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Regional Weather Variations and Yields Achieved in Soybean Crops

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Abstract

Monitoring weather conditions during soybean cultivation is essential in agricultural planning. The variation of these conditions, such as temperature, precipitation, relative humidity and soil moisture directly influence the productive performance of crop.With this, the objective of the work was to verify the effects of weather conditions on the soybean yield, carrying out the survey of the minimum, maximum and average temperature and the total precipitation during the cultivation of the soybean and collecting the data of productivity reached in the agricultural harvests of 2017/2018, 2018/2019 and 2019/2020 of soybeans in a commercial area with 15.5 ha, located in the Céu Azul City, Paraná State, Brazil. Regarding the results for the three soybean harvests, the air temperature remained adequate for the development of the crop in most of the cycle. And the values observed for precipitation indicated the occurrence of well-distributed rainfall in the 2019/2020 harvest, and in the 2017/2018 harvest there was irregular rainfall distribution, however there were no periods without precipitation. However, the large precipitation deficit occurred in the 2018/2019 harvest, where the lack of rain occurred in 28 days, between 12/03/2018 and 12/30/2018, indicating a drought in this period. The soybean yield obtained in the area in the 2019/2020 harvest was 3.727 t ha^{-1}, higher than the other two soybean harvests, being that 2018/2019 harvest reaching the lowest value, 2.394 t ha^{-1}, indicating the influence of the weather in the soyben yield achieved.

Keywords: weather conditions, soybean yield, soil moisture, temperature

1. Introduction

Agricultural crops still encounter obstacles to achieving high yields due to weather variations. Being that the weather is the main determining factor of yield in agricultural crops (Carmelo, 2018). According to Kurukulasuriya and Rosenthal (2013), agriculture is the sector most vulnerable to climate impacts. Thus, monitoring the main weather parameters is of fundamental importance to measure the impact of weather on agricultural crops.

The weather is extremely important, as it provides support and conditions for the growth and development of plants. Being that the changes in weather system patterns influence agricultural yields, including annual and subannual changes in temperature and precipitation (Snyder, Waldhoff, Ollenberger, & Zhang, 2021). Precipitation associated with water deficit is the main limiting factor for soybean yield in Brazil, but other atmospheric variables, such as air temperature, photoperiod and solar radiation, can both intensify and attenuate the effects of water deficit on soybean yield (Sentelhas et al., 2015).

The soybean crop is able to tolerate, in some cases, water deficit in short periods, but it can present a significant reduction in productivity in long periods without rain. Being that, the drop in performance resulting from the water deficit is of great importance, since the development of the crop is significantly affected by low precipitation and poorly distributed rainfall (Anda, Soós, Menyhárt, Kucserka, & Simon 2020). And, soybeans are more sensitive to water deficit in the reproductive stage (Montoya, García, Pintos, & Otero, 2017).

Ferrari, Paz, and Silva (2013) also report that excessive rainfall can lead to a reduction in soybean yield due to the decrease in leaf water potential and, consequently, stomatal closure, impairing photosynthesis, reducing soil aeration, development roots and nitrogen fixation in the soil.

Soybean cultivation studies indicate changes in yield due to weather variations (Nóia Junior, Fraisse, Karrei, Cerbaro, & Perondi, 2020), temperature (Ferreira & Rao, 2011); and precipitation (Farias, 2007; Bottega, Pinto, Queiroz, & Santos, 2013).

In this work, the objective was to verify the effects of weather conditions on the soybean yield achieved in the 2017/2018, 2018/2019 and 2019/2020 harvests in a commercial area in the Céu Azul City in the western region of the Paraná State.

2. Materials and Methods

2.1 Characteristics os Area, Climate and Soil

The experiment was carried out in three agricultural harvests 2017/2018, 2018/2019 and 2019/2020 in soybean cultivation in area located in the Céu Azul City, Paraná State, Brazil.

The area has approximately 15.5 ha and its central geographic location has approximate geographic coordinates of 25°06′32″S and 53°49′55″W. The local climate is classified as Cfa according to the Köppen classification. It is a humid climate, without a dry season and hot in the summer (Aparecido, Rolim, Richetti, Souza, & Johann, 2016). The average annual temperature in the Ceu Azul City is 18.5 °C and the average annual precipitation is 1890 mm.

