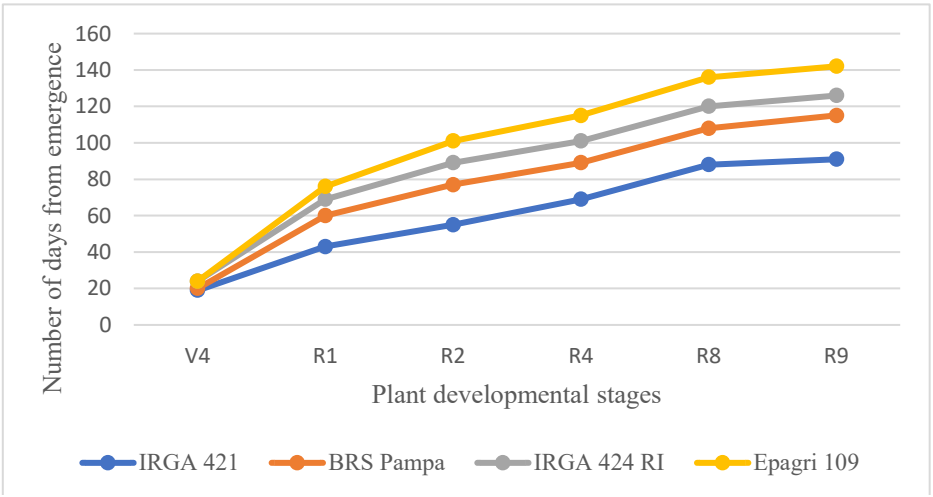


Table 1. Average number of days from emergence to each of the six plant developmental stages of 34 irrigated rice cultivars, obtained during twelve crop seasons (2004/2005 - 2015/2016), in Capão do Leão, RS, Brazil. The numbers between parenthesis indicate the average cycle of the cultivar, in days (Reunião, 2018), and between brackets the number of crop seasons in which the cultivar was evaluated.

Cultivar	Subgroup	Average number of days from emergence to the stage					
(Cycle)(Nr seasons)		V4	R1	R2	R4	R8	R9
IRGA 421(95) [7]	VS1	19 ns	43 d	55 e	69 e	88 e	91 d
Average (VS1)		19	43	55	69	88	91
BRS Atalanta (100) [12]	VS2	20 ns	45 d	62 e	75e	93 d	100 d
BRS Ligeirinho (95) [2]		20 ns	42 d	60 e	73 e	-	99 d
Average (VS2)		20	44	61	74	93	100
BRS 6 "Chuí" (110) [5]	S1	17 ns	51 c	69 d	82 d	100 d	104 c
BRS Querência (110) [12]		20 ns	54 c	72 d	84 d	104 c	111 c
Average (S1)		19	53	71	83	102	108
BRS Pampa (118) [8]	S2	20 ns	60 b	77 c	89 d	108 c	115 b
BRS Firmeza (120) [5]		25 ns	57 b	75 c	88 d	99 d	109 c
IRGA 417 (115) [9]		20 ns	60 b	76 c	88 d	107 c	105 b
IRGA 422 CL (120) [3]		15 ns	61 b	77 c	88 d	108 c	117 b
IRGA 423 (120) [3]		24 ns	61 b	75 c	87 d	107 c	115 b
IRGA 430 (120) [1]		26	62	78	92	109	114
Avaxi CL (120) [7]		20 ns	60 b	79 c	91 c	114 b	120 b
Inov CL (120) [7]		20 ns	60 b	77 c	90 d	112 b	119 b
Titan CL (120) [3]		23 ns	53 c	71 d	84 d	105 c	111 c
Guri Inta CL (120) [3]		22 ns	54 b	74 b	86 c	105 b	111 b
Puitá Inta CL (120) [5]		21 ns	63 c	80 c	91 d	112 c	119 c
Average (S2)		21	59	76	89	108	115
BRS Pelota (125) [6]	M1	18 ns	61 b	80 b	93 c	113 b	121 b
BRSCIRAD 302 (128) [3]		22 ns	67 b	85 b	100 b	121 b	129 b
BRS Sinuelo CL (130) [7])		22 ns	61 b	78 c	91 c	112 b	120 b
BR-IRGA 410 (123) [4]		17 ns	58 b	80 b	92 c	110 c	121 b
BR-IRGA 409 (126) [5]		20 ns	59 b	80 b	92 c	111 b	114 b
IRGA 429 (124) [1]		27	67	87	100	118	124
IRGA 426 (125) [3]		20 ns	61 b	79 b	91 c	112b	118b
IRGA 428 CL (125) [2]		21 ns	54 c	71 d	86 d	104 c	111 c
Lexus CL (128) [3]		20 ns	55 c	76 c	89 d	109 c	115 b
Average (M1)		21	60	80	92	112	119
BRS 7 "Taim (130) [5]	M2	17 ns	61 b	83 b	95 b	116 b	123 b
BRS Bojuru (135) [2]		19 ns	60 b	79 c	92 c	-	122 b
BRS Fronteira (135) [8]		20 ns	65 b	85 b	96 b	116 b	124 b
IRGA 424 (132) [8]		21 ns	63 b	84 b	96 b	117 b	125 b
IRGA 424 RI (133) [1]		24	69	89	101	120	126
IRGA 425 (132) [3]		17 ns	58 b	77 c	90 d	112 b	119 b
IRGA 427 (136) [2]		21 ns	58 b	80 b	94 c	112 b	118 b
Average (M2)		20	62	82	95	116	122
SCS BRS Tio Taka (141) [6]	L	23 ns	79 a	104 a	118 a	141 a	147 a
Epagri 109 (142) [4]		24 ns	76 a	101 a	115 a	136 a	142 a
Average (L)		24	78	103	117	139	145

