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CROP PRODUCTION

El Niño Southern Oscillation and the accumulation of chilling hours for dormancy breaking in temperate fruit in Southern Brazil

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ABSTRACT: The number of chilling hours is responsible for maximizing budding and flowering in temperate climate fruit trees, and this number varies widely between years. An important source of variability is the occurrence of the ENSO - El Niño Southern Oscillation. With the intent of further understanding, the objective set was to analyze the influence of ENSO on chilling hours in Rio Grande do Sul State. To perform the analysis it was used data of air temperature - below 7.2 ºC - from 24 meteorological stations. The results showed that when La Niña occurs, the percentage of chilling hours was above average for the period analyzed in all locations, and when El Niño occurs, the values were below average in 79% of the locations. The highest number of chilling hours, observed in each location, mainly occurred during the presence of La Niña and the lowest number was mainly observed during the occurrence of El Niño. The largest deviation (%) of chilling hours from the average occurred in May. Despite the month of July having the highest number of chilling hours, the occurrence of El Niño or La Niña does not show any difference between them. The month of September also shows no difference when comparing instances of El Niño and La Niña.
Key words: el niño, la niña, temperature, cold, climate fruit trees.

El Niño Oscilação Sul e o acúmulo de horas de frio para a superação da dormência em fruteiras de clima temperado no sul do Brasil

RESUMO: O número de horas de frio é responsável pela maximização da brotação e floração em fruteiras de clima temperado, e esse número varia muito entre os anos. Uma importante fonte de variabilidade é a ocorrência do ENOS - El Niño Oscilação Sul. Com intuito de um melhor entendimento, objetivou-se analisar a influência do fenômeno El Niño Oscilação Sul, sobre o acúmulo de horas de frio no estado do Rio Grande do Sul. Para isso, utilizou-se dados de temperatura do ar, abaixo de 7,2 ºC, de 24 estações meteorológicas. Os resultados mostraram que, quando da ocorrência de La Niña, o percentual de horas de frio foi superior à média em todas as localidades e durante o El Niño os valores ficaram abaixo da média em 79% das localidades. O maior número de horas de frio, observado em cada localidade ocorreu, predominantemente, durante a La Niña e, o menor número foi observado, predominantemente, durante a ocorrência de El Niño. O maior desvio (%) de horas de frio em relação à média ocorreu no mês de maio. Apesar do mês de julho ter o maior número de horas de frio, a ocorrência do El Niño ou La Niña não apresenta diferença entre si. O mês de setembro também não apresenta diferença na comparação entre os eventos de El Niño e La Niña.
Palavras-chave: el niño, la niña, temperatura, frio, fruteiras de clima temperado.

INTRODUCTION

Endodormancy is interrupted when deciduous plants are exposed to low temperatures for a certain period. For this, plants must be exposed to low temperatures during a period of time that is variable between genotypes (CAMPOY et al., 2011; LUEDELING et al., 2013; RUIZ et al., 2018), since the lack of cold can cause uneven sprouting, prolong anthesis and reduce the quality and quantity of fruits (ATKINSON et al., 2013; JONES et al., 2013). Overcoming this phase is important for the formation of a balanced plant with well-distributed structural and fruit-bearing branches, which allows the development of its maximum productive potential (CARVALHO et al., 2010). According to PIO et al. (2018) there is also production of temperate fruit trees in the subtropical and tropical regions, which is a great challenge due to the low cold conditions of this climate.

The Rio Grande do Sul State is an important producer of temperate fruits. The productivity of this temperate fruits is dependent on the number of chilling hours that occurs during the dormancy period, and this number varies widely between years. An important cause of this variability is the occurrence of the El Niño Southern Oscillation (ENSO) phenomenon (ANDERSON et al., 2018; KAYANO et al., 2019), which has a warm phase called El Niño and a cold phase called La Niña. The

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understanding of the influence of this phenomenon on the minimum temperature, and its consequent impact on overcoming the dormancy of temperate fruits, deserves to be analyzed, seeing as the information about this relationship are still incipient.

With the increased understanding and predictability of ENSO, there is also a greater awareness of the impacts and opportunities for the use of this information. According to CHAPMAN et al. (2021) ENSO-related climate predictions will benefit the agricultural sector, allowing farmers to reduce the negative impacts of climate variability and/or to capitalize on potentially beneficial effects.

