# Adaptability and stability of wheat cultivars in the Northern region of Rio Grande do Sul

# Adaptabilidade e estabilidade de cultivares de trigo na região norte do Rio Grande do Sul

DOI:10.34117/bjdv7n5-255
Recebimento dos originais: 12/04/2021
Aceitação para publicação: 12/05/2021

**Eduardo Carlos Rüdell**
Graduando em Bacharelado em Agronomia pelo Instituto Federal de Educação, Ciência e Tecnologia do Rio Grande do Sul.
Instituição: Instituto Federal de Educação, Ciência e Tecnologia do Rio Grande do Sul – Campus Sertão.
Endereço: Rodovia RS 135, Km 25 | Caixa Postal:21| CEP: 99170-000 | Distrito Eng. Luiz Englert |Sertão/Rio Grande do Sul-Brasil.
E-mail: eduardo.rudell@gmail.com

**Fernando Machado dos Santos**
Doutor em Fitotecnia pela Escola Superior de Agronomia Luiz de Queiroz – Universidade de São Paulo (USP).
Instituição: Instituto Federal de Educação, Ciência e Tecnologia do Rio Grande do Sul – Campus Sertão.
Endereço: Rodovia RS 135, Km 25 | Caixa Postal:21| CEP: 99170-000 | Distrito Eng. Luiz Englert |Sertão/Rio Grande do Sul-Brasil.
E-mail: fernando.machado@sertao.ifrs.edu.br

**Ricardo Lima de Castro**
Doutor em Genética e Melhoramento pela Universidade Federal de Viçosa (UFV)
Instituição: Empresa Brasileira de Pesquisa Agropecuária, Centro Nacional de Pesquisa de Trigo - Embrapa Trigo.
Endereço: Rodovia BR-285, Km 294 | Caixa Postal: 3081| CEP: 99050-970 | Passo Fundo/Rio Grande do Sul-Brasil.
E-mail: ricardo.castro@embrapa.br

**Argel José Giacomini**
Bacharel em Agronomia pelo Instituto Federal de Educação, Ciência e Tecnologia do Rio Grande do Sul.
Instituição: Instituto Federal de Educação, Ciência e Tecnologia do Rio Grande do Sul (IFRS) – Campus Sertão.
Endereço: Rodovia RS 135, Km 25 | Caixa Postal:21| CEP: 99170-000 | Distrito Eng. Luiz Englert |Sertão/Rio Grande do Sul-Brasil.
E-mail: argel_jose@hotmail.com

**Rodrigo Roider Fogolari**
Bacharel em Agronomia pelo Instituto Federal de Educação, Ciência e Tecnologia do Rio Grande do Sul.
Instituição: Instituto Federal de Educação, Ciência e Tecnologia do Rio Grande do Sul (IFRS) – Campus Sertão.

Endereço: Rodovia RS 135, Km 25 | Caixa Postal:21| CEP: 99170-000 | Distrito Eng. Luiz Englert |Sertão/Rio Grande do Sul-Brasil.
E-mail: rodrigo.fogolari@hotmail.com

**ABSTRACT**

The experiment evaluated the performance of 12 wheat cultivars indicated to be grown in the northern of Rio Grande do Sul. According to Scott-Knott's mean comparison test, they obtained higher grain yields of Ametista, Marfím, ORS Vintecinco, TBIO Mestre, TBIO Sintonia and TBIO Sinuelo, and regarding grain quality, Ametista, Jadeíte 11, ORS Vintecinco and Topázio. According to the method by Eberhart and Russell, Ametista, BRS Marcante, TBIO Iguaçu and TBIO Sinuelo were stable in relation to productivity and hectolitre weight. Using the Lin and Binns analysis, the Ametista showed higher average yield and greater stability in the evaluated cultivation conditions, and the TBIO Sintonia is indicated for favorable environments. In reference to the AMMI method, Ametista and TBIO Sinuelo were the most stable regarding productivity, and the 2014 and 2016 harvests were stable. In relation to hectolitre weight, Jadeíte 11 and TBIO Mestre and the year 2016 showed more stability.

**Keywords:** Genotype-Environment Interaction, Grain Yield, Grain Quality, Triticum Aestivum L, Stability, Adaptability.

**RESUMO**

O experimento avaliou o desempenho de 12 cultivares de trigo indicadas para cultivo no norte do estado do Rio Grande do Sul. De acordo com o teste de comparação da média de Scott-Knott, obtiveram maiores rendimentos de grãos as cultivares Ametista, Marfím, ORS Vintecinco, TBIO Mestre, TBIO Sintonia e TBIO Sinuelo, e em relação à qualidade dos grãos, Ametista, Jadeíte 11, ORS Vintecinco e Topázio. De acordo com o método de Eberhart e Russell, Ametista, BRS Marcante, TBIO Iguaçu e TBIO Sinuelo foram cultivares mais estáveis em relação à produtividade e peso do hectolitro. Utilizando a análise de Lin e Binns, a cultivar Ametista mostrou maior rendimento médio e maior estabilidade nas condições de cultivo avaliadas, e o TBIO Sintonia é o mais indicado para ambientes favoráveis. Em referência ao método AMMI, Ametista e TBIO Sinuelo foram as cultivares mais estáveis em relação à produtividade, e os cultivos de 2014 e 2016 foram estáveis. Em relação ao peso hectolitro, Jadeíte 11 e TBIO Mestre e o ano de 2016 demostraram mais estabilidade.

**Palavras-chave:** Interação Genótipo-Ambiente, Rendimento de Grãos, Qualidade de Grãos, Triticum Aestivum l, Estabilidade, Adaptabilidade.

## 1 INTRODUCTION

Wheat (Triticum aestivum L.) together with rice (Oryza sativa L.) and corn (Zea mays L.) are the world's major cereals grown, standing out for their importance to the global economy. The particularities of the Brazilian triticulture production in relation to the technological aspects of production, its insertion in the production systems, the aggregation of income to properties, the internal supply and the Brazilian commercial transactions with other countries give wheat crop a singular importance (Seapi, 2014). Besides being a profitable alternative, triticulture has great importance in the harvesting process for not leaving the areas without plant cover during the winter season, contributing to the reduction of weed infestation due to the high C:N ratio of the straw, for remaining longer periods on the soil (Concenço et al., 2018). Also, for its allelopathic effect and for inhibiting the emergence on weed species (Concenço et al., 2018).

In Brazil, the total cereal production is around 40% of the approximately 12 million tons consumed annually (Conab, 2020), being the Southern region responsible for approximately 90% of national grain production (Camponogara et al., 2015). Thus, seeking self-sufficiency in wheat production refers to the expansion of cultivation to new regions of the country, combining efforts to increase the area planted in regions already producing and improve productivity in both regions (Spadotto, 2014).

