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Fundamentals and applications of PlanejArroz, a software for irrigated rice management and yield estimation

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ABSTRACT

Despite being relatively high (7.7 t ha^{-1}), the average yield of irrigated rice in the State of Rio Grande Sul (RS) can be even higher, if the management practices are carried out at the most appropriate time, considering the date of occurrence of the main stages of plant development (PDS). The objective of this article was to demonstrate the fundamentals and applications of the software PlanejArroz to estimate the date of occurrence of six PDS, aiming the crop management, and the expected grain yield. Based on the degree-day method, the software estimates the date of each of the six PDS, using historical series (30 years) of climatic data, and updates these estimates using the current season's meteorological data. This information can be generated for 131 rice producing municipalities and for 41 cultivars recommended for cultivation in RS. Likewise, grain yield, for the three most sown cultivars, can be estimated as an average of 30 years and for the current cropping season. The PlanejArroz is a tool that allows management practices to be carried out at the most appropriate time, estimating the date of the occurrence of six PDS associated with these practices. It is also possible to simulate the most appropriate sowing dates and to obtain the expected average grain yield for the current season.

Introduction

The average grain yield of irrigated rice in the State of Rio Grande do Sul, which in the last three growing seasons was responsible for about 70% of the rice production in Brazil, is relatively high (7.7 t ha^{-1}) (IBGE, 2020). However, this grain yield can be even higher, reducing the yield gap indicated by Ribas et al. (2020b), if the management practices are carried out at the right time, considering the date of occurrence of the different plant developmental stages (PDS), as recommended by the South-Brazilian Society of Irrigated Rice - Sosbai (Reunião, 2018).

In order to achieve high yields in rice, the most important PDS to drive management practices are as follows. At the V4 (four-leaf) stage is the time for the first topdressing nitrogen fertilization (normally in V3 or V4) and the onset of flood irrigation. At R1 (panicle differentiation or at panicle initiation R0) stage is the time of the second topdressing nitrogen fertilization. From R2 (flag leaf collar formation) to R4 (anthesis) is the time when farmers can rise the water level to reduce the harmful effects of low air temperature and the critical phase for application of fungicide to control blast (Pyricularia grisea (Cooke) Sacc). The R8 (beginning of maturation) stage is an indicative that harvest is approaching, and the R9 (complete grain maturation) stage is an indicative for harvesting, which can be performed at this stage or slightly earlier (Counce et al., 2000; Reunião, 2018), or when kernels moisture is about 22% (Silva et al., 2020).

A quite challenging problem in the rice fields in Southern Brazil is that PDS, mainly panicle differentiation (PD or stage R1), is variable because it is temperature dependent (Stansel, 1975; Wilson Jr. et al, 2015). Therefore, it is preferable to express the stage R1 and the other PDS in days, but estimated by accumulated degree-days (DD), or thermal units, rather than based on calendar days (Slaton et al., 1996; Streck et al., 2006; Steinmetz et al., 2010).

Based on this principle, Steinmetz et al. (2015a) released, in August 2015, the software GD Arroz in its web version and, in August 2016, its App version for the Android platform. The software estimates the date of occurrence of the six most important PDS for management purposes, for seven subgroups of cultivars, in 17 municipalities of the State of Rio Grande do Sul. The degree-day approach has also been used, for many years, through the software DD50, to help rice farmers in the State of Arkansas (USA) to apply the proper crop management practices based on PDS (Wilson Jr. et al., 2015). Despite being based on another strategy, "Doutor Milho" (Embrapa, 2017) is an example of software that uses PDS for planning corn management.

In addition to crop management based on PDS, the sowing time, as well as the genetic potential and the cycle of the cultivar, can also greatly affect the yield of irrigated rice (Mariot et al., 2005; Menezes et al., 2012; Steinmetz et al., 2009). Process-based simulation models, such as SimulArroz (version 1.1), are tools that can be used to estimate rice grain yield potential at different sowing times and locations (Duarte Júnior, 2021). The model can also simulate the grain yield at the farm level, considering three levels of technology (high, medium, and low) (Rosa et al., 2015; Ribas et al., 2016).

Estimates of PDS, as well as grain yield, can also be obtained by other simulation models such as ORYZA2000 (Bouman et al., 2001), ORYZA version 3 model (Li et al., 2017), CERES-Rice (Jones et al. 2003), and InfoCrop (Aggarwal et al., 2006). These models, after being calibrated and validated, can be used for several purposes, including the definition of management strategies for rice production (Vilayvong et al., 2015). However, these softwares and specially the ORYZA, depending on the version used, may involve a reasonable degree of complexity and a great number of input data. Furthermore, the SimulArroz is a process-based model with fewer genetic parameters compared to the previously indicated models and widely tested in Rio Grande do Sul (Rosa et al., 2015, Ribas et al., 2016, 2017, 2020a) and that has performance similar to ORYZA (Duarte et al., 2021). Aiming to have a simple and operational tool, using a small number of input data, the software PlanejArroz was conceived to utilize the degree-day approach to estimate the PDS and the model SimulArroz to estimate the grain yield.

The objective of this article was to demonstrate the fundamentals and applications of the software PlanejArroz to estimate the date of occurrence of six rice plant developmental stages, aiming the crop management, as well as to estimate the expected grain yield at the farm level.

Material and Methods

The software PlanejArroz is composed by the modules "Management – Manejo" and "Grain yield – Produtividade" as indicated in its schematic diagram (Figure 1). If the user's "Interest - Interesse" is for "Management - Manejo", the next step is to indicate the "Municipality - Município", the "Cultivar - Cultivar", the "Crop stage - Estádio", the "Emergence date – Data de emergência" and, finally, "Consultation – Consulta". Its fundamentals and applications are described as follow.