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. Plant developmental stages according to the scale of Counce et al. (2000). VS1 = Very short 1; VS2 = Very short 2; S1 = Short 1; S2 = Short 2; M1 = Medium 1; M2 = Medium 2; L = Long, according to Steinmetz et al. (2018).

Values with equal letters in the column do not differ statistically from each other by the Mood test (at 95% confidence); ns = no statistical significance.

of the grains maturation (R8-R9) (Table 2). On the other hand, the subperiod from the four-leaf stage to that of panicle differentiation (V4-R1) was the one with the highest value (36 days), when considering the mean ND of all cultivars of this superiod, with statistical difference between cultivars, especially for those belonging to different subgroups. Figure 2 illustrates this behavior for four cultivars of different cycles. In this subperiod, there was a variation of 34 days (154%) when considering the extreme values obtained, that is, for the cultivars SCSBRS Tio Taka (56 days) and BRS Ligeirinho (22 days). When considering the same cultivars, that is, IRGA 421, IRGA 417 and BR-IRGA 409, the ND of the subperiod V4-R1 of this study was higher than those found by Freitas et al. (2006).

The second subperiod with the greatest difference among cultivars was that of panicle differentiation and booting (R1-R2), indicating a variation of 11 days (73%) when considering the highest value, 26 days for the cultivar Epagri 109 and lowest one, 15 days for the cultivar IRGA 421 (Table 2). These results are in line with those obtained previously by Steinmetz et al. (2009b).

When only three major periods of plant development were considered, the biggest differences among cultivars were between emergence and panicle differentiation (E-R1), indicating a variation of 37 days (88%) between SCSBRS Tio Taka (79 days) and BRS Ligeirinho (42 days) (Table 3). There were statistical differences beween cultivars, especially for those belonging to different subgroups. Figure 3 illustrates this behavior, using four cultivars with different cycles.

By being particularly influenced by temperature, the E-R1 period may have different values according to the sowing time. Early and late sowing tend, respectively, to lengthen and shorten the E-R1 period (Steinmetz et al., 2009ab; Singh et al., 2012). The photoperiod is another factor that can interfere in the duration of this period, depending on the sensitivity of the cultivar and the sowing time (Yoshida, 1981; Streck et al., 2006b). In this study, the influence of the sowing time on the E-R1 period cannot be evaluated as the results represent the averages of six sowing dates of several crop seasons (Tables 1 and 3).

One of the difficulties encountered in comparing the results with those obtained by other authors concerns the length of the vegetative period, which in this work was from emergence to panicle differentiation (E-R1), while other authors assumed that it was from emergence to booting (E-R2) (Watson et al., 2004; Streck et al., 2006a). It is likely that this is due to the fact that the R2 stage is easily identified in the field, without the need to perform destructive sampling of plants as occurs to determine the R1 stage (Stansel, 1975; Steinmetz et al.,2009a).

The problem is that the difference between the R1-R2 stages can be large, depending on the cultivar´s cycle. In this study, it varied between 15 and 26 days, respectively, for the cultivars IRGA 421 and Epagri 109 (Table 2).

Thus, when there is a need to determine the length of the vegetative period with greater accuracy, aiming at some management practice, it is recommended to use a method that allows determining the panicle differentiation stage (R1) and, if possible, the panicle initiation (PI). This is the case, for example, with nitrogen topdressing (NTD), which should be done at the panicle initiation stage (R0) according to Sosbai (Reunião, 2018). As this stage is difficult to be visualized directly on the plant, under field conditions, Steinmetz et al. (2014; 2015; 2018) suggest to use the degree-day method to estimate the date of occurrence of stage R1, visible to the naked eye, which occurs, on average, four days after stage R0 (Carli, 2016). In this way, it is possible to plan for NTD to be performed, at least four days before the estimated date of R1, so that nitrogen is available to plants at the R0 stage, as recommended by Sosbai (Reunião, 2018).