In contrast, there are some production barriers for wheat, which reduce its attractiveness, mainly the incidence of disease and a low investment of supplies in production. The diseases are related to climate, reducing crop yield in qualitative and quantitative levels, and according to the cultivar and management system adopted, losses between 5.5 and 79% are observed (Benin et al., 2017). The low investment is due to the high sensitivity of crops to climate variations, where successive meteorological events such as La Niña and El Niño have resulted in intense environmental variations, reflecting a significant reduction in crop productivity (Conab, 2017).

The productive potential of wheat is expressed under favorable conditions for development, with great influence of the environment and management, where each cultivar has its particularities in terms of climate and nutritional requirements. Thus, using adapted cultivars becomes important for higher yield (Capone et al., 2011). Moreover, the adaptability of each cultivar is directly linked to the region where it is grown (Embrapa, 2017). Understanding the behavior of the cultivars available on the market in relation to soil and climate and plant health conditions is very important since it allows farmers to obtain instruments that contribute to successful cultivation of wheat and, consequently, ensure the financial return with the crop.

The commercial classification of Brazilian wheat is classified according to the Normative Instruction No. 38, from November 30, 2010 (MAPA, 2010), which must meet the mandatory classification provided by the items I, II and III of Article (1), Law No. 9. 972, from May 25, 2000 (Brazil, 2000), which is an indication of quality that may, in many cases, not be confirmed due to various factors that influence technological quality, such as fertilization, phytosanitary control, soil management, weather conditions, pre and post-harvest management, etc. (Guarienti et al., 2017). Hectolitre weight, a mass of 100 liters expressed in kilograms, is used as a traditional measure for commercialization and indirectly expresses grain quality, reflecting their acceptance on the market for superior farinaceous yield.

The identification of genotypes with adequate agronomic performance in different conditions shows a positive impact for the development of new cultivars and the expansion of wheat production in the country (Caierão, 2006). It is also extremely important for decision-making when choosing cultivars to be grown by farmers. Therefore, it is important to know the productive potential and technological quality of the materials available on the market. In this context, the objective of the experiment was to evaluate 12 wheat cultivars indicated for the northern region of Rio Grande do Sul, seeking information on their yield potential, stability, productive adaptability and grain quality.

## 2 MATERIALS AND METHODS

The research was conducted at 705 m of altitude in relation to sea level, in the northern region of Rio Grande do Sul. According to the Köppen’s climate classification, the region has a climate type "Cfa", with well distributed rainfall and average annual temperature of 18.3ºC. The soil in the area is classified as dystrophic Red Nitosol (Embrapa, 2013).

The experiment was conducted during the years 2014, 2015, 2016 and 2017, in experimental design of randomized blocks (DBC) with four repetitions. Twelve wheat cultivars were evaluated: Amethyst, BRS Marcante, BRS Parrudo, Jadeíte 11, Marfím, ORS Vintecinco, Quartzo, TBIO Iguaçu, TBIO Mestre, TBIO Sinuelo and Topázio.

The sowing of cultivars was held in the first half of July of each year. The experimental units were 5 meters long and 5 rows spaced 0.2m apart. Sowing, fertilization, weed control, pest and disease management, crop treatments and management practices for all wheat cultivars followed the technical indications of the crop, according to the annual publication of the Brazilian Wheat and Triticale Research Commission (Embrapa). The harvest was carried out during November, manually, by the collection of 3 central rows when the grains were around 15% of humidity, in a useful area of 3 m² (5 m. x 0.2 m. x 3 rows). After trail and cleaning of grains, it was weighed and corrected to 13% of humidity and transformed to $kg.ha^{-1}$.

The data obtained were submitted to analysis of variance using the ASSISTAT software, v. 7.7 pt - Statistical Assistance, and a significant effect was verified for the parameters evaluated. The analysis was complemented by the Scott-Knott means grouping test ($p<0.05$). Other evaluations carried out to check the adaptability and stability by the use of the Genes program, v. 1990.2019.42 (Cruz, 2016).

The genotypes x environments interaction was to examined by three complementary procedures. The adaptability and stability parameters were estimated using the methods of Eberhart and Russell (1966), Lin and Binns (1988) and AMMI (Zobel et al., 1988). The method of Eberhart and Russell (1966) is based on regression analysis and has as adaptability parameters: the regression coefficient ($\beta 1$), average yield ($\beta 0$) and the stability of genotypes evaluated by the regression deviation ($\delta^2 d$). The Lin and Binns method (1988) estimates the parameter of stability and adaptability (Pi), where the most stable genotype is the one with the lowest value. The AMMI (Additive Main Effects and Multiplicative Interaction Analysis) method minimizes possible errors and ensures a more accurate and efficient interaction estimate. Also, the analysis allows visualization and graphical interpretation of the genotypes and environments evaluated, simplifying the relations of similarity and complementarity, among and within genotypes and environments (Yokomizo, 2013).

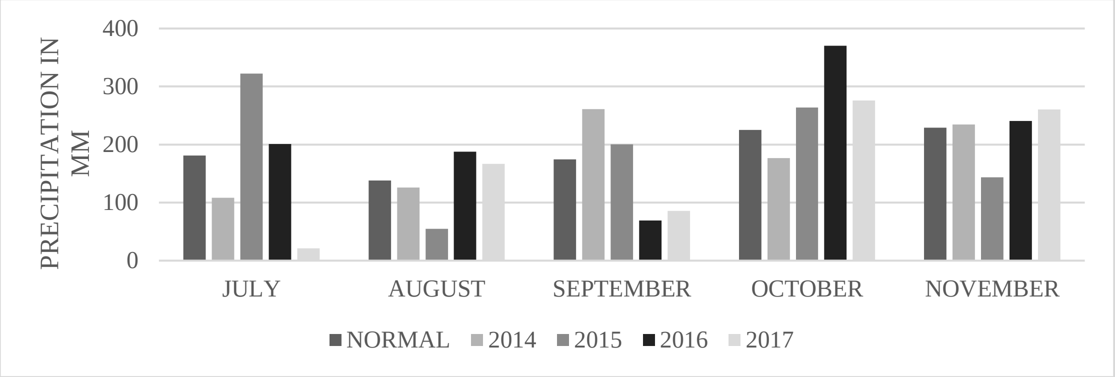
The climatological normal data were provided by the National Institute of Meteorology (Inmet, 2020) based on the nearest weather station - 83914 - located in Passo Fundo (RS-Brazil). The data were used to discuss the climatic variations that occurred during the years of development of this study, provided by the Embrapa Trigo Agrometeorology Laboratory (Embrapa, 2020).

## 3 RESULTS AND DISCUSSION

At the experimental location, the climatological conditions were very wide during the 4 years evaluated, which allowed separating them in different environments. The performance of the materials evaluated, although quite unique, enables to consider the wheat crop as highly sensitive to climatic variations during its cultivation period.