Management - (Inputs 1)

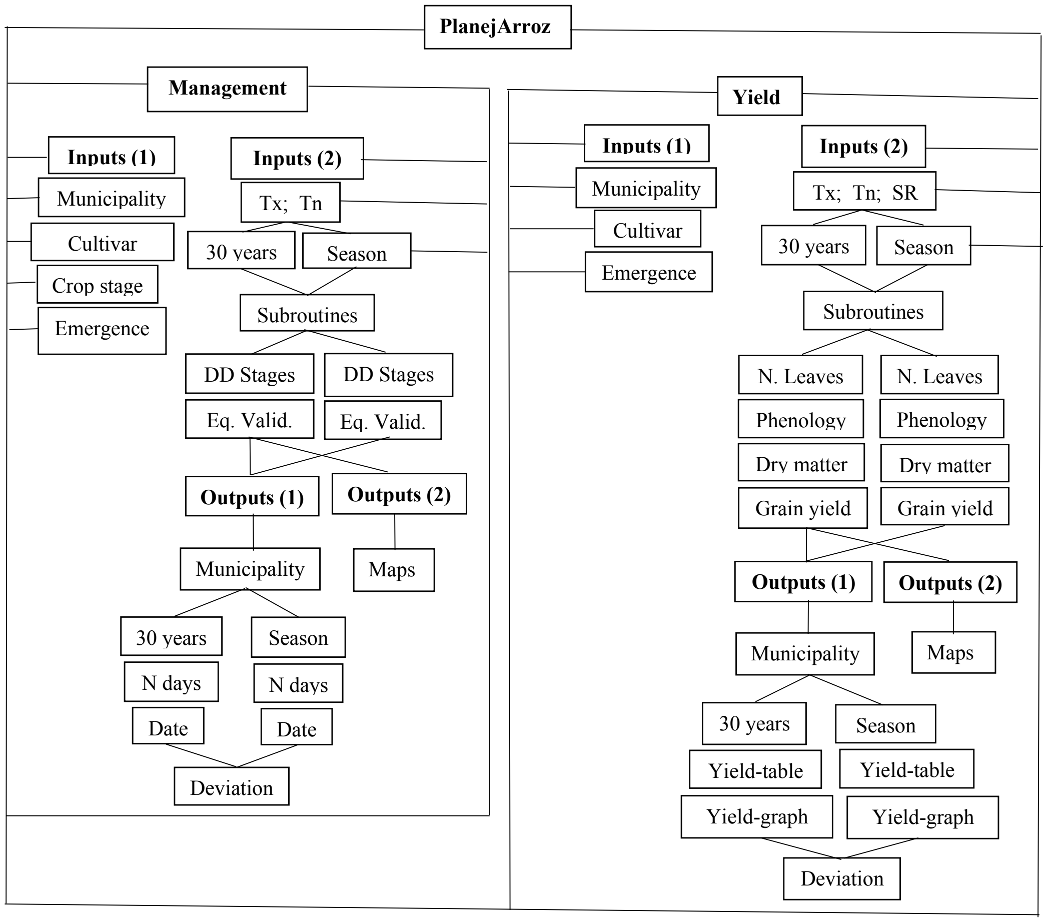
Municipality – Município

Select the municipality of interest in the State of Rio Grande do Sul, Brazil, by typing the first three letters. Altogether, there are 131 municipalities, which belong to the six rice producing regions used by the Rio Grande do Sul State Rice Institute - IRGA (Menezes et al., 2012). The information for these municipalities were generated from a network of 22 automatic weather stations from the National Institute of Meteorology (INMET), as shown in Figure 2.

Cultivar - Cultivar

Select the cultivar of interest. In total there are 41 cultivars, and for the first three of them (IRGA 424 RI, Guri

Figure 1. Schematic diagram of the PlanejArroz.



Inta CL and Puitá Inta CL) it was used the accumulated degree-days (DD) of each one. For the other 38 cultivars it was used the average DD of the seven subgroups to which each one belongs to, as indicated in Steinmetz et al. (2015a). These cultivars are: Avaxi CL; BR-IRGA 409; BR-IRGA 10; BRS 6 "Chuí"; BRS 7 "Taim"; BRS A701 CL; BRS Atalanta; BRS Firmeza; BRS Pampa; BRS Pampa CL; BRS Pampeira; BRS Querência; BRS Sinuelo CL; EPAGRI 106; EPAGRI 108; EPAGRI 109; Inov CL; IRGA 417; IRGA 421; IRGA 423; IRGA 424; IRGA 425; IRGA 426; IRGA 427; IRGA 428 CL; IRGA 429; IRGA 430; IRGA 431 CL; IRGAP H7CL; IRGAP H9CL; Lexus CL; Primoriso CL; SCS 116 Satoru; SCS 118 Marques; SCS 121 L; SCS 122 Miura; SCSBRS Tio Taka; Titan CL.

Crop stage - Estádio

Select one of the six rice developmental stage (Counce et al., 2000): V4 - Collar formation on Leaf 4; R1 - Panicle differentiation; R2 - Flag leaf collar formation; R4 - Anthesis; R8 - Single grain maturity; R9 - Complete panicle maturity. The name of each developmental stages has been simplified to favor the user's understanding, but the full name is found in Counce et al. (2000).

Emergence date – Data de emergência

Select the date of the crop emergence, available for the period from September 1st to December 31st. Consider 50% emergence date, that is, when about 50% of the crop seedlings are visible above soil surface (seedlings up to 2 cm height). The software was developed considering, fundamentally, the sowing system in dry soil (conventional, minimum tillage and no-tillage).

