ISSN 1808-8546 (ONLINE) 1808-3765 (CD-ROM)

PRODUTIVIDADE DA SOJA EM FUNÇÃO DA ÉPOCA DA SEMEADURA E DA IRRIGAÇÃO SUPLEMENTAR NA REGIÃO CENTRAL DO RS

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1 RESUMO

O presente estudo tem como objetivo avaliar a produtividade da soja em função da época de semeadura e da irrigação suplementar para as condições edafoclimáticas da região central do RS. O experimento de campo foi instalado na Estação Agronômica da Uergs em Cachoeira do Sul-RS. O delineamento experimental foi o de blocos ao acaso com parcelas subdivididas, no esquema fatorial (4x2). O fator “A” constituiu de quatro épocas de semeadura da soja: 23/10/19 (Época 1), 19/11/19 (Época 2), 19 /12/ 19 (Época 3), 16/1/20 (Época 4). O fator “D” constitui de dois regimes hídricos: irrigado e não irrigado (sequeiro). A cultivar utilizada foi a BMX Garra. A produtividade da soja irrigada foi superior a 4200 kg ha^{-1} para épocas de semeadura entre outubro e dezembro, com produtividade máxima de 4563,83 kg ha^{-1} para a semeadura em novembro, apresentando redução de 60% na semeadura em janeiro. A soja de sequeiro foi mais influenciada pela época de semeadura, apresentando produtividade máxima de 3587,28 kg ha^{-1} para semeadura em outubro com uma redução de aproximadamente 30 kg ha^{-1}dia^{-1} com o atraso da semeadura, chegando a 67% de redução na produtividade com semeadura de safrinha (janeiro).

Palavras-chave: déficit hídrico, rendimento de grãos, *Glycine max.*

OLIVEIRA, Z.B.; KNIES, A.E.; RODRIGUES, L.R.; SCHMIDT, D.A.;KURY, A.E
SOYBEAN PRODUCTION DURING THE SEEDING TIME AND SUPPLEMENTARY IRRIGATION IN THE CENTRAL REGION OF RS

2 ABSTRACT

This study aims to evaluate soybean productivity as a function of sowing time and supplementary irrigation under edaphoclimatic conditions in the central region of the RS. The field experiment was conducted at the Uergs Agronomic Station in Cachoeira do Sul-RS. The experimental design was a randomized block with subdivided plots, in the factorial scheme (4x2). The “A” factor constituted the four soybean sowing seasons: 23/10/19 (Season 1), 19/11/19 (Season 2), 19/12/19 (Season 3), 1/16/20 (Season 4). The “D” factor consists of two water regimes: irrigated and non-irrigated (rainfed). A cultivar used for BMX Garra. The

Recebido em 11/09/2020 e aprovado para publicação em 20/10/2021
DOI: http://dx.doi.org/10.15809/irriga.2021v26n4p774-786

productivity of irrigated soybeans was greater than 4200 kg ha^{-1} for sowing times between October and December, with a maximum productivity of 4563.83 kg ha^{-1} for sowing in November, a reduction of 60% in sowing in January. The rainfed soybean was more influenced by the sowing time, the maximum productivity increased from 3587.28 kg ha^{-1} for sowing in October with a reduction of approximately 30 kg ha^{-1}day^{-1} with the sowing delay, reaching 67% reduction in productivity with safrinha sowing (January).

Keywords: water déficit, grain yield, *Glycine max.*

3 INTRODUCTION

Soybeans are the main source of income for Brazil (the world's second-largest producer) and for rural producers. Revenue from exports from the Brazilian soybean agro-industrial complex represents approximately 8% of the country's total exports (AGNOL *et al*., 2020). Brazilian production during the 2019--20 harvest was estimated at 120.9 million tons (CONAB, 2020a).

In Rio Grande do Sul, soybean is the main summer crop. During the 2019--2020 harvest, it was planted on 5,964,516 ha, according to a survey by Emater/RS- Ascar (2020). However, the drought that lasted until February 2020 in early December 2019 reduced crop productivity (CONAB, 2020b). According to Emater/RS- Ascar (2020), in the municipality of Cachoeira do Sul, the second largest producer of grain in the RS, with 105,000 ha cultivated, the average soybean productivity was 1,560 kg ha $^{-1}$, with an estimated average productivity loss due to the water deficit of 55%.