In the 2014 crop, the first year of the field experiment, analyzing the monthly rainfall graphs in comparison to the climatological normal and considering that the period from July to November directly encompasses the entire wheat growing period, the amount of rainfall was lower in comparison to the climatological normal from July to August, a period that corresponds to the initial stages of crop development, as represented in Chart 1.

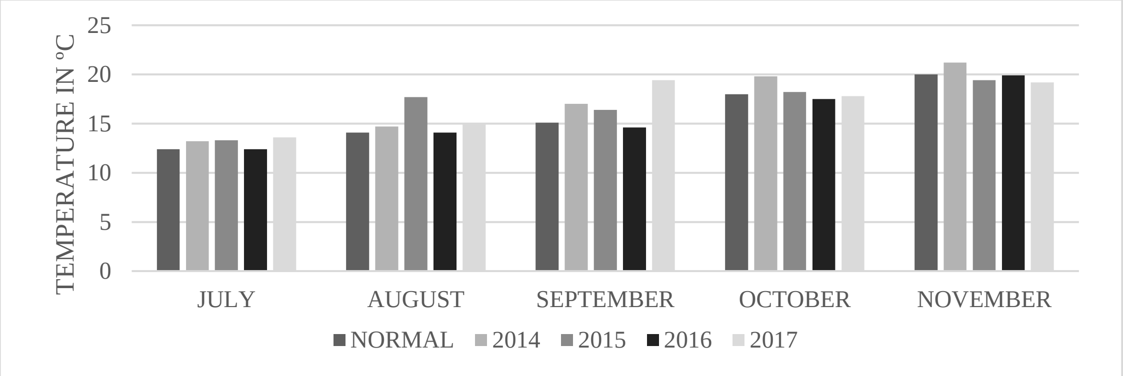
Chart 1. Average monthly precipitation in the period of the research in comparison with the climatological normal 1981-2010.




Source: Weather information of the station: 83914 – Passo Fundo (RS-Brazil)

Average temperatures remained higher throughout the crop development cycle (Chart 2), which normally results from reduced root development, the emission of productive tillers, leaf area, the percentage of fecundated flowers, the differentiation of spikes and flowers and the production of grains with lower weight (Pimentel et. al., 2015).

Chart 2. Average monthly temperature during the research period compared to the average normal temperature 1981-2010.




Source: Weather information of the station: 83914 – Passo Fundo (RS-Brazil)

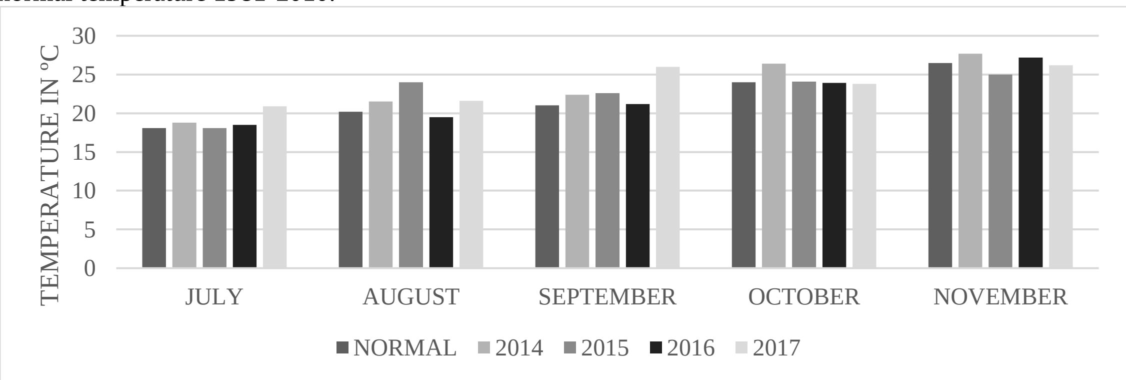
In September, rainfall remained above average, impairing the beginning of the reproductive period of cultivars. The excess rainfall and the high amount of water dissolved in the atmospheric air, combined with the high temperatures, have a direct effect on the appearance of fungal diseases and hinder to manage them due to excessive soil humidity, reducing production and grain quality (Benin et al., 2017).

In November, as the accumulated rainfall in the period was high, causing quantitative and qualitative losses of the grains because of the difficulty of harvesting with the ideal humidity. The excess of rain can cause losses in the crop by the delay in harvesting, remaining in the environment where there are great amplitudes of temperature and humidity, which contributes to the germination of the grains in the ear (pre-harvest germination) of susceptible materials, ample decrease in yield and decrease in weight of hectolitre (PH), resulting in a lower quality of these grains and, consequently, a lower commercial value (Wendt, 2007).

In 2014, there was no significant difference between the average grain yields of the evaluated wheat crops (Table 1). Regarding hectolitre weight, the cultivars Ametista (76 $kg.HL^{-1}$), Jadeíte 11 (76 $kg.HL^{-1}$), BRS Parrudo (75 $kg.HL^{-1}$), TBIO Iguaçu (75 $kg.HL^{-1}$), Topázio (75 $kg.HL^{-1}$) and ORS Vintecinco (74 $kg.HL^{-1}$) had the highest values (Table 1).

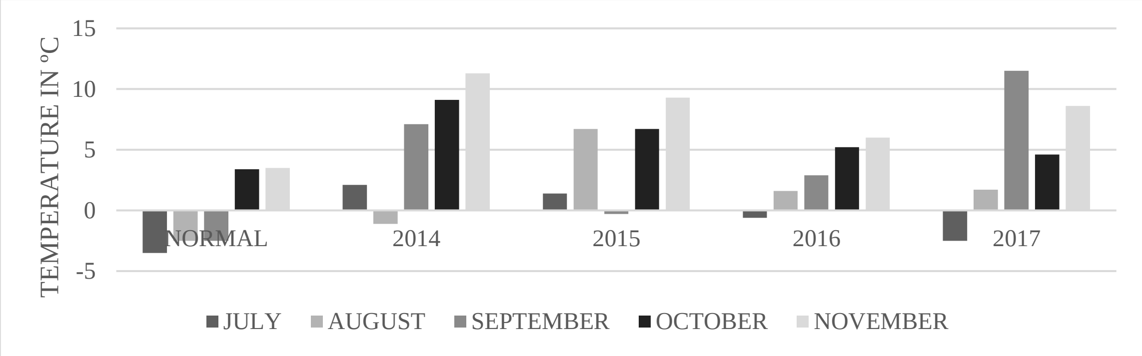
Among the four years studied, the lowest overall productivity of the cultivars was obtained in 2015. In this harvest, rainfall remained above average in the initial period of crop development, which combined with high temperature peaks during the months of August and September, (Graph 1 and 3), directly affected the vegetative stage of the crop, where yield components are determined. During September and October, high rainfall accumulated affected significantly the whole reproductive period, which accounts for yield and final grain quality. Still in this period, the occurrence of late frosts in September (Graph 4) drastically affected the reproductive period of the cultivars, causing lower yield than expected and lower grain quality, as shown in Table 1.