The objective of this research was to verify if there is a variation in the number of chilling hours during the occurrence of ENSO events, in both phases, in different places in Rio Grande do Sul State, Brazil.

MATERIALS AND METHODS

The meteorological stations used to develop this research covered Rio Grande do Sul State, Brazil and are shown in figure 1. The predominant climate in the most part of Rio Grande do Sul is classified as Cfa, and Cfb in the higher altitude regions, according to the Köppen climate classification. Hourly data from twenty-four Automatic Meteorological Stations of the National Institute of Meteorology (INMET) were used. The locations chosen were those that contained information on at least three years of data on each of the ENSO phases.

To calculate the number of chilling hours (CH), the total number of hours in which the air temperature was below 7.2 °C, calculated by the Eq.1, were considered:

$$HF_t = \sum_{i=t}^{t} T_{7,2} \quad (1)$$

Considering $T_{7,2} = \begin{cases} T < 7{,}2\,^{o}C = 1 \\ T > 7{,}2\,^{o}C = 0 \end{cases}$

In the equation, CH is the number of chilling hours, T is the hourly air temperature (°C).

The calculation of chilling hours was performed for each day, then the monthly calculation was carried out, and the accumulation during the months of May to September of each year, in each location. The indication of the occurrence of ENSO phases was based on the Oceanic Niño Index (ONI) data, obtained from NOAA - National Oceanic and Atmospheric Administration (NOAA, 2021). Statistical analysis was performed with the help of the SISVAR program, the Tukey's test being used at 5% probability, making comparisons of the accumulated values of chilling hours from May to September and also within each month, on the presence of El Niño, La Niña and during the period of neutrality.

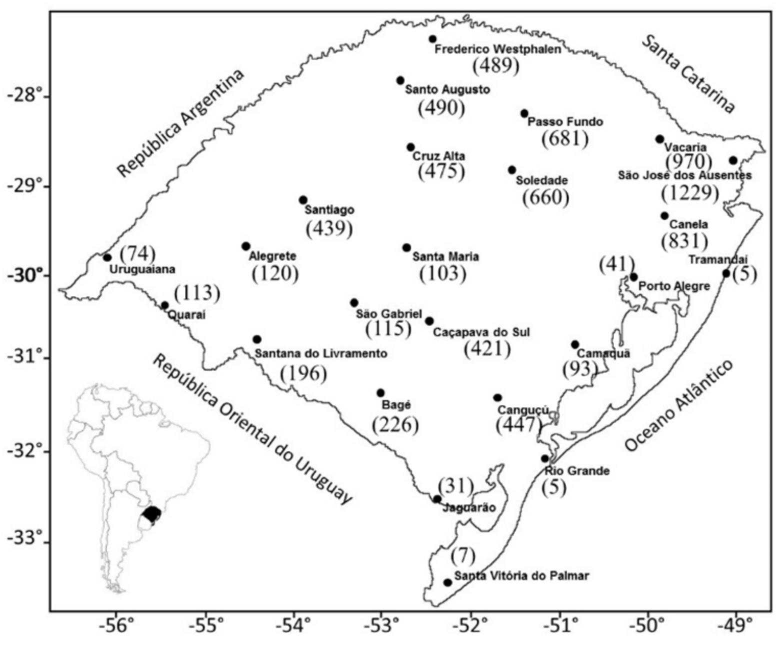

Figure 1 - Location of the meteorological stations and its altitudes (m).