The amount and distribution of rainfall during January and March may be the main limiting factors for soybean productivity in the RS (BERLATO; FONTANA, 1999; FERREIRA, 2006; ZANON *et al*., 2016). However, despite the known damage caused by water deficits to soybean productivity (SENTELHAS *et al*., 2015, ZANON *et al*., 2018), most areas cultivated with soybeans in the RS are in the rainfed regime (SENTELHAS *et al.,* 2015), with impressive use of irrigation in hillside areas.

Choosing the right sowing time on the basis of an understanding of the weather patterns that explain rainfall variability at a given location is one way to minimize the effects of climate on crop productivity (ZANON *et al*., 2016; ZANON *et al*., 2018). Sowing time is one of the most important management factors for crop productivity, as it influences crop water relationships, temperature, photoperiod, and solar radiation available to plants (POPP *et al*., 2002; SUBEDI *et al*., 2007).

The water requirements of soybeans vary between 450 and 850 mm depending on the climate and the length of the development cycle (DOORENBOS; KASSAN, 1994; REICHARDT, 1987). According to Zanon *et al.* (2018), for high yields (>5,000 kg ha $^{-1}$), approximately 800 mm of water is needed throughout the crop cycle. Therefore, supplemental irrigation is a strategy that can be adopted to meet crop water demands that are not fully met by rainfall and that can contribute to increased soybean productivity.

Matzenauer *et al.* (2003) reported that supplemental irrigation, staggered sowing, and the use of cultivars with different maturity stages can reduce the risks caused by water deficiency. Therefore, this study aims to evaluate soybean productivity according to sowing time and supplemental irrigation for the soil and climate conditions of the central region of the RS.

4 MATERIALS AND METHODS

A field experiment with soybean was conducted in an experimental area of the State University of Rio Grande do Sul, which is located in the district of Três Vendas in the municipality of Cachoeira do Sul - RS (29°53' S and 53° 00' W, altitude of 125 m). The climate of the region is classified by Köppen as humid subtropical, Cfa, which is predominant in the southern region. The soil of the experimental area was classified as typical dystrophic red argisol (EMBRAPA, 2013).

The experiment was conducted in a randomized complete block design with split plots in a 4x2 factorial scheme. Factor "A" consisted of four soybean sowing dates: October 23, 2019 (season 1), November 19, 2019 (season 2), December 19, 2019 (season 3), and January 16, 2020 (season 4). Factor "D" consisted of two water regimes: irrigated and nonirrigated (rainfed). The cultivar used was BMX Garra (Relative Maturity Group 6.3), which was sown with a tractor-seeder combination in a no-tillage system with 0.50 m row spacing at a seeding density of 280,000 plants ha $^{-1}$. The remaining management and culture treatments followed the agronomic recommendations for soybean crops.

The irrigation method used was conventional sprinkling, in which sprinklers (model Plona Pa 150 - 5 × 12 Mn) were installed at a spacing of 6 × 6 m, with an application rate of 12 mm h $^{-1}$. The crop was irrigated to maintain soil water storage close to 60% of the available water capacity (AWC) - moisture between field capacity and the permanent wilting point - in the layer from 0--60 cm of soil profile depth. This fraction of available water is called the real AWC. The results of the physical-hydraulic characterization of the soil can be seen in Table 1.

Table 1. Results of the physical-hydraulic characterization of the soil in the experimental area in 2019. Cachoeira do Sul, RS.

Layers (m)	**Granulometry (%)**			**Soil density (g cm $^{-3}$)**	**CAD (mm)**
	Sand	Silt	Clay		
0.0 – 0.2	51.6	36.0	12.4	1.51	30
0.2 – 0.4	44.3	42.8	13.0	1.46	34
0.4 – 0.6	38.7	43.6	17.7	1.33	34

The methodology for calculating crop evapotranspiration (ETc) was that proposed by Allen *et al.* (1998). The meteorological data required for calculating reference evapotranspiration (ETo) were obtained from an automatic meteorological station located near the experimental site managed by Irriga Global, which provided these data. To fit the Kc (simple) curve, the methodology proposed by Allen *et al.* (1998), with the canopy cover fraction (Fc) used. Fc was estimated via a 0.50 × 0.50 m grid with a 0.10 × 0.10 cm mesh , in which the canopy cover was obtained in relation to the maximum it can occupy for that row and plant spacing.