The soil of the experimental area has a clayey texture and is classified as typical Dystrophic Red Latosol (LVd) in the Brazilian Soil Classification System (Solos, 2013). The delimitation of the experimental area was carried out with GPS and for the composition of the sampling grid, 40 sampling points were used. At the sampling points, attributes related to altitude, slope, chemical and physical attributes (soil resistance to penetration, total porosity) were determined.

Figure 1 represents the location of the experimental area.

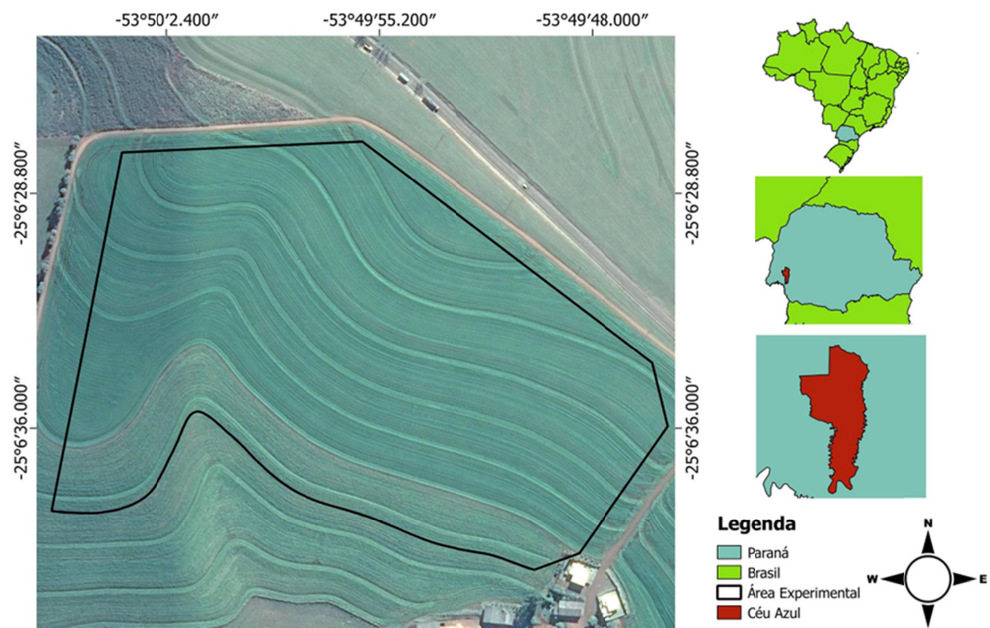

Figure 1. Representation of the experimental area and location coordinates

2.2 Monitoring of Weather Conditions

For the monitoring of weather conditions, in the work were used data provided by the System of Technology and Environmental Monitoring of Paraná (SIMEPAR) from the climatological station located in Cascavel City, City close to the experimental area.

The work used the climatological data contained in the periods with soybean cultivation in the experimental area in the 2017/2018, 2018/2019 and 2019/2020 harvests. The data used were: precipitation and minimum, maximum and average air temperatures.

In order to identify the weather parameters that may affect productivity and that are unsuitable for soybean cultivation, climatological data were grouped in periods of fourteen days, within each harvest, obtaining the minimum, maximum and average temperatures reached and precipitation total.

2.3 Planting, Harvesting and Yield

In soybean planting in the agricultural years 2017/2018, 2018/2019 and 2019/2020, the soybean cultivar used was Syngenta 1359, soybean cultivar super early cycle, and spacing between rows of 0.70 m was used to facilitate the traffic of machines, as the harvester and sprayer are adjusted for this spacing.

Harvesting was performed with a harvester equipped with GPS and a harvest monitor with a sensor attached to the top of the grain elevator. In the work, yield data were collected for the three soybean harvests and later relating the yield achieved with the weather data obtained. Thus, weather conditions, precipitation and minimum, maximum and average air temperatures during the seedling cultivation period were recorded, aiming to identify improper conditions for cultivation associated with deficits in the yields achieved.