RESULTS AND DISCUSSION

The number of chilling hours during the events of La Niña, El Niño and the Neutral years are presented in figure 2. Of the twenty-four locations analyzed, in twenty-three the number of chilling hours is higher when the La Niña phase occurs. Only in Santa Vitória do Palmar the highest chilling hours occurs in the presence of El Niño phase. However, statistically, this difference appears only in two of the meteorological stations: Vacaria and São José dos Ausentes. This may possibly be due to the great variability in chilling hours between the years studied. This observation was also obtained by CARDOSO et

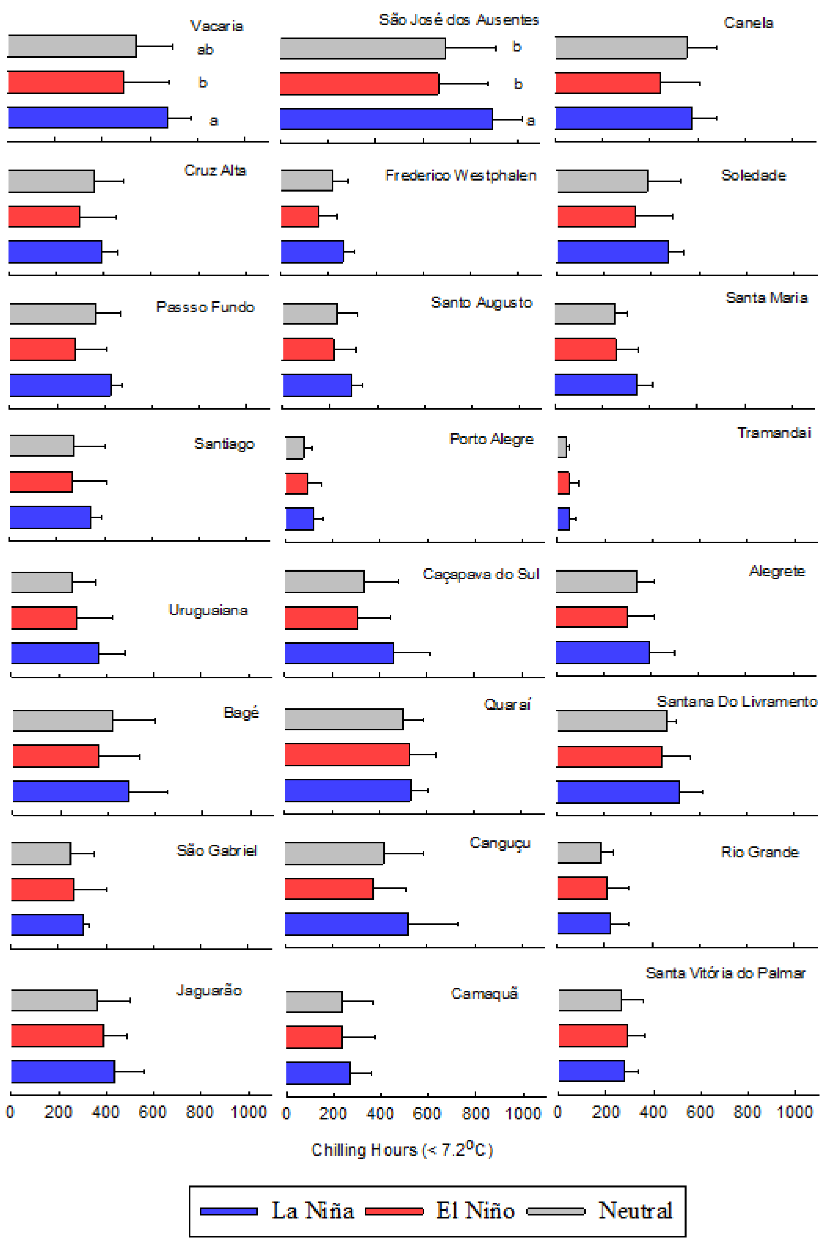

Figure 2 - Number of chilling hours (CH) lower than 7.2 ºC, from May to September, during La Niña (blue), El Niño (red) and Neutral (grey), at the meteorological stations. Different letters on the columns indicate significant differences (P < 0.05) between different events in the same location.

al. (2015), who observed high variability in the cold units, using different estimation methods, between different years for the city of Vacaria, RS.

RUSTICUCCI (2012) and RUSTICUCCI et al. (2017) observed that during the months with the presence of La Niña, cold waves, that are the persistency of cold days in a row, are more frequent in Argentina, and warm periods are more intense and persistent in the winter season during El Niño phase. In the winter months, cooling conditions are favored in the La Niña phase, with more frequent cold nights and days (FIRPO et al., 2012; RUSTICUCCI et al., 2017).