Measurements of the soil volumetric water content were performed via FDR sensors (0–60 cm) in irrigated and nonirrigated plots. The current CAD was calculated by subtracting the moisture content on the day of the reading and the moisture content at the permanent wilting point, multiplying it by the layer depth (mm).

Phenology assessments were performed once a week on two plants per plot. The phenological scale recommended by Embrapa (2007) was used. Leaf area and plant height were measured at the reproductive stage (R3 phenological stage). For this purpose, two plants were collected per experimental plot, from which the greatest length and width of the central leaflet of the trifoliate were measured manually with the aid of a ruler. The leaf area was estimated via the equation proposed by Richter *et al.* (2014). The leaf area index (LAI) was calculated as the ratio of the total leaf area of the plant to the soil area occupied by the plant. The plant height was measured from the soil surface to the last node.

For productivity analysis, plants were manually harvested from the central area of each experimental plot (3 m2), after which they were threshed, cleaned, subjected to grain moisture determination, and weighed. The weight obtained was corrected to a moisture content of 13% and extrapolated to hectares (kg ha $^{-1}$). For yield component analysis, the number of pods per plant was $^{-1}$, the number of grains per pod was $^{-1}$, and the thousand-grain weight (MMW) (g) was calculated; four plants per plot were randomly selected and processed manually. To determine the MW, the moisture content was measured, and the weight obtained was corrected to a moisture content of 13%.

The response variables obtained were subjected to analysis of variance via the “F” test and complementary analysis, i.e., the “Tukey” test (water regime factor) and regression analysis (sowing time factor), at a 5% error probability level via Sisvar software.

5 RESULTS AND DISCUSSION

The air temperature reached a maximum of 38°C in January (the hottest month) and a minimum of 8°C in April, when temperatures decreased due to the climatic characteristics of autumn. Soybeans adapt best to regions where temperatures range between 20°C and 30°C, with the ideal temperature for their development being approximately 30°C (FARIAS *et al*., 2020a). Solar radiation increases from October to December, where it begins to decrease (Figure 1). The availability of solar radiation for soybean crops is related to photosynthesis, elongation of the main stem and branches, leaf expansion, pod and grain set, and biological fixation (CÂMARA, 2000).

The duration of the development cycle (sowing to harvest) was 153, 126, 119 and 99 days for Seasons 1, 2, 3 and 4, respectively. The shortening of the cycle with the delay in sowing corroborates the results of Zanon (2015). The temperature and photoperiod influence the duration of the phases and the soybean development cycle (KANTOLIC, 2008), and variations in the development subperiods and in the duration of the cycle also occur as a function of the genotype (SETIYONO *et al*., 2007).

The crop water balance (Figure 2) demonstrated a better rainfall distribution throughout the cycle in Seasons 1 and 2, contributing to maintaining higher soil moisture. In Season 3, rainfall was well distributed during the initial and rapid growth phases, with considerable reductions in quantity and distribution during the reproductive phase.

In season 4, there were few rainy days, predominantly during the rapid growth phase and the beginning of the reproductive phase. The flowering period (particularly the last part of the flowering period) and the pod development period are the most sensitive to water deficit (DOORENBOS; KASSAM, 1994).

Figure 1. Results of temperature and global solar radiation data for the experimental period. Cachoeira do Sul, RS.