The second period of greatest difference among cultivars was between the stage of panicle differentiation and anthesis (R1-R4), indicating a variation of 14 days (54%) between the cultivars Epagri 109 (40 days) and IRGA 421 (26 days) (Table 3). Most cultivars showed similar ND values, causing statistical differences to occur only between some of them, especially those belonging to different subgroups. These results agree with those obtained previously by Steinmetz et al. (2009b).

The mean ND value of all cultivars for the period between anthesis and complete grain maturation (R4-R9) was 26 days, varying from 32 days for cultivar BRS Sinuelo CL and 20 days for BRS Bojuru (Table 3), with no statistical significance between the cultivars. These results agree with those obtained previously by Steinmetz et al. (2009b). The average value of 31 days for cultivars IRGA 421, IRGA 417 and BR-IRGA 409 obtained by Freitas et al. (2006), for the period R4-R8, is slightly above the average value of 27 days obtained in this work, for the same cultivars, but considering the period R4-R9.

The results of this study are an improvement over those obtained previously (Freitas et al., 2006; Streck et al., 2006a; Steinmetz et al. 2009b; 2015) because a greater number of cultivars (34) were evaluated, being most of them (around 70%) recommended for cultivation in the states of Rio Grande do Sul and Santa Catarina (Reunião, 2018). The ND to reach the main PDS can be useful tool for planning the most appropriate time to apply several cultural practices as recommend by Reunião (2018). This assertion is valid mainly for the localities with environmental conditions similar to where the data were obtained. If the ND to reach the main PDS data are transformed into accumulated degree-days a broader area can be covered for planning crop management as indicated by the softwares DD50 in

Table 2. Average number of days between the main plant developmental stages of 34 irrigated rice cultivars, obtained during twelve crop seasons (2004/2005 - 2015/2016), in Capão do Leão, RS, Brazil. The numbers between parenthesis indicate the average cycle of the cultivar, in days (Reunião, 2018), and between brackets the number of crop seasons in which the cultivar was evaluated.

Cultivar	Subgroup	Average number of days between the plant developmental stages					
(Cycle)(Nr seasons)		E-V4	V4-R1	R1-R2	R2-R4	R4-R8	R8-R9
IRGA 421(95) [7]	VS1	19 ns	24 d	15 c	11 ns	18 b	6 ns
Average (VS1)		19	24	15	11	18	6
BRS Atalanta (100) [12]	VS2	20 ns	25 d	17 c	12 ns	18 b	7 ns
BRS Ligeirinho (95) [2]		20 ns	22 d	19 c	13 ns	-	-
Average (VS2)		20	24	18	13	18	7
BRS 6 "Chuí" (110) [5]	S1	17 ns	34 c	18 c	13 ns	17 b	9 ns
BRS Querência (110) [12]		20 ns	34 c	17 c	13 ns	19 b	8 ns
Average (S1)		19	34	18	19	18	9
BRS Pampa (118) [8]	S2	20 ns	40 b	17 c	12 ns	20 b	7 ns
BRS Firmeza (120) [5]		25 ns	32 c	18 c	13 ns	16 b	8 ns
IRGA 417 (115) [9]		20 ns	40 b	16 c	12 ns	19 b	8 ns
IRGA 422 CL (120) [3]		15 ns	45 b	16 c	11 ns	20 b	9 ns
IRGA 423 (120) [3]		24 ns	37 b	14 c	12 ns	19 b	9 ns
IRGA 430 (120) [1]		26	37	16	13	17	5
Avaxi CL (120) [7]		20 ns	40 b	18 c	13 ns	21 a	8 ns
Inov CL (120) [7]		20 ns	40 b	17 c	13 ns	21 a	8 ns
Titan CL (120) [3]		23 ns	31 c	18 c	13 ns	21 a	6 ns
Guri Inta CL (120) [3]		21 ns	41 b	17 c	11 ns	21 a	7 ns
Puitá Inta CL (120) [5]		22 ns	32 c	20 b	12 ns	19 b	6 ns
Average (S2)		21	38	17	12	19	7
BRS Pelota (125) [6]	M1	18 ns	42 b	20 b	12 ns	19 b	8 ns
BRSCIRAD 302 (128) [3]		22 ns	45 b	18 c	15 ns	21 a	8 ns
BRS Sinuelo CL (130) [7]		22 ns	39 b	17 c	13 ns	21 a	8 ns
BR-IRGA 410 (123) [4]		17 ns	41 b	22 b	12 ns	19 b	9 ns
BR-IRGA 409 (126) [5]		20 ns	40 b	21 b	12 ns	19 b	11 ns
IRGA 429 (124) [1]		27	40	20	13	18	6
IRGA 426 (125) [3]		20 ns	40 b	19 c	12 ns	20 a	7 ns
IRGA 428 CL (125) [2]		21 ns	33 c	18 c	15 ns	18 b	7 ns
Lexus CL (128) [3]		20 ns	34 c	21 b	13 ns	20 a	6 ns
Average (M1)		21	39	20	13	19	8
BRS 7 "Taim (130) [5]	M2	17 ns	44 b	22 b	12 ns	19 b	9 ns
BRS Bojuru (135) [2]		19 ns	41 b	19 c	13 ns	-	-
BRS Fronteira (135) [8]		20 ns	45 b	20 b	12 ns	20 b	8 ns
IRGA 424 (132) [8]		21 ns	43 b	21 b	12 ns	21 a	8 ns
IRGA 424 RI (133) [1]		24	45	20	12	19	6 ns
IRGA 425 (132) [3]		17 ns	41 b	19 c	13 ns	23 a	7 ns
IRGA 427 (136) [2]		21 ns	37 b	23 b	14 ns	18 b	6 ns
Average (M2)		20	42	21	13	20	7
SCS BRS Tio Taka (141) [6]	L	23 ns	56 a	25 a	14 ns	23 a	6 ns
Epagri 109 (142) [4]		24 ns	52 a	26 a	14 ns	21 a	6 ns
Average (L)		24	54	26	14	22	6