Figure 2 shows that the sum of chilling hours differs when comparing different locations. These different values are due to the diversity of climatic factors such as: altitude, latitude, continentality and oceanity. At higher altitudes, there are more accounts of lower temperatures, that provide more chilling hours, while the inverse is observed at lower altitudes. In the cities of the Serra region, located at higher altitudes, a greater number of CH is observed. The meteorological station of São José dos Ausentes, that has an altitude of 1228 m, has the highest number of CH, followed by Vacaria (969 m). Quaraí (113 m) and Santana do Livramento (196 m) (Figure 1), despite being located at low altitudes, also have a high number of CH (Figure 2). These meteorological stations are located at the Campanha region, that of which, according to FIRPO et al. (2012), is the main entry route of cold fronts, causing a drop in temperature soon after their incursion; therefore, they have a high number of CH. The meteorological station of Uruguaiana, conversely, has less chance of occurrence of winds that cause sudden drops in temperature, even though it is also in the Campanha region, and the conditions for keeping the cold are less favorable. It is considered a hotter and drier region.

The meteorological stations of Santa Vitória do Palmar and Rio Grande, despite having higher latitudes (Figure 1) when compared to the other stations, are located in a coastal region that is more humid and thermally stable, which makes the number of chilling hours slightly above 200 h but the difference between ENSO events low.

Figure 3 shows the percentage deviation of the number of CH in each meteorological stations, compared with the average of all the years analyzed. Whenever La Niña phase occurred, there was always a positive deviation in the number of CH in 100% of the locations. Whenever El Niño occurred, nineteen of the twenty-four meteorological stations showed negative deviation (Figure 3). The four meteorological stations that showed positive CH deviation when El Niño occurred were Tramandaí, Santa Vitória do Palmar, Rio Grande and Quaraí; Porto Alegre does not show any deviation.

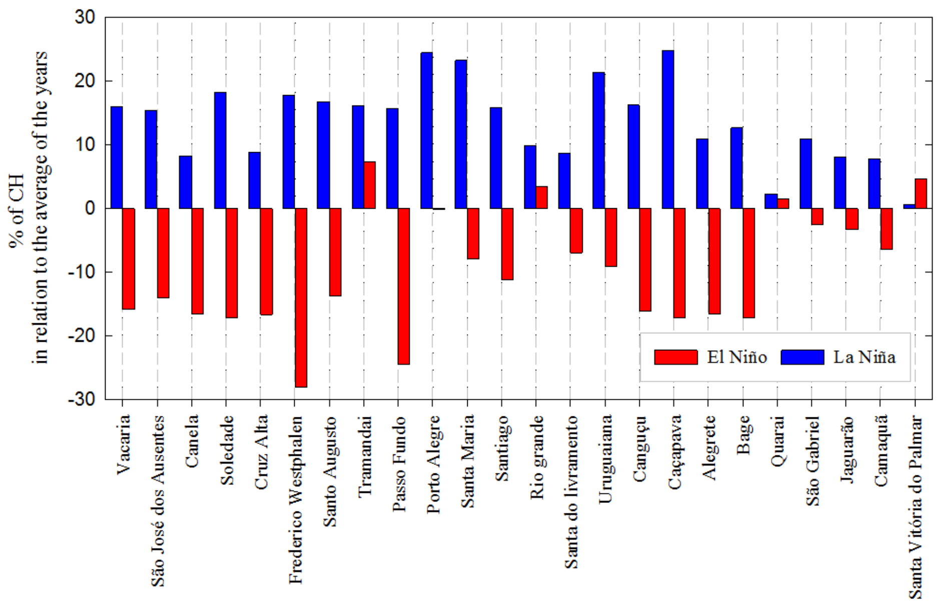

Figure 3 - Chilling hours (CH) deviations in each meteorological station.

Another important observation is that, when comparing the deviations in the cities of Frederico Westphalen, Caçapava do Sul, and Passo Fundo, the number of CH is higher than 40% when La Niña occurs when compared to the number of CH during El Niño. This indicates that El Niño or La Niña events interfere significantly in the number of CH in these locations.