2.4 Statistical Analysis

Statistical analysis was performed using a completely randomized design (CRD), with treatments represented by soybean yields and harvest monitor measurements considered as replicates. Tukey's test, at a 5% probability level, was used to compare the yields achieved in the harvests.

3. Results and Discussion

3.1 Analysis of Soil Chemical Attributes

The analyzes of the chemical attributes of the soil were carried out in 2017 and 2019 according to Table 1, following the history of soil management in the area and the criterion of the producer, there was no need for chemical analysis of the soil in 2018, as the producer adopts carrying out chemical analyzes of the soil at intervals of 2 years.

Table 1. The results of the analysis of soil chemical attributes

	Chemical attributes								
Year	Ca	Mg	K	Al	H+Al	CTC	P	V	pH
	------------------------------ cmolc/dm³ ------------------------------						mg/dm³	%	
2017	7.725	2.629	0.549	0.009	5.291	16.194	22.044	67.190	5.930
2019	6.104	2.601	0.611	0	3.971	12.961	27.722	69.911	5.501

The results presented for Ca, Mg, P, K, pH in the 2017 and 2019 in soil chemical analyzes are included in the very high interpretation class; and, CTC, V as high in the interpretation table of soil chemical parameters for the Paraná State by the authors Pauletti and Motta (2019), thus being considered suitable for soybean cultivation. The Al element was the only that presented a low amount in the years 2017 and 2019, but it is not an element considered essential in soybean cultivation.

However, due to the high demand for nutrients N, P and K in soybean cultivation, mineral fertilizer NPK 8-40-00 was used for fertilization, being applied throughout the area in the amount of 125 kg ha^{-1} made directly with the planting in the three soybean agricultural years.

3.2 Weather Data

The weather data collected during the 2017/2018, 2018/2019 and 2019/2020 soybean crops: precipitation, minimum, maximum and average temperatures, are represented in intervals of fourteen days in Table 2.

Table 2. Precipitation and temperature data for the 2017/2018, 2018/2019 and 2019/2020 soybean crops

Precipitation and temperature data from the climatological station located in Cascavel City					
Soybean Crop	Period	Precipitation (mm)	Minimum T (°C)	Maximum T (°C)	Average T (°C)
2017/2018	11/01-11/14/2017	149.00	11.90	31.00	20.85
	11/15-11/28/2017	173.00	12.70	34.10	21.63
	11/29-12/12/2017	11.00	16.10	33.20	23.39
	12/13-12/26/2017	262.00	17.20	33.50	23.58
	12/27-01/09/2018	186.20	16.00	30.80	22.23
	01/10-01/23/2018	256.80	17.60	29.50	22.80
	01/24-02/06/2018	17.40	16.00	32.40	24.09
	02/07-02/20/2018	389.00	15.20	32.50	22.78
	02/21-02/23/2018	0.60	13.80	31.50	22.42
2018/2019	11/05-11/18/2018	29.60	14.60	33.30	23.28
	11/19-12/02/2018	56.40	14.60	29.30	21.78
	12/03-12/16/2018	13.20	11.80	33.10	23.00
	12/17-12/30/2018	10.20	17.90	32.70	24.68
	12/31-01/13/2019	75.60	17.70	34.90	25.02
	01/14-01/27/2019	46.00	16.70	34.70	25.06
	01/28-02/10/2019	57.20	16.20	36.30	25.04
	02/11-02/24/2019	47.60	16.20	32.70	23.26
	02/25-03/05/2019	34.00	15.20	33.10	23.38
2019/2020	10/27-11/09/2019	128.60	16.20	36.30	24.44
	11/10-11/23/2019	52.20	15.10	34.10	24.08
	11/24-12/07/2019	78.00	12.30	32.10	21.99
	12/08-12/21/2019	207.20	15.70	32.40	21.72
	12/22-01/04/2020	7.60	13.80	34.00	24.17
	01/05-01/18/2020	114.20	17.00	32.10	24.18
	01/19-02/01/2020	41.40	15.70	32.40	23.19
	02/02-02/15/2020	70.80	15.50	33.30	24.09
	02/16-02/25/2020	50.00	12.10	34.60	24.85

Note. T: Temperature.