E-V4 (from emergence to the stage of four leaves); V4-R1 (from V4 to panicle differentiation); R1-R2 (from R1 to booting); R2-R4 (from booting to anthesis); R4-R8 (from anthesis to the beginning of maturation); R8-R9 (from the beginning of maturation to the complete ripening of grains). Plant developmental stages according to the scale of Counce et al. (2000). VS1 = Very short 1; VS2 = Very short 2; S1 = Short 1; S2 = Short 2; M1 = Medium 1; M2 = Medium 2; L = Long, according to Steinmetz et al. (2018).
Values with equal letters in the column do not differ statistically from each other by the Mood test (at 95% confidence); ns = no statistical significance

Table 3. Average number of days of three periods of the plant cycle, of 34 irrigated rice cultivars, obtained during twelve crop seasons (2004/2005 - 2015/2016), in Capão do Leão, RS, Brazil. The numbers between parenthesis indicate the average cycle of the cultivar, in days (Reunião, 2018), and between brackets the number of crop seasons in which the cultivar was evaluated.

Cultivar	Subgroup	Average number of days in the periods		
(Cycle) (Nr seasons)		E-R1 (VP)	R1-R4 (RP1)	R4-R9 (RP2)
IRGA 421(95) [7]	VS1	43 e	26 d	24 ns
Average (VS1)		43	26	24
BRS Atalanta (100) [12]	VS2	45 e	29 d	25 ns
BRS Ligeirinho (95) [2])		42 e	32 d	26 ns
Average (VS2)		44	31	26
BRS 6 "Chuí" (110) [5]	S1	51 d	31 d	26 ns
BRS Querência (110) [12]		54 d	30 d	26 ns
Average (S1)		53	31	26
BRS Pampa (118) [8]	S2	60 c	29 d	26 ns
BRS Firmeza (120) [5]		57 c	31 d	22 ns
IRGA 417 (115) [9]		60 c	27 d	27 ns
IRGA 422 CL (120) [3]		61 c	28 d	29 ns
IRGA 423 (120) [3]		61 c	26 d	28 ns
IRGA 430 (120) [1]		62	29	22
Avaxi CL (120) [7]		60 c	31 d	29 ns
Inov CL (120) [7]		60 c	30 d	29 ns
Titan CL (120) [3]		53 d	31 d	27 ns
Guri Inta CL (120) [3]		54 c	32 d	26 ns
Puitá Inta CL (120) [5]		63 d	28 d	28 ns
Average (S2)		59	29	27
BRS Pelota (125) [6]	M1	61 c	32 d	28 ns
BRSCIRAD 302 (128) [3]		67 b	33 c	29 ns
BRS Sinuelo CL (130) [7]		61 c	31 d	32 ns
BR-IRGA 410 (123) [4]		58 c	35 c	29 ns
BR-IRGA 409 (126) [5]		59 c	33 c	30 ns
IRGA 429 (124) [1]		67	33	24
IRGA 426 (125) [3]		61 c	31 d	27 ns
IRGA 428 CL (125) [2]		54 d	33 c	25 ns
Lexus CL (128) [3]		55 d	34 c	26 ns
Average (M1)		60	33	28
BRS 7 "Taim (130) [5]	M2	61 c	35 c	27 ns
BRS Bojuru (135) [2]		60 c	32 d	20 ns
BRS Fronteira (135) [8]		65 c	31 d	28 ns
IRGA 424 (132) [8]		63 c	33 c	29 ns
IRGA 424 RI (133) [1]		69	32	25
IRGA 425 (132) [3]		58 c	32 d	29 ns
IRGA 427 (136) [2]		58 c	36 a	24 ns
Average (M2)		62	33	26
SCS BRS Tio Taka (141) [6]	L	79 a	39 b	29 n
Epagri 109 (142) [4]		76 a	40 b	27 ns
Average (L)		78	40	28