From the results of figure 2, it is observed that most meteorological stations analyzed do not have a very high number of CH. This need varies in different species of temperate fruit according to PETRI et al. (2021): the apple tree from 200 to 1000 CH; the pear tree from 300 to 800 CH; the peach tree from 150 to 800 CH and the plum and kiwi tree from 300 to 1000 CH. Also CARDOSO et al. (2015) observed that even in Vacaria, which is located in one of the coldest regions of the State, it does not meet the cold needs of the main apple cultivars used in the region, requiring the use of chemical products to stimulate the overcoming of dormancy.

Figure 4 shows the maximum and minimum values of CH found, in each location, and the indication of the occurrence of La Niña, El Niño, and neutral. It is observed that the highest value was in São José dos Ausentes (1043 CH), followed by Canguçu (857 CH) and so on, continuing clockwise. Three cities presented maximum values between 700 and 800 CH, which in descending sequence are: Vacaria, Bagé, and Canela; four between 600 and 700, being Santana do Livramento, Caçapava do Sul, Jaguarão, and Quaraí. Four between 500 and 600 CH: Alegrete, Uruguaiana, Soledade, and Cruz Alta. Four between 400 and 500 CH: Passo Fundo, Santiago, Santa Maria, and Camaquã. Five between 300 to 400 CH: São Gabriel, Santa Vitória do Palmar, Santo Augusto, Frederico Westphalen, and Rio Grande. Porto Alegre below 200 and Tramandaí below 100.

It is important to highlight that in eighteen meteorological stations the highest values were present during the occurrence of the La Niña event, in four during the neutral period, and in two during the presence of El Niño. In fourteen locations, the lowest value was during the occurrence of El Niño, and in ten during years with neutrality (Figure 4).

Performing the monthly analysis, it was observed that May has the lowest CH, with values similar to the month of September (Figure 5), but, on the other hand, is the month with the highest percentage difference between the events (Table 1).

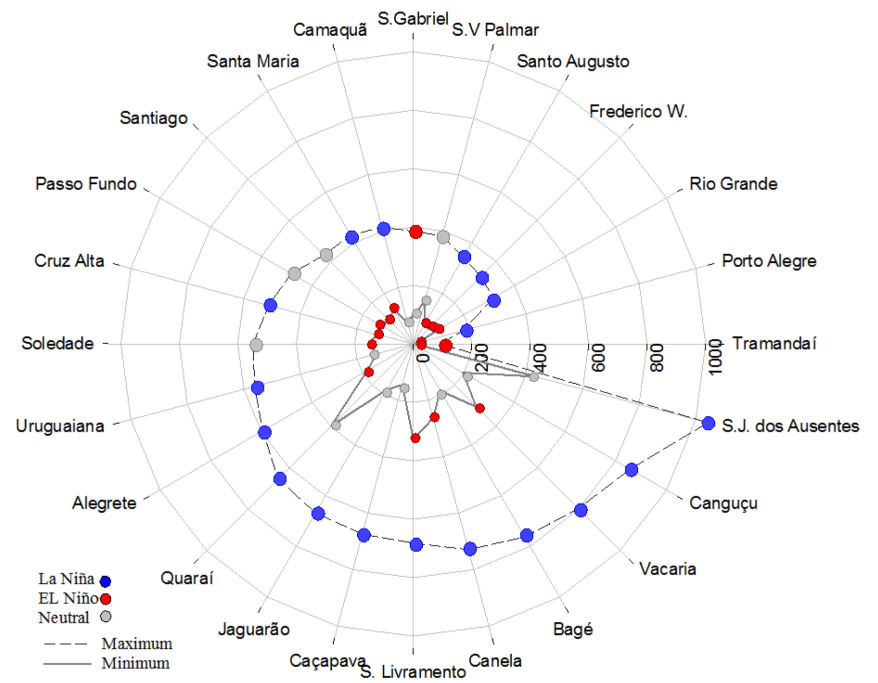

Figure 4 - Maximum and minimum values in each meteorological station and the indication when they occur (La Niña (blue), El Niño (red) and neutral (grey)).