Management - (Inputs 2)

To calculate the accumulated degree-days starting at crop emergence, the following equation was used:

$$DD = \sum_{i=1}^{n} (Tm - Tb)$$

where DD (°C d^{-1}) represents the sum of the difference between the average daily air temperature (Tm) and the base temperature (Tb) of 11 °C (Infeld et al., 1998) from the emergence (i = 1) to each of the six stages (n). The Tm was obtained by the arithmetic mean between the maximum (Tx) and minimum (Tn) daily air temperatures. To calculate the Tm, the thresholds of 34 °C and 21 °C were applied to Tx and Tn, respectively (Slaton et al., 1996). This equation is also used for the calculation of degree-day by the program

"DD50", a modification of the original concept of degree-day (DD) that uses upper thresholds for the daily values of Tx and Tn so that temperatures above these thresholds will not cause plants to develop more quickly (Slaton et al., 1996; Wilson Jr. et al., 2015).

The software uses to estimate the "Average 30 years – Média 30 anos" date for each of the six PDS a 30-year historical series (1987-2016) (POWER / NASA, 2018) of daily Tx and Tn air temperatures. For the current "Growing Season – Safra", the data of Tx and Tn are retrieved daily from 22 automatic weather stations of the National Institute of Meteorology (INMET) (Figure 2).

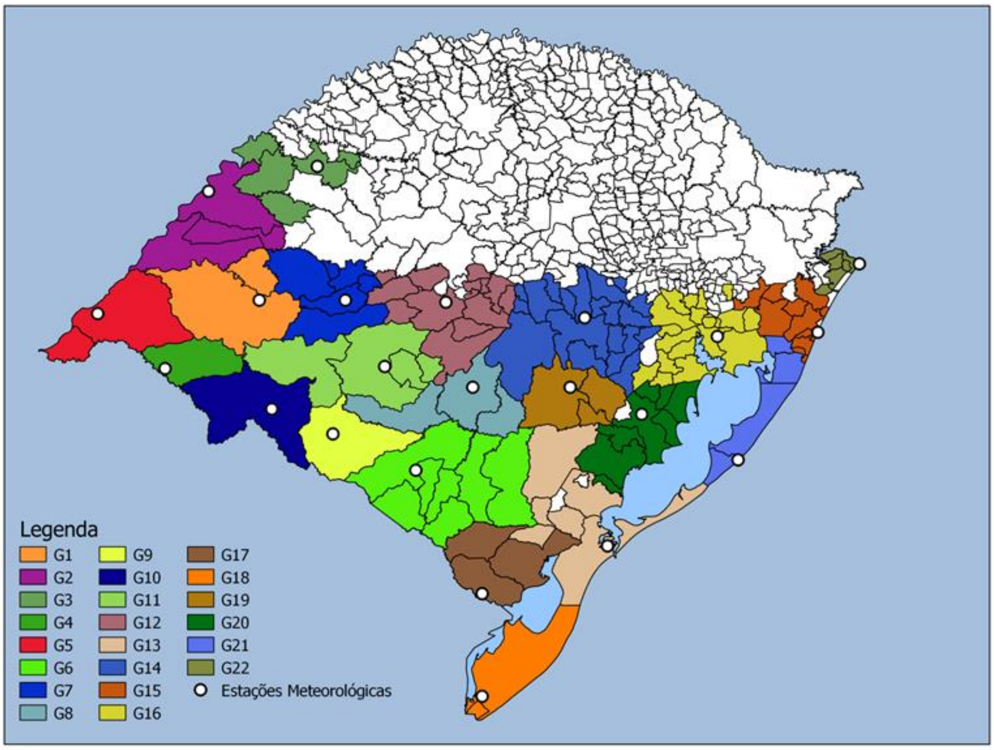
For three cultivars (IRGA 424 RI, Guri Inta CL and Puitá Inta CL), which have been the most used by farmers in Rio Grande do Sul in the last five years, it was used the accumulated degree-days (DD) based on experimental data of four agricultural crop seasons (data obtained by the first author, unpublished). For the other 38 cultivars, it was used the mean DD of the subgroups to which each one belongs to (Steinmetz et al., 2018) (identified as "DD Stages" in Figure 1). To the obtained data on the duration from emergence to each of the six PDS, for the set of 30 years of data, linear regression equations generated in the process of validating the degree-days' method were applied (Steinmetz et al., 2015b), except for stage R1, in which the equations used were those described in Steinmetz et al. (2014) (identified as "Eq. Valid." in Figure 1).

The equations were coded in FORTRAN, enabling the automatic computation of the number of days between the emergence and each of the six PDS, as well as the corresponding date of occurrence of the referred PDS. The data related to the current growing season were also calculated using the mean DD indicated previously.

The number of days from emergence until each of the six PDS, and the respective date of occurrence of these stages, in the current growing season, as well as the deviation (days) between the periods calculated with the daily Tm of the current growing season and the mean daily Tm of 30 years are updated daily through automatic computation by the program, according to the data received from INMET automatic weather stations.

The software recalculates these values daily, using the data received, which replace the historical data, according to the current date. The number of days in which the average daily temperature of the current season is used varies from zero, when the date of the consultation is before or equal to the date of the selected emergence (ie, there are still no observations for the current growing season), to the total number of days from crop emergence to each of the six PDS, the closer the consultation is to the expected date of occurrence of that PDS. Finally, the software automatically updates the values stored in the database that feeds the Web page and, consequently, the App. The same principle applies to the crop yield data.

Figure 2. Groupings of municipalities assigned to each of the National Institute of Meteorology´s 22 automatic weather stations used in PlanejArroz: G1 (Alegrete), G2 (São Borja), G3 (São Luiz Gonzaga), G4 (Quaraí), G5 (Uruguaiana), G6 (Bagé), G7 (São Vicente do Sul), G8 (Caçapava do Sul), G9 (Dom Pedrito), G10 (Santana do Livramento), G11 (São Gabriel), G12 (Santa Maria), G13 (Rio Grande), G14 (Rio Pardo), G15 (Tramandaí), G16 (Porto Alegre), G17 (Jaguarão), G18 (Santa Vitória do Palmar), G19 (Encruzilhada do Sul), G20 (Camaquã), G21 (Mostardas), G22 (Torres). Map prepared by Ary J. Duarte Júnior.