E-R1 = from emergence to panicle differentiation (Vegetative period - VP); R1-R4 = from panicle differentiation to anthesis (Reproductive period 1 - RP1); R4-R9 = from anthesis to full maturity of the panicle grains (Reproductive period 2 - RP2). VS1 = Very short 1; VS2 = Very short 2; S1 = Short 1; S2 = Short 2; M1 = Medium 1; M2 = Medium 2; L = Long, according to Steinmetz et al. (2018).
Values with equal letters in the column do not differ statistically from each other by the Mood test (at 95% confidence); ns = no statistical significance.

Figure 2. Average number of days for subperiods E-V4 (from emergence to the stage of four leaves), V4-R1 (from V4 to panicle differentiation), R1-R2 (from R1 to booting), R2-R4 (from booting to anthesis), R4-R8 (from anthesis to the beginning of maturation), R8-R9 (from the beginning of maturation to the complete ripening of grains), of four irrigated rice cultivars, of Very short (IRGA 421), Short (BRS Pampa), Medium (IRGA 424 RI) and Long (Epagri 109) cycles, obtained during twelve crop seasons (2004/2005 - 2015/2016), in Capão do Leão, RS, Brazil.

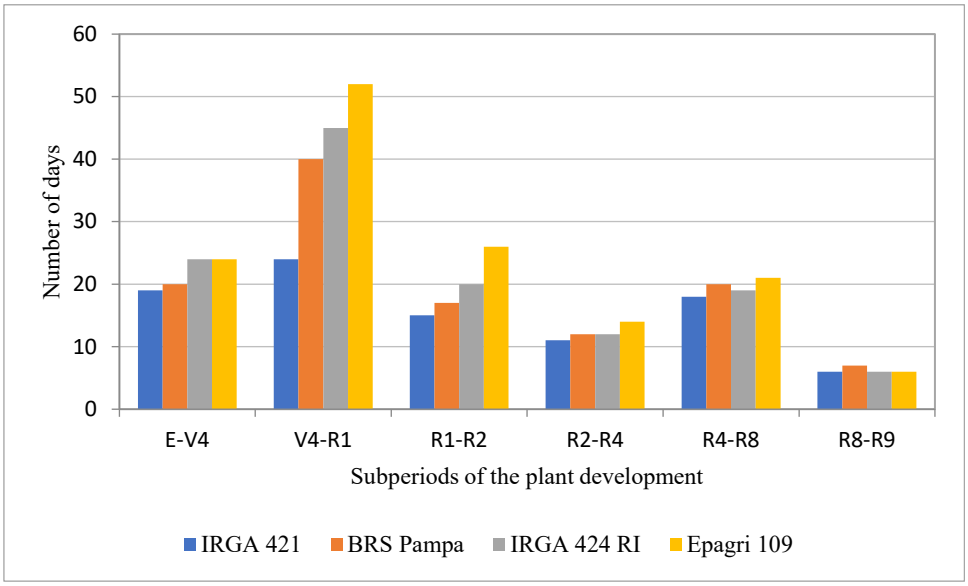
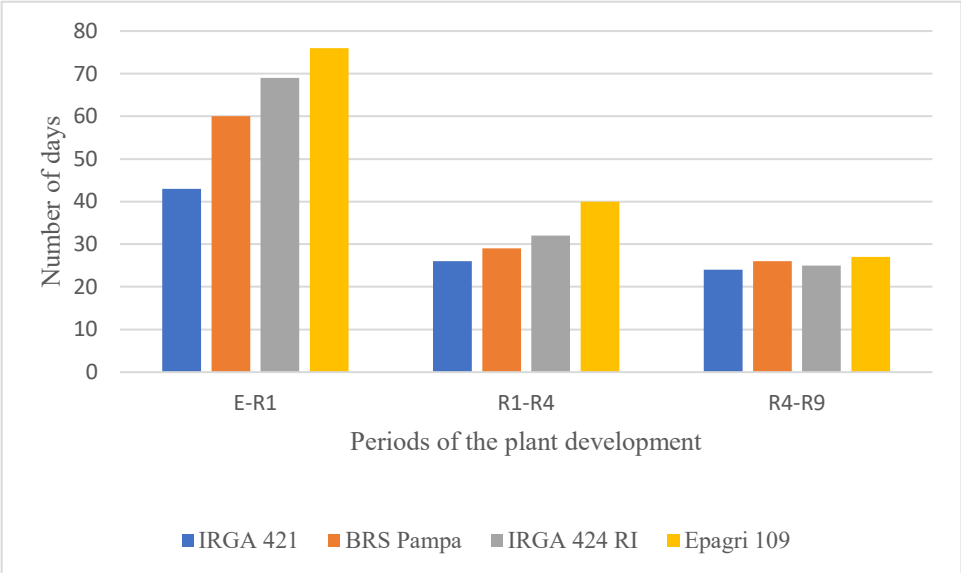