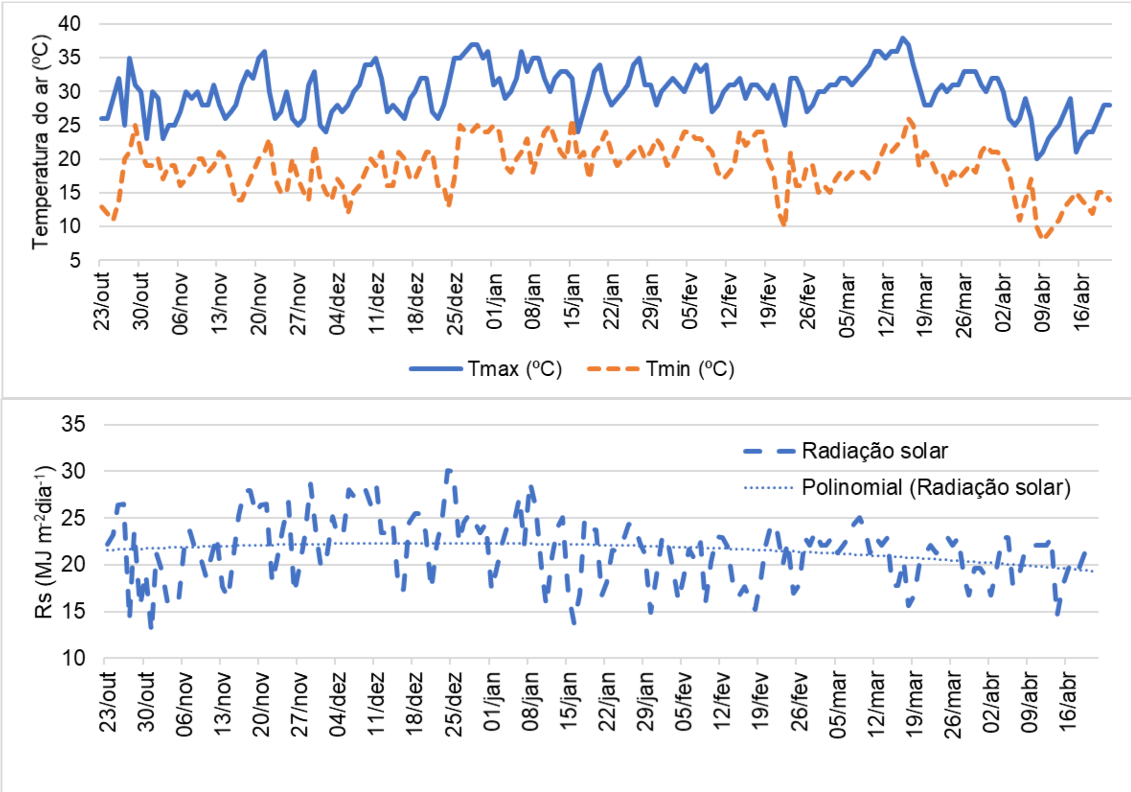
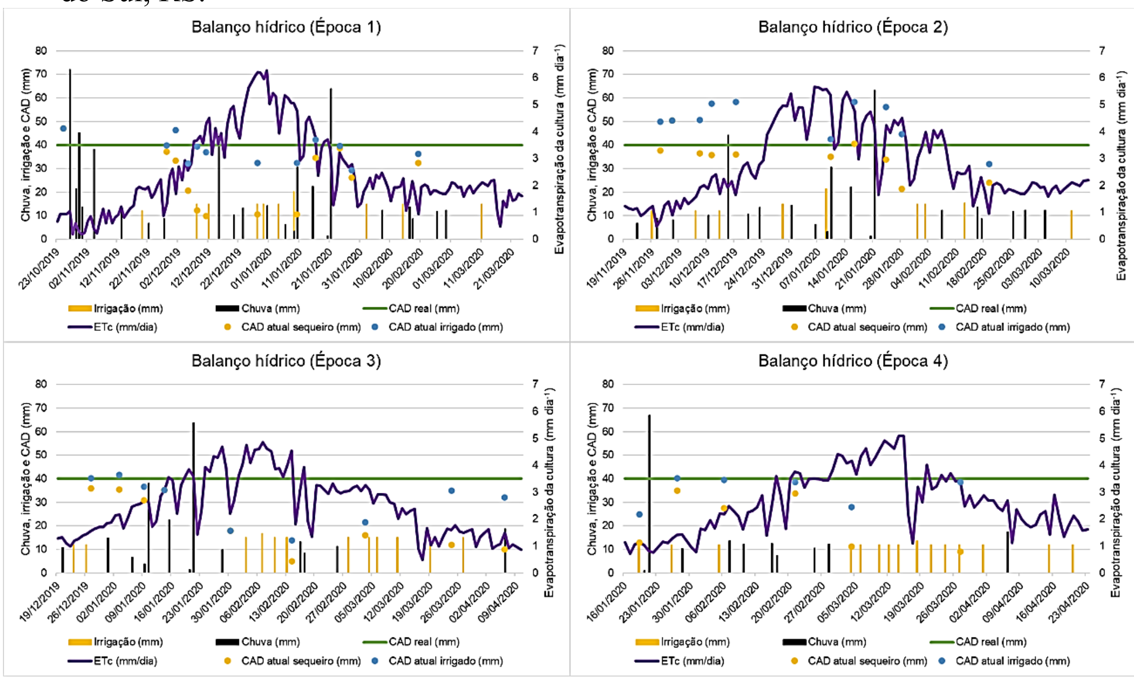