Chart 3. Maximum average monthly temperature during the research period in relation to the maximum normal temperature 1981-2010.




Source: Weather information of the station: 83914 – Passo Fundo (RS-Brazil)

Chart 4. Minimum monthly absolute temperature during the research period in relation to the minimum normal absolute temperature 1981-2010.




Source: Weather information of the station: 83914 – Passo Fundo (RS-Brazil).

Table 1. Grain yield (kg.ha$^{-1}$) and Weight of hectoliter (Kg.hL$^{-1}$) of 12 wheat cultivars, in four agricultural crops (2014 to 2017), in the northern region of Rio Grande do Sul-Brazil. IFRS, Sertão (RS-Brazil), 2020.

| Cultivar/year | 2014 | | 2015 | | 2016 | | 2017 | | AVERAGE[1] | |
|---|---|---|---|---|---|---|---|---|---|---|
| Ametista | 3.222 bA | 76 bA | 2.462 bA | 74 cB | 4.722 aA | 79 aA | 2.855 bA | 72 cA | 3.315 A | 75 A |
| BRS Marcante | 2.735 bA | 73 bB | 2.012 cB | 70 cC | 4.528 aB | 78 aA | 2.619 bA | 72 bA | 2.973 B | 73 B |
| BRS Parrudo | 2.621 bA | 75 aA | 1.641 cB | 67 bD | 4.098 aB | 77 aA | 2.218 bA | 69 bB | 2.645 B | 72 C |
| Jadeíte 11 | 2.386 bA | 76 bA | 2.138 bA | 72 cB | 4.099 aB | 79 aA | 2.774 bA | 71 cA | 2.849 B | 74 A |
| Marfím | 2.691 bA | 70 bC | 1.538 bB | 69 bD | 4.861 aA | 78 aA | 3.006 bA | 70 bB | 3.024 A | 72 C |
| ORS Vintecinco | 2.387 bA | 74 bA | 2.596 bA | 76 aA | 4.994 aA | 78 aA | 2.645 bA | 71 cA | 3.155 A | 75 A |
| Quartzo | 2.931 bA | 72 bB | 1.916 cB | 71 bC | 4.243 aB | 79 aA | 2.059 cA | 70 bB | 2.788 B | 73 B |
| TBIO Iguaçu | 2.413 bA | 75 bA | 1.887 bB | 68 dD | 4.801 aA | 79 aA | 2.541 bA | 71 cA | 2.910 B | 73 B |
| TBIO Mestre | 2.882 bA | 74 bA | 2.636 bA | 71 cC | 4.477 aB | 78 aA | 2.396 bA | 70 cA | 3.098 A | 73 B |
| TBIO Sintonia | 2.779 bA | 71 bC | 2.469 bA | 69 bD | 5.085 bA | 78 aA | 2.132 bA | 66 cC | 3.116 A | 71 C |
| TBIO Sinuelo | 2.738 bA | 73 bB | 2.213 bA | 71 cC | 4.911 bA | 77 aA | 2.415 bA | 69 cB | 3.069 A | 73 B |
| Topázio | 2.252 bA | 75 bA | 2.311 bA | 74 bB | 4.404 aB | 80 aA | 2.678 bA | 70 cB | 2.911 B | 75 A |
| [1]Average | 2.667 b | 74 b | 2.152 c | 71 c | 4.602 a | 78 a | 2.528 b | 70 d | 2.987 | 73 |
| [2]Cv% | 15,65 | 2,35 | | | | | | | | |

[1]The averages followed by different lower case letters in the row and upper case letters in the column differ according to the Scott-Knott's test at the 5% probability level. [2]CV – Coefficient of variation.

Stress caused by high temperatures drastically limits production and has great impact during the reproductive stage (Teixeira et al., 2017). Also, long hours of exposition to high temperature, as well as short exposures to very high temperature, such as those occurred in the year 2015, reduce the yield of the crop, having a singular effect in each of the cultivars, because of the sensitivity to this stress (Stone & Nicolas, 1996).

Thus, it is possible to understand that productivity in 2015 was low (average of 2,152 kg.ha$^{-1}$) compared to other years, and the cultivars that stood out in production were TBIO Mestre (2,636 kg.ha$^{-1}$), ORS Vintecinco (2,596 kg.ha$^{-1}$), TBIO Sintonia (2,469 kg.ha$^{-1}$), Ametista (2,462 kg.ha$^{-1}$), Topázio (2,311 kg.ha$^{-1}$), TBIO Sinuelo (2,213 kg.ha$^{-1}$)

and Jadeíte 11 (2,138 kg.ha$^{-1}$) (Table 1). In relation to the hectolitre weight, climatic factors interfered significantly. The ORS Vintecinco cultivar stood out with the highest value (76 kg.HL$^{-1}$), but most of the materials did not present good production parameters (Table 1).

In the 2016 harvest, August and October, rainfall exceeded the normal, but without affecting significantly the development of cultivars. In the remaining months, the combination of lower temperatures and reduced rainfall favored the crop. In addition, there was less pressure from diseases because of the climatic conditions that allowed the application of fungicides periodically to protect the crop and, thus, giving conditions for the expression of the productive potential by keeping the plants healthy until the end of the cycle.

Grain yield of the cultivars in 2016 was high, an average of 4,602 kg.ha$^{-1}$. The cultivars with the highest yields were TBIO Sintonia (5,085 kg.ha$^{-1}$), ORS Vintecinco (4,994 kg.ha$^{-1}$), TBIO Sinuelo (4,911 kg.ha$^{-1}$), Marfím (4,861 kg.ha$^{-1}$), TBIO Iguaçu (4,801 kg.ha$^{-1}$) and Ametista (4,722 kg.ha$^{-1}$). Despite propitious conditions, some cultivars did not present hectolitre weight equal or superior to 78 kg.hL$^{-1}$ (BRS Parrudo and TBIO Sinuelo). Although not differing statistically from the others, they did not reach the minimum necessary to belong to Group II Type 1, intended for grinding and other purposes, according to the current normative instruction, IN No. 38, November 30, 2010 (MAPA, 2010).

In the 2017 harvest, sowing was carried out with the lowest humidity of the four years of the experiment, where the accumulated in July was 21.3 mm., impairing the initial development of the crop and delaying nitrogen fertilization coverage in appropriate periods (Graph 1). Thus, according to Wiethölter (2011), especially when there is an excess of crop residues from previous crops, such as corn, there is a strong immobilization of nitrogen added to the basic fertilization, which is used in the process of straw mineralization and important to anticipate nitrogen fertilization coverage in higher doses, so that no damage occurs to the crop. However, since there was not enough humidity in the soil to perform this practice, production losses may have occurred because of delayed application of nitrogen fertilizers.