The averages of the fourteen-day temperature intervals over the entire period of the 2017/2018, 2018/2019 and 2019/2020 crops remained between 20 °C and 30 °C, with the minimum temperatures being above 10 °C and the maximum temperatures that occurred in the crops were below 40 °C, remaining according to MAPA (2017) within the appropriate conditions for soybean cultivation, results that indicate that temperature was not a determining factor for the variation in soybean productivity. In agreement with this result, in the Roncador and Boa Esperança Cities, in the Paraná State, in Brazil, during the soybean crops of 2008/2009, 2009/2010 and 2010/2011, temperatures remained between 20 °C and 30 °C, not compromising the final productivity achieved (Oliveira, Silva, & Yokoo, 2019).

Regarding precipitation in the 2017/2018 soybean crop, there was excessive precipitation and irregular rainfall distribution, but without periods with no precipitation. In turn, in the 2018/2019 cultivation, the averages of the fourteen-day intervals also indicate a large variation in the amount of rainfall, including the presence of drought in the period between December 3, 2018 and December 30, 2018. In line with this result, in the 2011/2012 crop year there was a deficit of precipitation, in relation to that recommended for the soybean cycle, with the occurrence of the “La Niña” phenomenon, causing a reduction in soybean yield of 44, 29 and 10% respectively, in the states of Rio Grande do Sul, Paraná and Mato Grosso do Sul (CONAB, 2013).

On the other hand, during the 2018/2019 soybean crop, there was a better distribution of precipitation, with rain occurring in all periods in the soybean cycle. Result obtained that is in agreement with the results of Carmelo (2018) in soybean planting in southern Brazil. Since, Farias (2011) express that the water availability during the growing season constitutes the main limitation to reach the yield potential of soybeans and the main cause of variability of grain yields observed from one year to another.

The total precipitation during the soybean cycle in the 2017/2018 and 2018/2019 crops respectively reached the values of 1445.0 mm $cycle^{-1}$ mm and 369.8 mm $cycle^{-1}$, results that are outside the range considered ideal according to Lourenço (2020), which indicates that during its cycle the soybean plant needs a total of water that varies between 450 to 800 mm $cycle^{-1}$. In contrast, in the 2019/2020 soybean crop, precipitation reached a value of 750 mm $cycle^{-1}$, in line with the work of Schenatto (2014) and Camicia (2018) who, like this work, obtained results greater than 450 mm $cycle^{-1}$ and less than 800mm $cycle^{-1}$ of the precipitation for the same area in soybean crops in 2012/2013 and 2015/2016, respectively.

With this, it is observed that the adequate precipitation level occurred in the 2019/2020 soybean crop, favoring the performance of soybean plants. And, in contrast, there was a deficit in the amount of rainfall in the 2018/2019 crop, which is outside the recommended range, so it is considered that the water available for soybeans during its cycle may have limited plant development in the 2018/2019 soybean crop, because according to Anda, Soós, Menyhárt, Kucserka, and Simon (2020), water deficiency during soybean cultivation is the most important environmental variable that contributes to the reduction of soybean yield.

On the other hand, there was excess precipitation in soybean cultivation in 2017/2018, which is outside the ideal precipitation limits for soybean cultivation recommended by Lourenço (2020), which may have caused a decrease in the final productivity achieved.

3.3 Soybean Yield

The soybean yield obtained in the experimental area in the 2017/2018, 2018/2019 and 2019/2020 crops were, respectively, 2.984 t ha^{-1}; 2,394 t ha^{-1}; and, 3,727 t ha^{-1}.

Figure 2 shows the comparison of yields achieved in the three crops analyzed in the experimental area.