Maps were elaborated in a geographic information system from the interpolation of the relief model of the State of Rio Grande do Sul with equation obtained for each ten-day period (TDP) by multiple regression between the independent variables, altitude, latitude and longitude, and the number of days after emergence for each of the six stages, as a dependent variable, in the 22 locations where this parameter was estimated by the degree-day method. As a result of the combination of the three most seeded cultivars and seven cultivar maturity groups, for eleven ten-day periods (from September 1st to December 2nd), and from the six phenological stages, 660 maps representing the classes of 'number of days after emergence' were produced.

Consultation - Consulta

This is the final step before the results. In the Web version, the "Consultation - Consulta" is made separately, by "Consultation by municipality – Consulta por município" and by "Consultation by map - Consulta por mapa".

Grain yield – Produtividade (Inputs 1, 2)

If the user's "Interest - Interesse" is for "Grain yield - Produtividade", the next step is to indicate the "Municipality - Município", the "Cultivar - Cultivar", the "Emergence date – Data de emergência" and, finally, "Consultation – Consulta", as follow. As previously indicated, in the "Cultivar" section, the options are IRGA 424 RI, Guri Inta CL and Puitá Inta CL. The other choices, except for the "Crop stage - Estádio", are similar to those of "Management".

Grain yields for the three previously mentioned cultivars were estimated by the SimulArroz model, version 1.1 (Rosa et al., 2015), using daily maximum (Tx) and minimum (Tn) air temperatures and solar radiation (SR). SimulArroz is the result of two previous models, ORYZA2000 (Bouman et al., 2001) and InfoCrop (Aggarwal et al., 2006). What differentiates SimulArroz from these two models is that it contains a sub-model for the appearance of leaves (LN), and the final number of leaves in the main stem and contains technological levels of rice farming (Rosa et al., 2015, Ribas et al., 2016, 2017, 2020a). It calculates phenology, dry matter (DM) production and yield on a daily time step. The LN is based on Haun Stage (Haun, 1973) and is calculated using the Wang and Engel model modified for rice (Streck et al., 2008).

The DM production is calculated through the radiation use efficiency (RUE) and the leaf area index (LAI) (Connor et al., 2011). The photosynthetically active radiation (PAR) is assumed as 50% of the incoming solar radiation, and the leaf light extinction coefficient is 0.4 from emergence to anthesis (R4) and 0.6 after R4 until physiological maturity. Grain yield and yield components are calculated by equations described in the InfoCrop (Aggarwal et al., 2006) and ORYZA2000 (Bouman et al., 2001) models, and with specific calibration for the most used cultivars in the flooded rice systems in southern Brazil. The model SimulArroz version 1.1 is available for download (free) at the homepage of the Federal University of Santa Maria (www.ufsm.br/simulArroz).

The TDP average yields were established from the first TDP of September until the second TDP of December, denominated "Average 30 years – Média 30 anos", utilized the same climate database used for phenology. The grain yield of the "Crop Season – Safra" was estimated using the daily data received from INMET. The "Deviation – Desvio" represents the difference between the average data (climatology) and those of the current crop season. The TDP maps, representing the average yield of thirty years were interpolated, also in geographic information system, using the ordinary kriging method.

In the same way as in "Management", in the Web version, the "Consultation - Consulta" is made separately, by "Consultation by municipality – Consulta por município" and by "Consultation by map - Consulta por mapa".

The software PlanejArroz is available (free) as App for mobile devices (Google Play Store) and Web (http://planejarroz.cpact.embrapa.br). The first screen of the App is shown in Figure 3.

Results and Discussion

Crop Management

After filling in the fields indicated previously, the PlanejArroz presents a set of data that can be considered as output information from the program as following.

To exemplify the module "Management - Manejo", the following variables were selected: Municipality: "Santa Maria"; Cultivar: "IRGA 424 RI"; Crop stage: "R1 - Panicle differentiation"; Emergence date: "5th October". After filling in the indicated fields, select "Consultation - Consulta". The results of this consultation appear, in sequence, as shown in Figures 4 and 5.

In "Average 30 years – Média 30 anos", the field "No. days (E-R1) – Nº dias (E-R1)" indicates that this cultivar, on the average of 30 years of daily Tm data, required 69 days after seedling emergence to reach the R1 stage (Figure 4 – on the left handside). The "Date (R1) – Data (R1)" field indicates that 69 days after emergence (5/10) corresponds to 13/12 (Figure 4 – on the left handside). This indicates the average date on which stage R1 occurred in the thirty years period.

In "Crop season - Safra", the field "No. days (E-R1) - Nº dias (E-R1)" was 67 days and "Date (R1) - Data (R1)" was 11/12, making the "Deviation (days) - Desvio (dias)" less 2 days (Figure 4 – on the left handside). This means that in

Figure 3. Opening screen of the App PlanejArroz.