Figure 3. Average number of days in the vegetative period (from emergence to panicle differentiation: E-R1), reproductive 1 (from panicle differentiation to anthesis: R1-R4) and reproductive 2 (from anthesis to complete grain maturation: R4-R9), of four irrigated rice cultivars, of Very short (IRGA 421), Short (BRS Pampa), Medium (IRGA 424 RI) and Long (Epagri 109) cycles, obtained during twelve crop seasons (2004/2005 - 2015/2016), in Capão do Leão, RS, Brazil.



the State of Arkansas (USA) (Wilson Jr. et al., 2015) and PlanejArroz in the State of Rio Grande do Sul (Steinmetz et al., 2021b).

Conclusions

The vegetative period (from the emergence-E to the stage of panicle differentiation-R1) is the one with the longest duration, around 50% of the total cycle, and also the biggest differences between cultivars when compared to the reproductive period 1 (from stage R1 to anthesis-R4) and reproductive period 2 (from stage R4 to full maturity of the panicle grains-R9);

The average number of days to reach the different plant developmental stages varies according to the cycle length of the cultivars, and the subperiod of longer duration is that between the four-leaf and panicle differentiation stages (V4-R1).

Authors´ contribution

S. STEINMETZ was responsible for the design of the work, acquisition and analysis of data and in writing the article. A. M. MAGALHÃES JÚNIOR, A M. and P. R. R. FAGUNDES helped in defining the cultivars to be evaluated in each season and in writing the article. S.V. CUADRA and I. R. de ALMEIDA collaborated in writing the article.

Acknowlegements

The authors would like to thank the trainees at Embrapa Clima Temperado who helped in obtaining the phenological data over the years: Alexandre N. Deibler; Anderson B. Schneider; André da R. Ulguim; Eduardo Goulart; Felipe L. de L. Nobre; Igor N. Schneid; Jackson B. A. Pintanel; Jonathan G. Oliveira; Rafael C. Santos; Shemene J. S. A. Audeh; Silas S. Costa; the Assistant Denise D. Dos Santos for her help in tabulating the data; and to Researcher Ricardo A. Valgas for the statistical analysis of the data.

References

CARLI, C. De; 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.

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.

FREITAS, T. F. S. de; SILVA, P. R. F. da; STRIEDER, M. L.; SILVA, A. A. da.. Validação de escala de desenvolvimento para cultivares brasileiras de arroz irrigado. **Ciência Rural**, Santa Maria, v. 36, n. 2, p. 404-410, mar-abr, 2006.

IBGE. Levantamento Sistemático da Produção Agrícola – LSPA. **Séries históricas**. SIDRA (Banco de Tabelas Estatísticas). Available at: https://sidra.ibge.gov.br/tabela/6588#resultado. Accessed on: Aug. 13 2020.

REUNIÃO TÉCNICA DA CULTURA DO ARROZ IRRIGADO, 25., 2003, Balneário Camboriú, SC. **Arroz irrigado**: recomendações técnicas da pesquisa para o Sul do Brasil. Itajaí, SC: SOSBAI, 2003. 126 p.