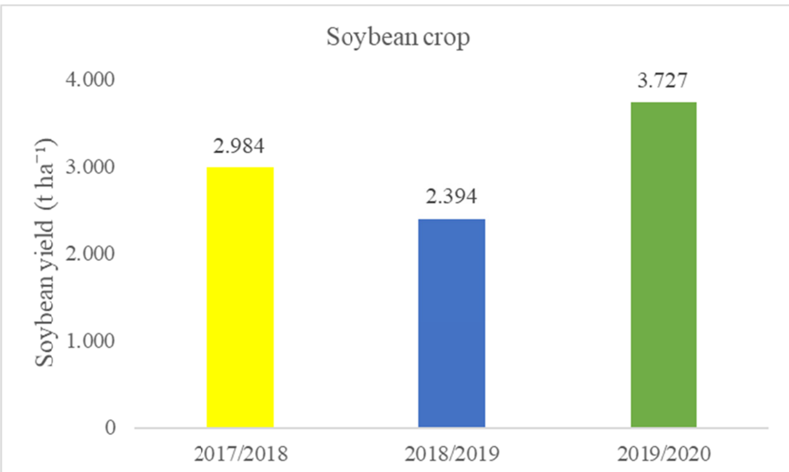

Figure 2. Productivity achieved in the experimental area in soybean crop

It can be seen in Figure 2 that in the 2019/2020 soybean crop, productivity was 55.68% higher than in 2018/2019; and, 24.9% higher than 2017/2018, and the higher productivity result achieved is in line with Radin, Schonhofer and Tazzo (2017) who also obtained higher productivity in soybean cultivation with adequate amount and distribution of precipitation and non-occurrence of drought during the soybean cycle.

Regarding the statistical analysis, performing the Tukey test to compare the average yields of soybean crops, it was observed that there was a significant difference in the yields of the three crops, with the productivity of each crop divergent in relation to the other two yields.

Thus, with the yield data analyzed in Figure 2, it was observed that the deficit or excess of precipitation was a determining factor for the variation in yield.

Comparing the 2019/2020 crop: in the 2018/2019 crop there was a decrease of 380.2 mm of precipitation during the soybean cycle, compromising 1.333 t of production; and in 2017/2018 there was an excess of 695 mm of precipitation during the soybean cycle, reducing the final production achieved by 0.743 t.

4. Conclusions

Keeping the temperature within limits considered ideal for the development and production of soybeans has no influence on the variation in soybean yield.

On a regional scale, in an area without irrigation technology, where a monoculture agricultural environment predominates, a microclimate can be generated that is directly dependent on the variability and amount of rainfall in the soybean cycle.

The deficit or excess in precipitation and the incidence of poorly distributed rainfall during the soybean cycle influence the development of the crop, generating negative results in soybean yield.

The occurrence of drought during soybean cultivation can lead to a deficit of available water for soybean plants, influencing their development and, consequently, influencing the final yield achieved by the crop.

Precipitation in excess of the recommended amount during the soybean cycle causes excess water and reduced aeration in the soil, causing, as a consequence, a decrease in soybean yield.

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References

Anda, A., Soós, G., Menyhárt, L., Kucserka, T., & Simon, B. (2020). Yield features of two soybean varieties under different water supplies and field conditions. *Field Crops Research, 245*. https://doi.org/10.1016/j.fcr.2019.107673

Aparecido, L. E. de O., Rolim, G. D. S., Richetti, J., Souza, P. S., & Johann, J. A. (2016). Köppen, Thornthwaite and Camargo climate classifications for climatic zoning in the State of Paraná, Brazil. *Ciência e Agrotecnologia, 40*(4), 405-417. https://doi.org/10.1590/1413-70542016404003916

Bottega, E. L., Pinto, F., Queiroz, D. M., & Santos, N. T. (2013). Variabilidade espacial e temporal da produtividade de soja no Cerrado brasileiro. *Revista Agrarian, 6*, 167-177. http://doi.org/10.30612/agrarian.v6i20.1503

Camicia, R. G. da M. (2018). *Seleção de variaveis para geração de zonas de manejo e diferentes densidades de semeadura de soja* (Tese de Doutorado em Engenharia Agrícola, Universidade Estadual do Oeste do Paraná, Cascavel/PR, Brazil).

Carmelo, V. (2018). *Variabilidade pluviométrica e produção de soja: Análise comparativa entre regiões produtoras do Brasil, Estados Unidos e Índia* (Tese de Doutorado em Geografia, Universidade Estadual Paulista, Presidente Prudente/SP, Brazil). Retrieved from file:///C:/Users/55459/Downloads/carmello_v_dr_prud%20(2).pdf

CONAB (Companhia Nacional de Abastecimento). (2013). *Acompanhamento da safra brasileira: Grãos, oitavo levantamento da safra de grãos 2011/2012*. Brasília: Safra 2011/12, CONAB.