Figure 2. Water balance for soybean crops in four sowing seasons from 2019--20. Cachoeira do Sul, RS.



The 2019--20 agricultural year was characterized by low accumulated rainfall values below the climatological normal for Cachoeira do Sul (Table 1). According to the 1961--1990 climatological normal data for the period from October to March, when the soybean crop is in the field, the accumulated rainfall value is 710.6 mm. Notably, (Table 2) the sum of rainfall during the cycle was lower than the crop's water demand, with the exception of Season 1, when the accumulated rainfall was greater than the accumulated ETc. Even so, there was an irregular distribution of rainfall (Figure 2), causing a reduction in soil water storage during the reproductive phase. For sowing seasons 3 and 4, supplemental irrigation met practically all of the crop's water demand during the reproductive phase, extending until the end of the cycle (Figure 2). Gajić *et al.* (2018) reported that irrigation is necessary for soybean cultivation in semidry and dry years when the amount of seasonal rainfall is less than 300 mm. In wet years, with favorable rainfall quantity and distribution during the growing season, yields are similar to those obtained with irrigation.

Table 2. Components of the water balance of soybean crops in the four sowing seasons from 2019--20. Cachoeira do Sul, RS.

Water balance parameters	Season 1	Season 2	Season 3	Season 4
ETc (mm)	380.7	324.6	283.0	256.0
Accumulated rainfall (mm)	484.8	312.9	222.0	115.0
Accumulated irrigation (mm)	152.0	129.0	175.0	181.0

The environmental conditions related to the sowing date (solar radiation availability, temperature, photoperiod, and rainfall distribution) and the adopted water regime (irrigated or rainfed) affected the plant growth parameters (LAI and height), yield components, and soybean productivity. There were differences between the sowing dates for all the response variables analyzed. The water regime did not influence the number of grains per pod [(1)]. Interactions among the factors included plant height, number of pods per plant [(1)], and productivity (Table 3).

Table 3. Summary of the analysis of variance for the response variables. Cachoeira do Sul, RS.

	Calculated F value					
	Plant Height (cm)	**IAF**	**Plant pods $^{-1}$**	**Bean pods $^{-1}$**	**PMG (g)**	**Productivity (kg ha $^{-1}$)**
THE	82.41*	28.40*	42.39*	18.21*	7.47*	97.85*
D	112.54*	28.12*	51.87*	3.66 ^{ns}	59.67*	183.73*
A x D	4.12*	0.95n ^{s}	12.96*	0.91 ^{ns}	1.68 ^{ns}	15.99*
Repetition	2.27 ^{ns}	0.87 ^{ns}	0.05 ^{ns}	1.16 ^{ns}	0.07 ^{ns}	0.27 ^{ns}
CV (%)	12.89	25.46	14.00	4.58	8.52	10.36

where A = sowing time factor; D = water regime factor; IAF = leaf area index; PMG = thousand grain weight; CV = coefficient of variation; * significant and ^{ns} not significant according to the "f" test at a 5% probability of error level.