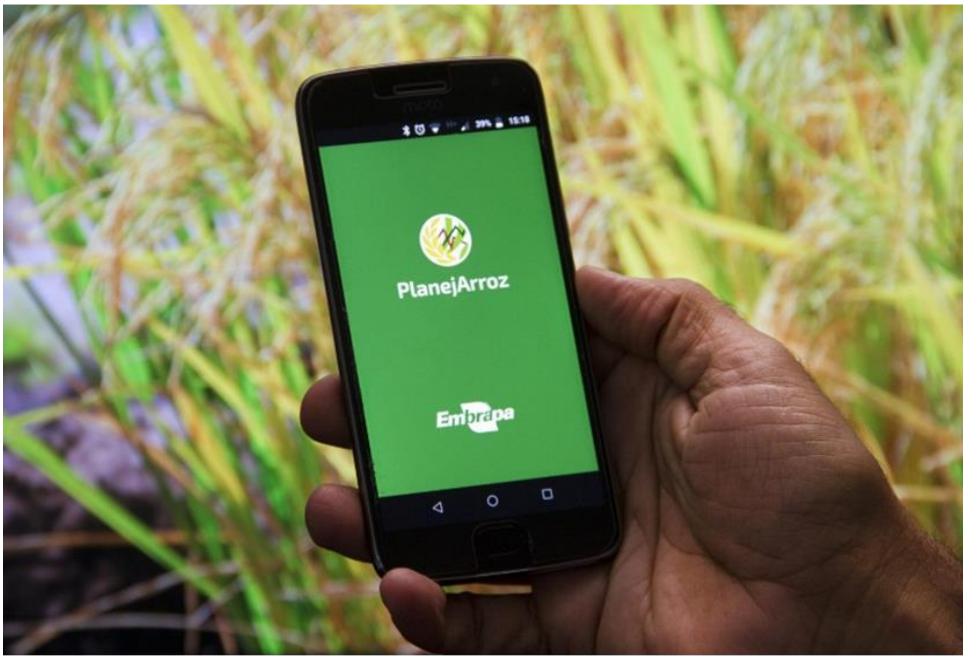


Figure 4. Output of the App for "Management – Manejo" indicating, on the left handside, the average number of days from the emergence to panicle differentiation "Nº dias (E-R1)", the average date of R1 ("Data (R1)"), based on 30 years of data ("Média 30 anos"), and in the growth season ("Safra"), deviation ("Desvio") from the mean (days), images of the R1 stage in the plant and in the field and, on the right handside, the management recommended ("Manejo em R1") by the South-Brazilian Society of Irrigated Rice-Sosbai (Reunião, 2018) for the R1 stage, and part of the next image, that is, the map.

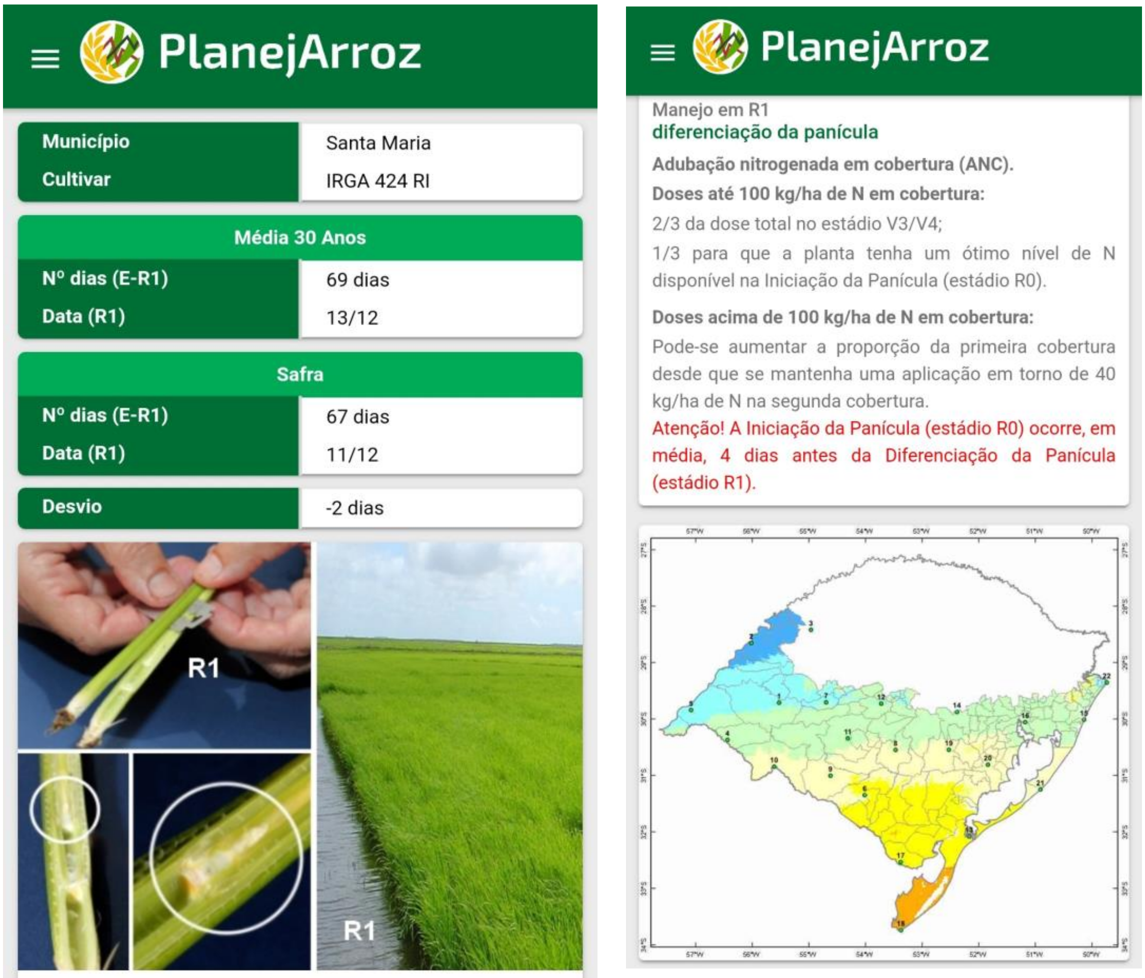
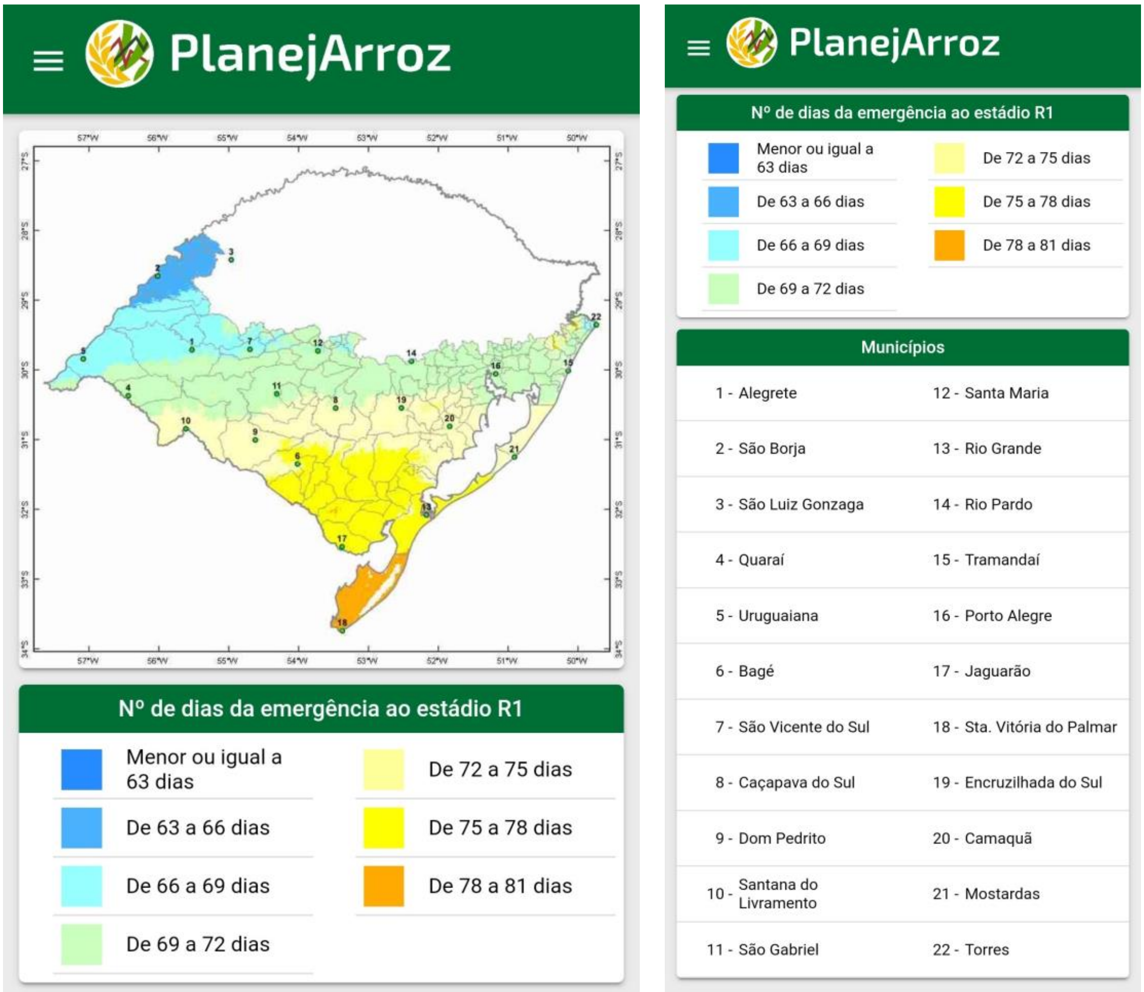