Grain yield of the Marfím cultivar was 3,006 kg.ha$^{-1}$, but did not differ significantly from the other cultivars evaluated and presented a general average in 2017 of 2,528 kg.ha$^{-1}$ (Table 1). Regarding grain quality, the mean hectolitre weight obtained was the lowest among the four years evaluated - 70.1 $kg.HL^{-1}$ (Table 1). This is explained by the previous average rainfall that occurred in the months of October and November, compromising the harvest of the materials, where the plants being in a stage of physiological maturation remained in the field because the excess moisture does not allow the harvest at the ideal time, causing qualitative losses in grains.

By evaluating the cultivars in the 4 years using the method of Eberhart and Russell (1966), the productivity of the cultivars Ametista, Jadeíte 11, TBIO Mestre and Topázio had specific adaptation to unfavorable environments ($\beta i<1$). The cultivars BRS Marcante, BRS Parrudo, ORS Vintecinco and Quartzo were the closest to broad or general adaptability, with βi statistically equal to the unit ($\beta i=1$), and the cultivars Marfím, TBIO Iguaçu, TBIO Sintonia and TBIO Sinuelo adapting to favorable environments ($\beta i>1$) (Table 2). The cultivars Ametista, BRS Marcante, TBIO Iguaçu, and TBIO Sinuelo were stable (non-significant regression deviation). Regarding the Scott-Knott (1974) 5% probability mean comparison test, the cultivars that showed superior performance in the analysis were: Ametista (3,315 $kg.ha^{-1}$), ORS Vintecinco (3,155 $kg.ha^{-1}$), TBIO Sintonia (3,116 $kg.ha^{-1}$), TBIO Mestre (3,098 $kg.ha^{-1}$), TBIO Sinuelo (3,069 $kg.ha^{-1}$) and Marfím (3,024 $kg.ha^{-1}$) (Table 1).

Table 2. Estimation of stability and adaptability parameters in relation to productivity ($kg.ha^{-1}$) and weight of hectoliter ($Kg.hL^{-1}$), by the Eberhart and Russell (1966) method, for 12 wheat cultivars evaluated in four agricultural crops (2014 to 2017), in the northern region of Rio Grande do Sul-Brazil. IFRS, Sertão (RS-Brazil), 2020.

| Genotype | Average yield | Average PH | Bi yield | Bi PH | Δ²di yield | Δ²di ph | R² (%) yield | R² (%) PH |
|---|---|---|---|---|---|---|---|---|
| Ametista | 3.315 a[1] | 75,30 a[1] | 0,89 + | 0,772 ns | 17643,2052 ns | - 0,2566 ns | 98,23 | 96,84 |
| BRS Marcante | 2.973 b | 73,24 b | 0,98 ns | 0,872 ns | 9566,4372 ns | 1,3086 ns | 98,99 | 88,4 |
| BRS Parrudo | 2.645 b | 71,92 c | 0,935 ns | 1,198 ns | 55581,5289 ** | 5,558 ** | 96,13 | 82,47 |
| Jadeíte 11 | 2.849 b | 74,41 a | 0,771 ++ | 1,003 ns | 56696,6547 ** | 0,252 ns | 94,32 | 95,37 |
| Marfím | 3.024 a | 71,67 c | 1,193 ++ | 1,061 ns | 257186,4373 ** | 2,8889 * | 90,68 | 86,48 |
| ORS Vintecinco | 3.155 a | 74,83 a | 1,08 ns | 0,588 ** | 145365,2332 ** | 4,2666 ** | 93,24 | 58,73 |
| Quartzo | 2.788b | 72,92 b | 0,929 ns | 1,093 ns | 139340,4652 ** | 0,4846 ns | 91,39 | 95,22 |
| TBIO Iguaçu | 2.910 b | 73,31 b | 1,169 ++ | 1,166 ns | 14846,5293 ns | 4,9373 ** | 99,08 | 83,19 |
| TBIO Mestre | 3.098a | 73,34 b | 0,849 ++ | 0,938 ns | 73471,2326 ** | - 0,6892 ns | 94,12 | 99,62 |
| TBIO Sintonia | 3.116 a | 71,03 c | 1,181 ++ | 1,348 * | 149794,1445 ** | 0,1253 ns | 94,13 | 97,7 |
| TBIO Sinuelo | 3.069 a | 72,56 b | 1,13 ++ | 0,891 ns | 5242,5679 ns | - 0,5398 ns | 99,42 | 98,68 |
| Topázio | 2.911 b | 74,70 a | 0,891 + | 1,071 ns | 89517,4532 ** | 1,8386 * | 93,64 | 90,14 |

[1]The averages followed by different lower case letters in the column differ by the Scott-Knott test at the 5% probability level. ns Not significant. ++ and + significantly different from 1, by the T test at 1% and 5% probability, respectively. ** significantly different from 0, by test F, at 1% probability.

The results of the stability and adaptability analysis in relation to productivity and weight of hectolitre, obtained by the Lin and Binns method are presented in Table 3 and Table 4. The Ametista cultivar presented the lowest value of Pi among all genotypes, showing that this cultivar presents, besides high productivity, greater stability in the cultivation conditions in the region evaluated during the years of study. Regarding the favorable environments, the TBIO Sintonia stood out mostly in relation to this parameter and, consequently, its sowing under conditions of higher technological level can be recommended.

Table 3. Stability and adaptability estimates (Pi) in relation to productivity according to the Lin and Binns method (1988) for 12 wheat cultivars evaluated in four agricultural crops (2014 to 2017), in the northern region of Rio Grande do Sul (RS-Brazil). IFRS, Sertão (RS-Brazil), 2020.