Irrigation resulted in average increases of 42% and 39% in the LAI and plant height, respectively (Table 4). According to Taiz and Zeige (2013), one of the first responses to water stress is reduced growth, which explains the lower LAI and plant height values in rainfed areas. Chunfeng *et al*. (2019) reported that the leaf area of soybean plants increases significantly with irrigation of up to 400 mm.

Zanon *et al*. (2018) reported that to achieve high productivity, an LAI greater than 6.3 is necessary. This value was exceeded in irrigated plants (season 1, season 2 and season 3), whereas in rainfed plants, the LAI was greater than 6.3 only in season 2. The stress caused by water deficiency determines the presence of poorly developed plants of small stature with small leaves and short internodes (FARIAS *et al.,* 2020b).

The higher LAI results and plant height in Seasons 2 and 3 (Figure 3) can be explained by the greater thermal accumulation in the initial phase of the crop (first 30 days) and the greater availability of solar radiation (Figure 1). In Season 4, the limiting factors for biomass production are solar radiation (Figure 1) and the photoperiod. For the region's latitude, the photoperiod varies from approximately 10 a.m. on June 21 to 2 p.m. on December 21.

The number of pods per plant $^{-1}$ and the PMG weight were also higher in the irrigated plants than in the control plants by an average of 28% (23 pods) and 19% (38 g), respectively (Table 4). Correa *et al.* (2019) reported that sprinkler irrigation promoted an increase in PMG on average in the cultivars under study, on the order of 20 g, in relation to the treatment without irrigation.

Table 4. Results of the IAF, plant height, number of pods per plant -1, number of grains per pod $^{-1}$, PMG and productivity of irrigated and rainfed soybeans for four sowing seasons. Cachoeira do Sul, RS.

Tratamentos		IAF	Altura de plantas (cm)	Vagens planta $^{-1}$	Grãos vagem $^{-1}$	PMG (g)	Produtividade (kg ha^{-1})
Ép. 1	Irr.	7,93 a	60,25 a	126,13 a	2,19 ^{ns}	197,87 a	4430,30 a
	Seq.	4,66 b	28,75 b	79,50 b	2,21 ^{ns}	162,06 b	3587,28 b
Ép. 2	Irr.	12,59 a	109,88 a	77,69 a	2,30 ^{ns}	216,49 a	4563,83 a
	Seq.	9,74 b	74,25 b	66,69 b	2,33 ^{ns}	164,78 b	2651,62 b
Ép. 3	Irr.	11,01 a	87,75 a	65,06 a	2,22 ^{ns}	184,70 a	4242,70 a
	Seq.	5,74 b	50,50 b	52,56 b	2,21 ^{ns}	152,83 b	1691,42 b
Ép. 4	Irr.	4,17 a	43,25 a	56,56 a	2,01 ^{ns}	180,02 a	1860,68 a
	Seq.	1,77 b	30,38 b	33,19 b	2,03 ^{ns}	144,94 b	1164,47 b