Figure 5. Output of the App for “Management - Manejo” indicating, on the left handside, the map with the classes of the average number of days from the emergence to panicle differentiation (“Nº de dias da emergência ao estádio R1”) in the 131 municipalities of the State of Rio Grande do Sul, the location of the 22 automatic weather stations of the National Institute of Meteorology (INMET), and on the right handside, the municipalities (“Municípios”) of the 22 weather stations.



the period from 5/10 (seedling emergence) until reaching the DD necessary for the occurrence of stage R1, ie 11/12, the average air temperature (Tm) was higher than the historical average Tm (30 years). In Figure 4 – on the right handside, the recommendations of Sosbai (Reunião, 2018) on the management practices that should be carried out in the field, at the R1 stage, and the map are also indicated.

In the sequence, it is shown the spatialization of the information generated containing the map, the classes of number of days to reach the R1 stage and the municipality of each of the 22 weather stations (Figure 4). This map query is intended to indicate to the user not only the information of the selected municipality, but also for the surrounding municipalities.

The information made available on the maps refers to classes of “No. days (E-crop stage)” - “Nº dias (E-estádio)” for emergence periods of 10 days, on the average of 30 years, considering the intermediate value of the ten-day period (TDP). Thus, the map for the 1st TDP of October refers to the emergence of October 5th, the map for the 2nd TDP of October refers to the emergence of October 15th, and so on. Figure 4 indicates that the duration of the E-R1 phase is similar in most of the municipality of Santa Maria and in the municipalities that belong to the same class (from 69 to 72 days), represented by the green color on the map. Therefore, in all these municipalities, the application of any management practice associated with this crop stage could be similar to that of Santa Maria.

The operating principle of the software is the same for each of the other five PDS of the rice plant, that is, V4, R2, R4, R8 and R9. For each of these developmental stages there is a summary of the management practices recommended by Sosbai (Reunião, 2018).

In some situations, the difficulty in defining the date of 50% of crop emergence, due to the unevenness of seedling emergence, caused by the scarcity and/or irregularity in the distribution of rain, can influence the precision regarding the date of occurrence of each of the six developmental stages, estimated by the degree-day method. If two different emergence dates occur, for crops sown on the same date, it is recommended that two separate crops be considered, instead of averaging the two emergence dates.

Grain yield

If the "Interest - Interesse" is for "Grain yield - Produtividade", the following steps are: to indicate the "Municipality - Município", the "Cultivar - Cultivar" and the "Date of Emergence – Data de emergência", and finally, by clicking on "Consult - Consultar".

Municipality – Município

Select the municipality of interest from the 131 listed.

Cultivar - Cultivar

Select one of the three available cultivars, namely IRGA 424 RI, Guri Inta CL and Puitá Inta CL.