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

RIBAS, G. G.; ZANON A. JR.; POERSCH, A. H.; DUARTE JR. A. J.; RIBEIRO, B. S. M. R.; ROSSATO, I. G.; PILLECO, I. B.; MEUS, L. D.; SILVA, M. R. da; NASCIMENTO, M. de F.; STRECK, N. A.; SOUZA, P. M. de; PEREIRA, V. F. Potencial e lacuna de produtividade de arroz irrigado no Brasil: um estudo de caso. In: MEUS, L. D. **Ecofisiologia do arroz visando altas produtividades**. Santa Maria. Universidade Federal de Santa Maria, 2020. Cap. 5, p. 167-179.

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.

SIEGEL, S.; CASTELLAN, N. J. Jr. **Nonparametric statistics for the behavioral sciences**. 2nd ed., New York: McGraw-Hill, 1988.

SINGH, A. K.; CHANDRA, N.; BHARTI, R. C.. Effects of genotype and planting time on phenology and performance of rice (*Oryza sativa* L.). **Vegetos**, Patna, v. 25, n. 1, p. 151-156, 2012. Available at: http://icarrcer.in/wp-content/uploads/2016/01/EffectOfGenotype.pdf Accessed on: Jun. 14 2017.

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.; FAGUNDES, P. R. R.; MAGALHÃES JÚNIOR, A. M. de; SCIVITTARO, W. B.; DEIBLER, A. N.; ULGUIM, A. da R.; NOBRE, F. L. de L.; PINTANEL, J. B. A.; OLIVEIRA, J. G.; SCHNEIDER, A. B. **Determinação dos graus-dia e do número de dias para atingir o estádio de diferenciação da panícula de cultivares de arroz irrigado.** Pelotas:Embrapa Clima Temperado, 2009a. 29p. (Embrapa Clima Temperado. Boletim de Pesquisa e Desenvolvimento, 88).

STEINMETZ, S.; FAGUNDES, P. R. R.; MAGALHÃES JÚNIOR, A. M. de; SCIVITTARO, W. B.; DEIBLER, A. N.; ULGUIM, A. da R.; NOBRE, F. L. de L.; PINTANEL, J. B. A.; OLIVEIRA, J. G.; SCHNEIDER, A. B. **Soma térmica e número de dias para atingir os principais estádios de desenvolvimento de 16 cultivares de arroz irrigado.** Pelotas:Embrapa Clima Temperado, 2009b. 31p. (Embrapa Clima Temperado. Boletim de Pesquisa e Desenvolvimento, 89).

STEINMETZ, S.; CUADRA,S. V.; PEREIRA, C. B.; SANTOS, E. L. dos; ALMEIDA, I. R. de. **GD Arroz: programa baseado em graus-dia para estimar a data de diferenciação da panícula visando a adubação nitrogenada cobertura.** Pelotas:Embrapa Clima Temperado, 2014. 12p. (Embrapa Clima Temperado. Circular Técnica, 155).

STEINMETZ, S.; CUADRA,S. V.; PEREIRA, C. B.; SANTOS, E. L. dos; ALMEIDA, I. R. **GD Arroz: programa baseado em graus-dia como suporte ao planejamento e à tomada de decisão no manejo do arroz irrigado.** Pelotas:Embrapa Clima Temperado, 2015. 8p. (Embrapa Clima Temperado. Circular Técnica, 162).

STEINMETZ, S.; CUADRA, S. V.; ALMEIDA, I. R. de.; MAGALHÃES JÚNIOR, A. M. de; FAGUNDES, P. R. R. Soma térmica e estádios de desenvolvimento da planta de grupos de cultivares de arroz irrigado. **Agrometeoros**, Passo Fundo, v. 25, n. 2, p. 405-414, dez., 2017.

STEINMETZ, S.; CUADRA, S. V.; PEREIRA, C. B.; SANTOS, E. L. dos; ALMEIDA, I. R. de. Fundamentos do programa GD Arroz, versões Web e Aplicativo, e seu uso no manejo do arroz irrigado. **Agrometeoros**, Passo Fundo, v. 26, n. 1, p. 1-10, jul., 2018.

STEINMETZ, S.; CUADRA, S. V.; ALMEIDA, I. R. de.; MAGALHÃES JÚNIOR, A. M. de; 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: 10.31062/agrom.v29.e026814

STEINMETZ, S.; PEREIRA, C. B.; SANTOS, E. L. dos; CUADRA, S. V.; ALMEIDA, I. R.; STRECK, N. A.; BENEDETTI, R. P.; DUARTE JÚNIOR, A. J.; ZANON, A. JR.; RIBAS, G. G.; SILVA, M. R. da; 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: 10.31062/agrom.v29.e026847

STRECK, N.A.; BOSCO, L. C.; MICHELON, S.; WALTER, L. C.; MARCOLIN, E. Duração do ciclo de desenvolvimento de cultivares de arroz em função da emissão de folhas no colmo principal. **Ciência Rural**, Santa Maria, v.36, n.4, p.1086-1093, 2006a.