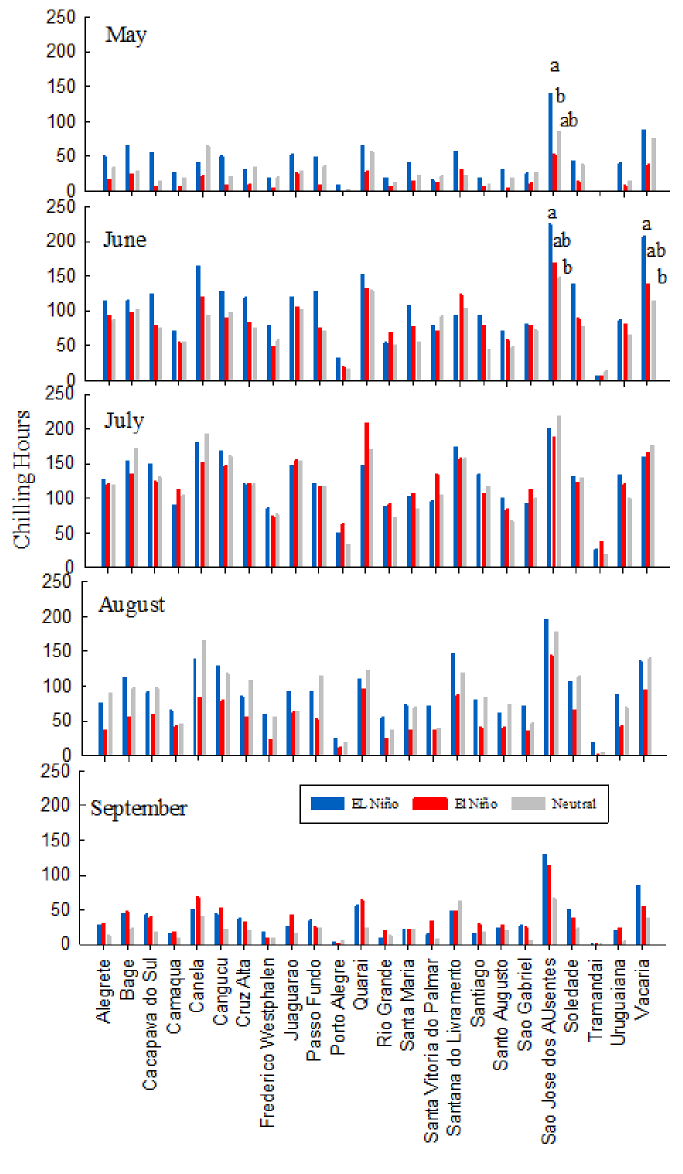

Figure 5 - Number of hours of cold in the 24 analyzed locations, from May to September, during El Niño, La Niña and Neutral years events. Different letters on the columns indicate significant differences ($P < 0.05$) between different events in the same location.

When La Niña occurred, the CH was 52% higher than the average of the analyzed period. When El Niño occurred, the CH was 53% below the average. The months of June and August showed an increase of 20 and 21% during La Niña and a decrease of 5 and 31% when there is El Niño, respectively. An important observation is that in the month of July there was no significant variation of deviation in relation to the average, and with that it can be inferred that this month does not suffer variations in the number of CH due to the events that are occurring.

CONCLUSION

The number of chilling hours was higher in La Niña events compared to El Niño and during La Niña, the percentage of chilling hours was higher than the average in 100% of the locations and when El Niño

Table 1 - Deviation (%) of chilling hours (CH), during El Niño and La Niña phases, on analyzed months.

	-----------------Deviation (%)--------------------				
ENSO* phase	May	June	July	August	September
La Niña	52	20	2	21	11
El Niño	-53	-5	1	-31	17

* El Niño Southern Oscillation.

was present, the chilling hours was below the average by 79%. The maximum values of chilling hours occurred in eighteen locations during the presence of La Niña, in four during the period of neutrality, and in two during the El Niño. The minimum values of chilling hours were observed during the El Niño occurrence in fourteen locations, and in ten during neutrality years.

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DECLARATION OF CONFLICT OF INTEREST

The authors declare no conflict of interest. The founding sponsors had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript, and in the decision to publish the results.

AUTHORS' CONTRIBUTIONS

Conceptualization: BR. Data acquisition: BR, BPC and RWM. Design of methodology and data analysis: BR, BPC and RWM. BR prepared the draft of the manuscript. All authors critically revised the manuscript and approved of the final version.

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