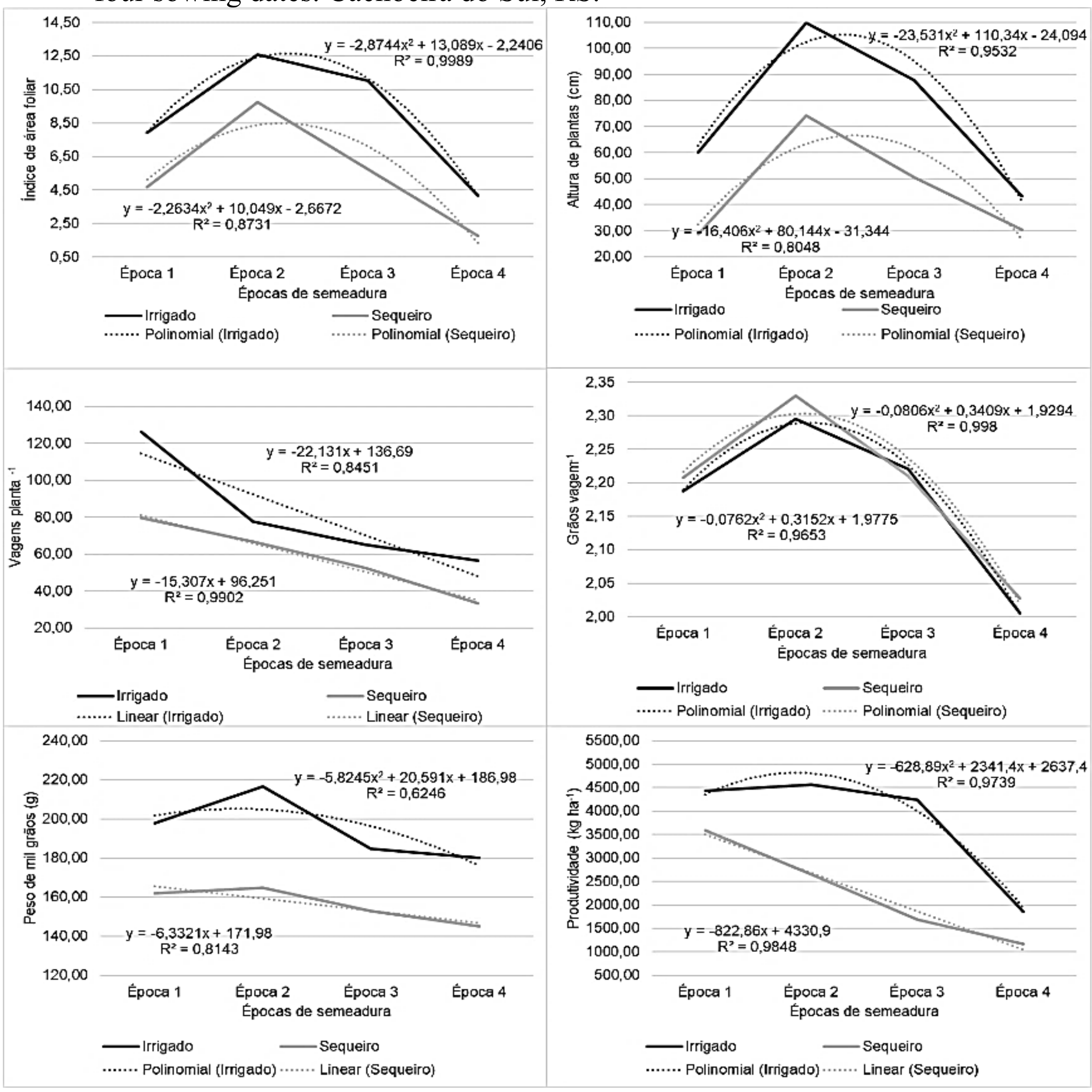
where the numbers followed by different letters in the column (for the same period) differ from each other according to the "Tukey" test at the 5% significance level; ^{ns,} not significant at the 5% probability of error; Ép, sowing season; Irr, irrigated; Seq, rainfed; IAF, leaf area index; and PMG, thousand grain weight (g).

The number of pods per plant $^{-1}$ linearly decreased, as there was a delay in the sowing season (Figure 3), which was associated with a reduction in water availability during the reproductive period of the crop (Figure 2). Significant water deficits cause physiological changes in soybean plants that, during the flowering phase, can result in the premature fall of flowers, causing pod abortion (FARIAS *et al*., 2020a, STRECK, 2004; TAIZ; ZAIGER, 2013).

The number of grains per pod presented a polynomial fit (irrigated and rainfed), in which the highest values were observed in Season 2, without the influence of the water regime (Table 4 and Figure 3). The number of grains per pod $^{-1}$, among the other direct components, is the one that presents the smallest variation (MUNDSTOCK; THOMAS, 2005).

The PMG and productivity showed a linear fit for the rainfed area, with values decreasing as the sowing season progressed, which was associated with lower water availability during the reproductive phase, especially in Seasons 3 and 4 (Figure 2). For the irrigated area, the fit is polynomial, with higher results in Season 2 (Figure 3), which may be related to the greater availability of solar radiation during the reproductive phase. According to Zanon *et al.* (2018a), by adapting the sowing season, it is possible to adjust the critical period of the crop (reproductive) to the period of greatest available solar radiation and thus increase the productivity potential.