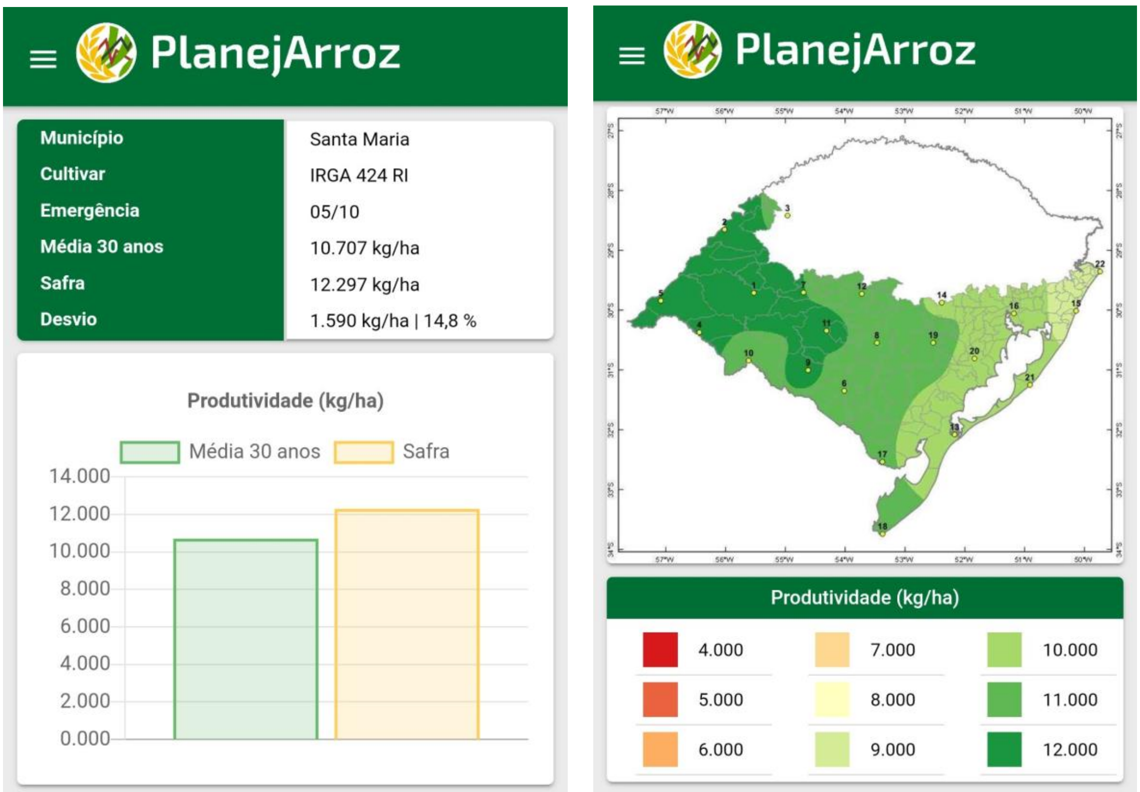
Emergence data – Data de emergência

Select the date corresponding to 50% emergence of the crop seedlings. For productivity, in the same way as for management, the program was developed considering, fundamentally, the sowing system in dry soil (conventional, minimum tillage and no-tillage). To exemplify, information similar to that of phenology was used, that is: Municipality: "Santa Maria"; Cultivar: "IRGA 424 RI"; Emergence date: "5 October". After filling in the indicated fields and selecting "Consult - Consultar", the results will appear, in sequence, as shown in Figure 6.

In "Average 30 years – Média 30 anos", the value of 10,707 kg/ha is obtained, while in "Crop Season - Safra" it indicates 12,297 kg/ha, corresponding to a "Deviation - Desvio" of 1,590 kg / ha or a "Deviation - Desvio" of 14.8 %. This indicates that the meteorological data used in the SimulArroz (Tx, Tn and solar radiation) of the growth season in question, until the day when the consultation was made, were more favorable for the grain yield of the crop than the historical data (30 years). Below the table, a graph is displayed comparing the average grain yield of 30 years to that of growth season. Next, the map showing the spatialization of grain yield is shown, followed by the grain yield classes (Figure 6).

The PlanejArroz (App for mobile devices - Android and Web platform) is a tool that can help the rice farmers to carry out the management practices at the most appropriate times, as recommended by Sosbai (Reunião, 2018), by estimating the date of occurrence of six PDS associated with these practices. Some examples of these uses are given by Steinmetz et al. (2018). However, it should be emphasized that these management practices,

Figure 6. Output of the App for "Grain yield - Produtividade" indicating, on the left, the data with the "Average of 30 years – Média 30 anos", in the "Growth season - Safra" and "Deviation - Desvio" between both, in kg/ha and in percentage, and comparative graph of grain yield of the 30-year average and in the growth season. On the right handside, there is the map with the "Average grain yield of 30 years", in the 131 municipalities of the State of Rio Grande do Sul, the location of National Institute of Meteorology´s 22 automatic weather stations and the grain yield classes ("Produtividade (kg/ha") of the map.



as well as the most suitable periods to utilize them, are only suggestions given by Sosbai. The decision to use them or not should be made by the farmer or in agreement with the technical assistance agent who guides him/her.

Likewise, considering that the date of occurrence of each of the six PDS can be influenced by other factors (Streck et al., 2006; Steinmetz et al., 2013), it is recommended that users, or rice farmers properly speaking, use the information generated by this App as a complementary tool, and not the only one, for planning and making decisions regarding the timing of carrying out management practices.

In addition to the management-related part, the grain yield estimate of PlanejArroz can also be useful in previously planning the crop features with regard, for example, to the choice of sowing time, according to the cultivar, which presents, in average terms (30 years), the highest levels of grain productivity. Likewise, after the crop is established, it is possible to estimate, well in advance, the expected grain yield to be achieved, based on the average climate data (30 years) of the municipality. On the other hand, using the information from the "Management" module, it is possible to estimate the probable harvest date using the date of occurrence of the R9 stage as a reference. As the crop develops, these estimates may be updated with information related to the weather conditions of the crop season.