Farias, J. R. B. (2011). *Limitações climáticas-obtenção de rendimentos máximos de soja*. Rosário: V Congresso da Soja do Mercosul.

Farias, J. R. B., Nepomuceno, A. E., & Neumaier, N. (2007). *Ecofisiologia da soja* (Circular Técnica 48). Londrina, PR: Embrapa Soja.

Ferrari, E., Paz, A., & Silva, A. C. (2015). Water deficit on the soybean metabolismo in early sowings. *Nativa, 3*(1), 67-77. http://doi.org/10.14583/2318-7670.v03n01a12

Ferreira, D. B., & Rao, V. B. (2011). Recent climate variability and its impacts on yields in Southern Brazil. *Theoretical and Applied Climatology, 105*, 83-97. http://doi.org/10.1007/s00704-010-0358-8

Kurukulasuriya, P., & Rosenthal, S. (2003). Climate change and agriculture: a review of impacts and adaptations. The World Bank Environment Department. Retrieved from http://hdl.handle.net/10986/16616

Lourenço, L. F. (2020). *O efeito da deficiência hídrica em plantas de soja* (Tese de Doutorado em Ciências, Universidade de São Paulo, Brazil). https://doi.org/10.11606/T.11.2020.tde-02102020-154804

MAPA (Ministério da Agricultura, Pecuária e Abastecimento). (2017). Portaria Nº 16, de 20 de julho de 2017. *Aprova o ZARC para o Estado do Paraná*. Brasília, Diário Oficial da União de 21 de Julho de 2017.

Montoya, F., García, C., Pintos, F., & Otero, A. (2017). Effects of irrigation regime on the growth and yield of irrigated soybean in temperate humid climatic conditions. *Agricultural Water Management, 193*, 30-45. https://doi.org/10.1016/j.agwat.2017.08.001

Nóia Junior, R. D. S., Fraisse, C. W., Karrei, M A. Z., Cerbaro, V. A., & Perondi, D. (2020). Effects of the El Niño Southern Oscillation phenomenon and sowing dates on soybean yield and on the occurrence of extreme weather events in southern Brazil. *Agricultural and Forest Meteorology, 290*, 108038. https://doi.org/10.1016/j.agrformet.2020.108038

Oliveira, R. de R., Silva, R. V., & okoo, S. C. (2019). *A influência climática na cultura da soja nos municípios de Roncador e Boa Esperança-PR, dos anos de 2008 a 2017*. XI EPCC Encontro Internacional de Produção Cientifica.

Pauletti, V., & Motta, A. C. V. (2019). *Manual de adubação e calagem para o estado do Paraná* (2nd ed.). Curitiba, PR: Núcleo Estadual Paraná da Sociedade Brasileira de Ciência do Solo-NEPAR-SBCS.

Radin, B., Schonhofer, A., & Tazzo, F. (2017). Impacto da quantidade e frequência de chuva no rendimento da soja. *Agrometeoros, 25*(1), 19-26. http://doi.org/10.31062/agrom.v25i1.26263

Schenatto, K. (2014). *Utilização de métodos de interpolação e agrupamento para definição de unidades de manejo em agricultura de precisão* (Dissertação de Mestrado em Engenharia Agrícola, Universidade Estadual do Oeste do Paraná, Cascavel/PR, Brazil). Retrieved from https://tede.unioeste.br/handle/tede/2637

Sentelhas, P. C., Battisti, R., Câmara, G. M. S., Farias, J. R. B., Hampf, A., & Nendel, C. (2015). The soybean yield gap in Brazil—Magnitude, causes and possible solutions for a sustainable production. *Journal of Agricultural Science, 153*, 1394-1411, https://doi.org/10.1017/S0021859615000313

Snyder, A., Waldhoff, S., Ollenberger, M., & Zhang, Y. (2021). Empirical estimation of weather-driven yield shocks using biophysical characteristics for U.S. rainfed and irrigated maize, soybeans, and winter wheat. *Environmental Research Letters, 16*(9), http://doi.org/10.1088/1748-9326/ac15ce

Solos, E. (2013). *Sistema brasileiro de classificação de solos*. Centro Nacional de Pesquisa de Solos: Rio de Janeiro.