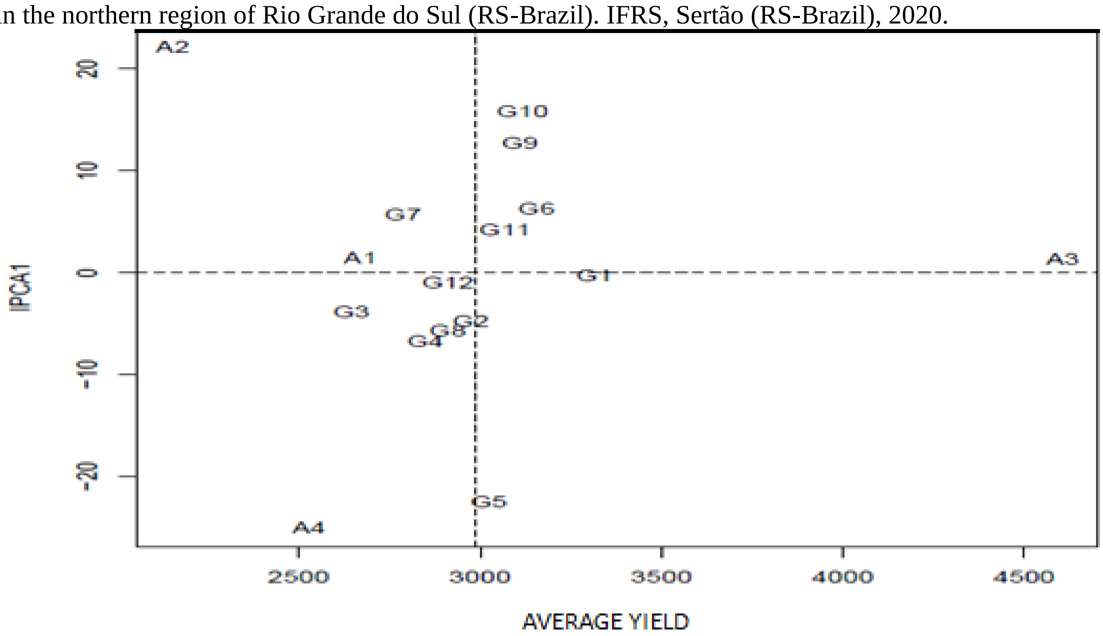
| Genotype | General Pi | Genotype | Favorable Pi | Genotype | Unfavorable Pi |
|---|---|---|---|---|---|
| Ametista | 23.202,944 | TBIO Sintonia | . | Ametista | 8.830,319 |
| TBIO Sinuelo | 99.192,633 | ORS Vintecinco | 4.251,803 | TBIO Mestre | 81.264,837 |
| TBIO Mestre | 100.644,385 | TBIO Sinuelo | 15.265,723 | TBIO Sinuelo | 127.168,270 |
| ORS Vintecinco | 104.848,840 | Marfim | 25.203,493 | BRS Marcante | 129.444,341 |
| TBIO Sintonia | 123.644,107 | TBIO Iguaçu | 40.453,768 | ORS Vintecinco | 138.381,185 |
| BRS Marcante | 136.042,128 | Ametista | 66.320,820 | TBIO Sintonia | 164.858,810 |
| TBIO Iguacu | 189.271,722 | BRS Marcante | 155.835,488 | Jadeíte 11 | 166.988,044 |
| Marfim | 192.415,812 | TBIO Mestre | 158.783,031 | Topázio | 192.387,155 |
| Topázio | 202.411,261 | Topázio | 232.483,577 | TBIO Iguaçu | 238.877,706 |
| Jadeíte 11 | 246.885,115 | Quartzo | 354.839,940 | Marfim | 248.153,252 |
| Quartzo | 276.173,985 | Jadeíte 11 | 486.576,328 | Quartzo | 249.952,000 |
| BRS Parrudo | 368.439,014 | BRS Parrudo | 488.022,601 | BRS Parrudo | 328.577,818 |

Table 4. Stability and adaptability estimates (Pi) in relation to the hectolitric weight according to the Lin and Binns method (1988) for 12 wheat cultivars evaluated in four agricultural crops (2014 to 2017), in the Northern region of Rio Grande do Sul (RS-Brazil). IFRS, Sertão (RS-Brazil), 2020

| Genotype | General Pi | Genotype | Favorable Pi | Genotype | Unfavorable Pi |
|---|---|---|---|---|---|
| Ametista | 0,625 | Ametista | 0,250 | ORS Vintecinco | 0,189 |
| ORS Vintecinco | 1,095 | Jadeíte 11 | 0,250 | Ametista | 1,000 |
| Topázio | 1,345 | Topázio | 0,250 | Topázio | 2,440 |
| Jadeíte 11 | 2,433 | TBIO Mestre | 0,500 | Jadeíte 11 | 4,616 |
| TBIO Mestre | 4,553 | Quartzo | 2,000 | TBIO Mestre | 7,106 |
| Quartzo | 6,044 | TBIO Mestre | 2,000 | Quartzo | 7,838 |
| BRS Marcante | 6,107 | BRS Parrudo | 2,210 | TBIO Sinuelo | 8,426 |
| TBIO Sinuelo | 6,463 | BRS Marcante | 3,189 | BRS Marcante | 9,026 |
| TBIO Iguaçu | 8,368 | Quartzo | 4,250 | Marfim | 13,838 |
| Marfim | 11,919 | TBIO Sinuelo | 4,500 | TBIO Iguaçu | 16,235 |
| BRS Parrudo | 12,779 | TBIO Sintonia | 7,250 | TBIO Sintonia | 21,553 |
| TBIO Sintonia | 14,401 | Marfim | 10,000 | BRS Parrudo | 23,348 |

In the biplot AMMI model (Figure 1), the x-axis represents the productivity in kg.ha$^{-1}$ of the cultivars evaluated in the four environments (2014, 2015, 2016 and 2017) and the y-axis represents the first interaction of the axis (IPCA1). The genotypes and environments closest to the zero axis in the figure represent higher stability. The more distant from zero, the more adapted to specific environments. The Ametista and TBIO Sinuelo cultivars proved to be the most stable among the materials. The cultivars that expressed good stability with above average yield were the BRS Marcante and ORS Vintecinco. The cultivars Topázio and BRS Parrudo showed good stability with below average productivity among the evaluated cultivars. The cultivars Marfím, TBIO Mestre and TBIO Sintonia were less stable with above average yields.

Figure 1. Biplot AMMI with the main axis of interaction (IPCA1) x productivity in kg ha$^{-1}$, for 12 wheat cultivars evaluated in environments A1 (year 2014), A2 (year 2015), A3 (year 2016) and A4 (year 2017) in the northern region of Rio Grande do Sul (RS-Brazil). IFRS, Sertão (RS-Brazil), 2020.




Genotypes evaluated: G1: Ametista G2: BRS Marcante G3: BRS Parrudo G4: Jadeíte 11 G5: Marfím G6: ORS Vintecinco G7: Quartzo G8: TBIO Iguaçu G9: TBIO Mestre G10: TBIO Sintonia G11: TBIO Sinuelo G12: Topázio. Years (environments) evaluated: A1: 2014 A2: 2015 A3: 2016 A4: 2017.