It should be emphasized that the grain yield estimated by PlanejArroz is based on the "average" level of technology. As a result, it is likely that there will be differences in relation to grain yield obtained under field conditions. These differences may be more expressive in farms that use different levels of technology as compared to the average level. As a result, it is suggested to use the "Grain yield" module of PlanejArroz as a tool to have a reasonable estimate of the grain yield to be obtained, instead of waiting for high accuracy of this estimate.

In addition to what was shown in this article, the software provides other information, such as: "File - Arquivo", where the last consultations made are stored; "About - Sobre", which addresses the reasons for developing this software, as well as the partnerships involved; "Contact - Contato", indicating the people who can be contacted in case of doubt or the need for specific information.

Finally, it should be emphasized that this software is unique because it allows obtaining information on both "Management" and "Grain yield" for the main rice producing municipalities of the state of Rio Grande do Sul. This is a differential when compared to the DD50 program (Wilson Jr. et 2015), for example, a well-known and useful tool for the rice growers of the state of Arkansas (USA) which focus only on PDS estimates for crop management. It is a modern digital tool that fits the concept of Agriculture 4.0, as indicated by Steinmetz et al. (2020), and available (free) as an App and via web. It is also unique because it is the result of the efforts of four public institutions (EMBRAPA, UFSM, IRGA and INMET), which are references in their areas of expertise.

Despite the highlights presented previously, the software has some uncertainties and / or limitations. In the "Management" module, the following ones can be indicated: - the dates of PDS of the cultivars, except for the first three (IRGA 424 RI, Guri Inta CL and Puitá Inta CL), are estimated based on the sum of DD of the subgroup to which it belongs to and not of the cultivar itself; - the dates of the PDS are estimated by the degree-day method, which basically considers the average air temperature (Tm). In some specific situations, it is likely that these PDS dates may be affected by other variables, such as: delay in the beginning of the definitive irrigation; delay in the PDS due to the influence of chemical treatments (herbicides, fungicides, etc.); sowing density; temperature of the irrigation water.

In the "Grain yield" module, these uncertainties and / or limitations are relate to: - possible differences between the productivity levels estimated by the software, which uses the "average technological level" (Rosa et al., 2015, Ribas et al., 2016, 2017, 2020a), and those obtained in the fields, especially when the technological level used is far above or much below the average level; - differences in productivity due to possible shortages associated with the SimulArroz validation process in the distinct producing rice regions of the state of Rio Grande do Sul; - microclimate in some farms may not be fully represented in the meteorological inputs from weather stations, mainly solar radiation during January and February.

Conclusions

The PlanejArroz is a tool that can help the rice farmers to carry out management practices at the right time by estimating the date of occurrence of six plant developmental stages associated with these practices;

The "Grain yield" module can be useful both in the simulation of the sowing times in which the highest levels of grain yield can be obtained, based on the historical series of climatic data, as well as in the expected grain yield to be obtained in the current growing season.

Authors' contribution

S. STEINMETZ: Interinstitutional articulation, work design, acquisition of phenological data related to the "Management" module and writing of the article. C. B. PEREIRA: Development of the web version, collaboration in the development of the App and in the review of the article. E. L. dos SANTOS: Maintenance and operation of meteorological databases, collaboration in the development of the web and App, and in the review of the article. S. V. CUADRA: Adequation of the Management module for the FORTRAN language, collaboration in the evaluation of the results of that module, and in the writing of the article. I. R. de ALMEIDA: Collaboration in the evaluation of the results of the Management module, with emphasis on mapping, and in the review of the article. N. A. STRECK: Interinstitutional articulation, work design, acquisition of data related to the "Yield" module and writing of the article. R. P. BENEDETTI: App development, adaptation of the "Yield" module to run on Embrapa's computational structure and review of the article. A. J. DUARTE JÚNIOR, A. J. ZANON, G. G. RIBAS and M. R. da SILVA: Collaboration in the acquisition of data related to the "Yield" module and in the revision of the article. R. M. KROEFF: Interinstitutional articulation, collaboration in the validation process of the "Management" module and in the review of the article. S. D. PRESTES: Interinstitutional articulation, maintenance of Inmet's automatic weather stations and transfer of daily data to Embrapa, and revision of the article.

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Fundamentos e aplicações do programa PlanejArroz no manejo e na estimativa de produtividade do arroz irrigado

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RESUMO

Apesar de relativamente alta (7,7 t ha^{-1}), a produtividade média do arroz irrigado no Estado do Rio Grande Sul (RS) pode ser ainda maior, se as práticas de manejo forem realizadas no momento mais adequado, considerando a data de ocorrência dos principais estádios de desenvolvimento da planta (EDP). O objetivo deste artigo foi demonstrar os fundamentos e a utilização do software PlanejArroz para estimar a data de ocorrência de seis EDP, visando o manejo da cultura, e a produtividade de grãos esperada. Com base no método de graus-dia, o software estima a data de cada um dos seis EDP, usando séries históricas (30 anos) de dados climáticos, e atualiza essas estimativas usando os dados meteorológicos da safra em andamento. Essas informações podem ser geradas para 131 municípios produtores de arroz e para 41 cultivares recomendadas para cultivo no RS. Da mesma forma, a produtividade de grãos, para as três cultivares mais semeadas, pode ser estimada como média de 30 anos e para a safra em andamento. O PlanejArroz é uma ferramenta que permite que as práticas de manejo sejam realizadas no momento mais adequado, estimando a data de ocorrência de seis EDP associados a essas práticas. Também é possível simular as datas de semeadura mais adequadas e obter a produtividade média de grãos esperada para a safra atual.

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