STRECK, N.A.; BOSCO, L. C.; MICHELON, S.; ROSA, H. T.; WALTER, L. C.; PAULA G. M. de; CAMARA, C.; LAGO, I.; MARCOLIN, E. Avaliação da resposta ao fotoperíodo em genótipos de arroz irrigado. **Bragantia**, Campinas, v.65, n.4, p.533-541, 2006b.

WATSON, N.T.; COUNCE, P.A.; SIEBENMORGEN, T.J. Growth stages of 12 rice cultivars (*Oryza sativa L.*) expressed in DD50 thermal heat units. Available at: http//www.arkrice.org/research_results/2004_PDFs/529_2.pdf. Accessed on: Jul. 15 2006.

WILSON JUNIOR., C. E.; NORMAN, R. J.; SLATON, N. A.; BRANSON, J. W.; BOOTHE, D. L. **DD50 computerized rice management program**. Little Rock, AR: University of Arkansas: Division of Agriculture: Cooperative Extension Service [2015?]. (Agriculture and Natural Resources. Computer Technical Series). Available at: https://www.uaex.uada.edu publications/PDF/FSA-2124.pdf. Accessed on: Jul. 15 2015.

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.

YOSHIDA, S. **Fundamentals of rice crop science**. Los Baños: IRRI, 1981. 269p.

CITATION

STEINMETZ, S.; MAGALHÃES JÚNIOR, A.M.; FAGUNDES, P.R.R.; CUADRA, S.V.; ALMEIDA, I.R. Number of days to reach the main plant developmental stages of irrigated rice cultivars. **Agrometeoros**, Passo Fundo, v.30, e027127, 2022.

agrometeoros
REVISTA DA SOCIEDADE BRASILEIRA DE AGROMETEOROLOGIA

ISSN 2526-7043 www.sbagro.org.br DOI: http://dx.doi.org/10.31062/agrom.v30.e027127

Número de dias para atingir os principais estádios de desenvolvimento da planta de cultivares de arroz irrigado

Silvio Steinmetz[1(*)], Ariano Martins de Magalhães Júnior[1], Paulo Ricardo Reis Fagundes[1], Santiago Vianna Cuadra[2] e Ivan Rodrigues de Almeida[2]

[1]Embrapa Clima Temperado. Rodovia BR 392, km 78, Caixa Postal 403, CEP 96.010-971 Pelotas, RS.
E-mails: silvio.steinmetz@embrapa.br, ariano.martins@embrapa.br e paulo.fagundes@embrapa.br
[2]Embrapa Agricultura Digital. Av. Dr. André Tosello, 209 – Cidade Universitária, CEP 13083-866 Campinas, SP.
E-mails: santiago.cuadra@embrapa.br e ivan.almeida@embrapa.br
[(*)]Autor para correspondência.

INFORMAÇÕES

História do artigo:
Recebido em 2 de setembro de 2022
Aceito em 29 de novembro de 2022

Termos para indexação:
Oryza sativa L.
duração de subperíodos do ciclo
fenologia

RESUMO

O objetivo deste trabalho foi determinar o número de dias (ND) necessários para atingir os principais estádios de desenvolvimento da planta (EDP) de cultivares de arroz irrigado. Experimentos de campo foram conduzidos na Estação Experimental Terras Baixas (ETB) da Embrapa Clima Temperado, município de Capão do Leão, RS, durante 12 safras, sendo utilizadas seis épocas de semeadura em cada safra. Dez plantas de cada cultivar foram marcadas e tiveram os EDP acompanhados durante todo o ciclo. Os resultados indicaram que o ND para atingir cada um dos seis EDP variou de acordo com o ciclo das cultivares, tendo havido diferença estatística entre algumas cultivares. O ND para atingir os estádios R1 (diferenciação da panícula), R4 (antese) e R9 (maturidade completa da panícula) da cultivar IRGA 424, por exemplo, foi de 63, 96 e 125, respectivamente. O número médio de dias para atingir os diferentes estádios de desenvolvimento da planta varia de acordo com o comprimento do ciclo das cultivares e o subperíodo de maior duração é o compreendido os estádios de quatro folhas e o de diferenciação da panícula (V4-R1).

REFERENCIAÇÃO

STEINMETZ, S.; MAGALHÃES JÚNIOR, A.M.; FAGUNDES, P.R.R.; CUADRA, S.V.; ALMEIDA, I.R. Number of days to reach the main plant developmental stages of irrigated rice cultivars. **Agrometeoros**, Passo Fundo, v.30, e027127, 2022.