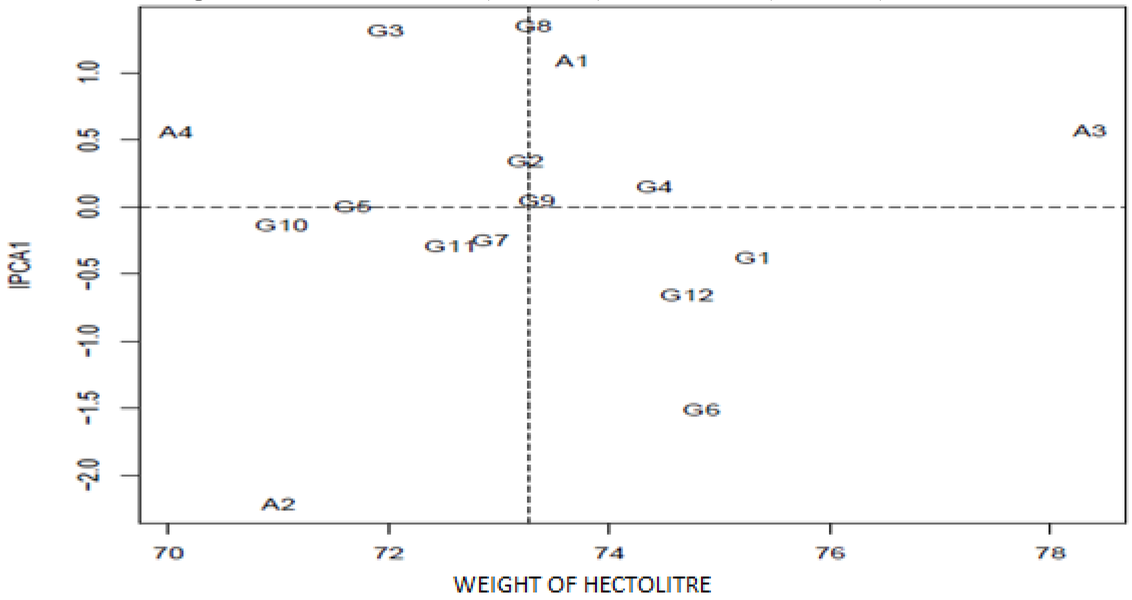
The environments A1 (2014) and A3 (2016) were stable indicating that the climatic factors had a similar effect on all of the cultivars studied. The year 2014 was not favorable considering that the productivity of the cultivars was below the average of the 4 years evaluated. However, the A3 environment (year 2016) showed good stability and above average productivity (4,602 kg ha$^{-1}$), showing the climatic factors that occurred during this crop year are ideal for growing wheat in the region. The A2 (year 2015) and A4 (year 2017) environments were much lower in relation to the stability of the materials, showing same average productivity of the 12 cultivars evaluated.

Regarding the AMMI analysis of hectolitre weight of the evaluated cultivars (Figure 2), the x-axis represents the PH in the 4 environments evaluated (years 2014, 2015, 2016 and 2017) and the y-axis represents the first interaction of the axis

ISSN: 2525-8761

(IPCA1).The Jadeíte 11 and TBIO Master cultivars, and the A3 environment (year 2016), were the closest to the zero axis in the figure, showing greater stability. The more isolated in relation to zero are more adapted to specific environments. The Marfím cultivar showed good stability, but had a lower performance in relation to the average of the evaluated cultivars. The cultivars that expressed good stability with hectolitre weight above the average were Ametista and BRS Marcante. The Quartzo, TBIO Sintonia and TBIO Sinuelo cultivars showed good stability but with a PH below the average among the evaluated cultivars. The less stable cultivars were ORS Vintecinco and TBIO Iguaçu, with a PH above average, and the BRS Parrudo cultivar that presented a hectolitre weight below average.

Figure 2. Biplot AMMI with the main axis of interaction (IPCA1) x weight of hectolitre, for 12 wheat cultivars evaluated in environments A1 (year 2014), A2 (year 2015), A3 (year 2016) and A4 (year 2017) in the northern region of Rio Grande do Sul (RS-Brazil). IFRS, Sertão (RS-Brazil), 2020.




Genotypes evaluated: G1: Ametista G2: BRS Marcante G3: BRS Parrudo G4: Jadeíte 11 G5: Marfím G6: ORS Vintecinco G7: Quartzo G8: TBIO Iguaçu G9: TBIO Mestre G10: TBIO Sintonia G11: TBIO Sinuelo G12: Topázio. Years (environments) evaluated: A1: 2014 A2: 2015 A3: 2016 A4: 2017.

Only the A3 (year 2016) and A4 (year 2017) environments showed stability, but the year 2017 was not favorable for wheat cultivation since the weight of hectolitre was below average of the 4 years evaluated. However, the environment A3 (year 2016) showed good stability and PH above average (78.3 $kg.HL^{-1}$), which shows that the climatic factors during this year of cultivation were also ideal for grain quality.

## 4 CONCLUSIONS

According to the method of Eberhart and Russell (1966), the cultivars Ametista, BRS Marcante and TBIO Mestre presented adaptation to unfavorable environments and the cultivars Marfím, TBIO Iguaçu and TBIO Sintonia presented adaptability to favorable environments, for both characteristics evaluated. Regarding the Lin and Binns method (1988), the Ametista cultivar showed superior performance in both characteristics evaluated. In reference to the AMMI method (Zobel et al., 1988), the Ametista and TBIO Sinuelo cultivars are the most stable in relation to productivity, where the 2014 and 2016 environments were stable. In relation to hectolitre weight, the cultivars Jadeíte 11 and TBIO Mestre showed greater stability and the year 2016 also stood out.

Therefore, it is possible to affirm that wheat cultivars are strongly influenced by the edaphoclimatic conditions to which they are submitted, reproducing unique responses for each parameter evaluated and, therefore, it is essential to consider climate prognoses to define the cultivar to be grown during the cold season in the northern region of Rio Grande do Sul – Brazil.

## LITERATURE CITED

1. Benin, G.; Storck, L.; Marchioro, V. S.; Bornhofen, E.; Woyann, L.G.; Trevizan, D.M. Seleção ambiente-específica de genótipos para rendimento de grãos e responsividade à aplicação de fungicida em trigo. Revista Ceres, v. 64, nº 2, p. 167-175, Viçosa, 2017. http://dx.doi.org/10.1590/0034-737x201764020009.

2. Brasil. Presidência da República. Lei nº 9.972, de 25 de maio de 2000. https://www2.camara.leg.br/legin/fed/lei/2000/lei-9972-25-maio-2000-377281-norma-pl.html. Set. 2019.

3. Caierão, E.; Silva, M.S.; Scheeren, P.L.; Del Duca, L.J.A.; Junior, A.N.; Pires, J.L. Análise da adaptabilidade e da estabilidade de genótipos de trigo como ferramenta auxiliar na recomendação de novas cultivares. Ciência Rural vol. 36 nº4. Santa Maria, 2006. https://doi.org/10.1590/S0103-84782006000400011.

4. Camponogara, A.; Gallio, E.; Borba, W. F. de; Georgin J. O atual contexto da produção de trigo no Rio Grande do Sul. Revista do Centro de Ciências Naturais e Exatas – UFSM Santa Maria. v. 19, n. 2, p. 246-257, 2015. https://doi.org/10.5902/2236117015437.

5. Companhia Nacional de Abastecimento - Conab. Acompanhmanento da safra brasileira de grãos, v. 7 - Safra 2019/20 - n. 6 - Sexto levantamento, Brasília, p. 1-31, 2020. https://www.conab.gov.br/info-agro/safras/graos/boletim-da-safra-de-graos. 10 Abr. 2020.

6. CONAB - Companhia Nacional de Abastecimento. A cultura do trigo. Brasília, 2017. 218 p.

7. Concenço, G.; Ito, M.A.; Marques, R.F.; Melo, T.S.; Silva, L.B.X. da; Linhares, L.T. Trigo como supressor de infestação de capim-amargoso. Embrapa Agropecuária Oeste - Comunicado Técnico 234. 7 p., 2018. https://www.infoteca.cnptia.embrapa.br/infoteca/handle/doc/1095174. Set. 2019.

8. Cruz, C. D. Programa Genes – Ampliado e integrado aos aplicativos R, Matlab e Selegen. Acta Scientiarum. Agronomy, v. 38, n. 4. Maringá, 2016 p. 547-552. https://doi.org/10.4025/actasciagron.v38i4.32629.

9. Eberhart, S.A.; Russell, W.A. Stability Parameters for Comparing Varieties. Crop Science, 6, 36-40. 1966. http://dx.doi.org/10.2135/cropsci1966.0011183X000600010011x.

10. Embrapa - Empresa Brasileira de Pesquisa Agropecuária. Informações técnicas para trigo e triticale safra 2017. 10ª Reunião da Comissão Brasileira de Pesquisa de Trigo e Triticale Londrina, PR, 2016. https://www.embrapa.br/busca-de-publicacoes/-/publicacao/1064344/informacoes-tecnicas-para-trigo-e-triticale---safra-2017. Set. 2017.

11. Embrapa – Empresa Brasileira de Pesquisa Agropecuária. Informações técnicas para trigo e triticale. Reunião da comissão brasileira de pesquisa de trigo e triticale. https://www.reuniaodetrigo.com.br/index.php?menu=pagina&CODPAGINA=283. Jan 2020.

12. Embrapa – Empresa Brasileira de Pesquisa Agropecuária. Laboratório de agrometeorologia. http://www.cnpt.embrapa.br/pesquisa/agromet/app/principal/agromet.php. Jan. 2020.

13. Embrapa – Empresa Brasileira de Pesquisa Agropecuária. Sistema Brasileiro de Classificação de Solos. 3 ed. Brasília, DF. 2013. 353p.

14. FAO. 2020. Crop Prospects and Food Situation - Quarterly Global Report No. 1, March 2020. Rome. https://doi.org/10.4060/ca8032en.

15. Guarienti, E.M.; Miranda, M.Z. de; Cunha, G.R. da; Tibola, C.S.; Nicolau, M. Qualidade tecnológica de trigo colhido e armazenado no Brasil – safra 2015. Embrapa Trigo. Documentos online, 170. Passo Fundo, 66p. 2017. http://www.infoteca.cnptia.embrapa.br/infoteca/handle/doc/1074733.

16. INMET. Instituto Nacional de Meteorologia. Normal climatológica 1981-2010. http://www.inmet.gov.br/portal/index.php?r=clima/normaisClimatologicas. Jan. 2020.

17. Lin, C. S.; Binns, M. R. A superiority measure of cultivar performance for cultivar x location data. Canadian Journal of Plant Science, 68: 193-198. 1988. https://www.nrcresearchpress.com/doi/pdfplus/10.4141/cjps88-018. Dez, 2019.

18. MAPA - Ministério da Agricultura, Pecuária e Abastecimento. Instrução Normativa Nº 38, 30 Nov. 2010. 11 p. http://www.codapar.pr.gov.br/arquivos/File/pdf/TrigoInstrucaoNormativa3810.pdf.

19. Capone, A.; Lui, J.J.; Silva, T.R.; Dias, M.A.R.; Melo, A.V. Avaliação do comportamento de quinze cultivares de cana-de-açucar na Região Sul do Tocantins. Journal of Biotechnology and Biodiversity, 2011, vol.2, n.3, 72-80.

20. Pimentel, A.J.B.; Rocha, J.R.A.S.C.; Souza, M.A.; Ribeiro, G.; Silva, C.R.; Oliveira, I.C.M. Caracterização de cultivares de trigo para tolerância ao calor e seus efeitos sobre alguns componentes da produção. Revista Ceres, vol. 62 nº 2. Viçosa, 2015. http://dx.doi.org/10.1590/0034-737X201562020009.

21. SEAPI - Secretaria Estadual Da Agricultura, Pecuária e Agronegócio. Governo do estado do Rio Grande do Sul. Plano decenal da secretaria da agricultura para a agropecuária e o agronegócio gaúcho. Porto Alegre. Mar, 2014. 120 p. http://www.abpm.org.br/portugues/mensagens/imprensa/100_2014/planodecenalgaucho.pdf. Abr. 2018.

22. Spadotto, C.A. Trigo: a autossuficiência necessária e possível. Campinas: Embrapa Gestão Territorial, 2014. https://www.infoteca.cnptia.embrapa.br/infoteca/bitstream/doc/988514/1/Trigoabril2014.pdf. Set. 2019.

23. Stone, P.J.; Nicolas, M.E. Effect of timing of heat stress during grain filling on two wheat varieties differing in heat tolerance. II. Fractional Protein Accumulation. Functional Plant Biology 23, 739-749. 1996. https://doi.org/10.1071/PP9960739.

24. Teixeira, S.B.; Ávila, G.E.; Moraes, I.L.; Armesto, R.S.; Silva, R.S.; Schmitz, V.N.; Deuner, S. Viabilidade de sementes de arroz produzidas em condições supra-ótimas de temperaturas. Revista da 14ª jornada da pós-graduação e pesquisa - congrega urcamp. p.2723-2736. 2017. http://revista.urcamp.tche.br/index.php/rcjpgp/issue/view/70. Jun, 2020.

25. Wendt, W.; Caetano, V.R.; Nunes, C.D.M. Rendimento de grãos e fatores de produção de trigo em função da ocorrência de precipitação pluviométrica na fase reprodutiva. Pelotas, 2007. https://ainfo.cnptia.embrapa.br/digital/bitstream/item/31292/1/comunicado-163.pdf. Jul, 2018.

26. Wiethölter, S. Fertilidade do solo e a cultura do trigo no Brasil. In: Pires, J.L.F.; Vargas, L.; Cunha, G.R. Trigo no Brasil: bases para produção competitiva e sustentável. Passo Fundo: Embrapa Trigo, Capítulo 6, p.135-185. 2011.

27. Yokomizo, G.K.; Duarte, J.B.; Vello, N.A.; Unfried, J.R. Análise AMMI da produtividade de grãos em linhagens de soja selecionadas para resistência à ferrugem asiática. Pesquisa agropecuária brasileira, vol. 48 nº10. Brasília, 2013. http://dx.doi.org/10.1590/S0100-204X2013001000009.

28. Zobel, R.W.; Wright, M.J.; Gauch, H.G. Statistical analysis of a yield trial. Agronomy Journal, Madison, v. 80, p. 388-393, 1988. https://doi.org/10.2134/agronj1988.00021962008000030002x.