Figure 3. Regression equations for the LAI, plant height, number of pods per plant $^{-1}$, number of grains per pod $^{-1}$, PMG and productivity of irrigated and rainfed soybeans for the four sowing dates. Cachoeira do Sul, RS.



For rainfed soybean, there was a 52% productivity reduction from Season 1 to Season 3 and a 67% reduction from Season 1 to Season 4 (Table 4 and Figure 3). This productivity reduction was approximately 30 kg ha $^{-1}$ day $^{-1}$ with the sowing delay. Studies indicate productivity losses of up to 70% in off-season sowings compared with the preferred time (RODRIGUES *et al.,* 2001; BRACCINI *et al.,* 2004; RODRIGUES *et al*., 2008; STÜLP *et al*., 2009). This result demonstrates the importance of early sowing in rainfed areas to increase productivity (Table 4).

The productivity of irrigated soybeans was 39% greater than that of rainfed soybeans (Table 4). Pedrotti (2014), evaluating the best times for soybeans and corn, in which the crops express their maximum potential, both under irrigation and rainfed, obtained an average increase in productivity for irrigated soybeans of 14%.

The productivity increases due to irrigation were 843, 1912, 2551, and 696 kg ha $^{-1}$ for Seasons 1, 2, 3, and 4, respectively. The largest increase in season 3 can be attributed to the magnitude of the water deficit during the crop's reproductive phase, which also occurred in season 4 (Figure 2), negatively impacting the yield components and productivity of rainfed soybeans (Table 4). In the second crop (season 4), in addition to water deficit, solar radiation and photoperiod are also factors that limit productivity.

The productivity of irrigated soybean was less influenced by the sowing season between October and December (Seasons 1 to 3), being greater than 4200 kg ha $^{-1}$ (Table 4), with a maximum productivity of 4563.83 kg ha $^{-1}$ for November sowing (Figure 3). There was an approximately 60% reduction in productivity in Season 4 compared with the previous period.

Jaybhay *et al*. (2019) obtained maximum yields of 3221 kg ha $^{-1}$ with irrigation during the initial flowering and grain filling phases of soybeans. According to these authors, in addition to the optimal yield, this is the strategy for obtaining the maximum net economic return. Gajić *et al*. (2018) evaluated different irrigation strategies, including total irrigation (100%), 0%, 65% and 40% total irrigation and a control (no irrigation), and reported a maximum productivity of 3690 kg ha $^{-1}$ in the 0.65% treatment.

Thus, on the basis of the results presented here, it is possible to recommend a sowing date (Table 5) for soybean crops in the central region of the RS for agricultural years with expectations of rainfall below the climatological normal, as was the case from 2019--20.

Table 5. Sowing date recommendations and justifications for such decision-making on the basis of the results obtained in this work. Cachoeira do Sul, RS.

	Water regime	
	Dryland	**Irrigated**
Sowing date	October 23 or closest to this date	October 23 to December 19
	Justification	
Impacts on productivity	reduction in productivity of approximately 30 kg ha $^{-1}$ day $^{-1}$ with delayed sowing.	productivities greater than 4000 kg ha $^{-1}$, with the highest productivities with sowings close to November 19 (maximization of radiation)
Limiting environmental factors	water : for all sowing dates; solar radiation: late sowing.	radiation : late sowing.

6 CONCLUSIONS

In the central region of the RS, the 2019–20 agricultural year was characterized by low rainfall and an irregular distribution, requiring between 150 and 180 mm of supplementary irrigation to meet the crop's water demand and maintain soil water storage at desired levels, depending on the sowing season adopted.

The productivity of irrigated soybeans was greater than 4200 kg ha $^{-1}$ for the sowing season between October and December, with a maximum productivity of 4563.83 kg ha $^{-1}$ for sowing in November, indicating a 60% reduction in sowing in January.

Rainfed soybeans were most influenced by the sowing season, with a maximum productivity of 3587.28 kg ha $^{-1}$ for sowing in October and a reduction of approximately 30 kg ha $^{-1}$ day $^{-1}$ with delayed sowing, reaching a 67% reduction in productivity with sowing in the second crop (January).

7 REFERENCES

AGNOL, AD; OLIVEIRA, AB; LAZZAROTTO, JJ; HIRAKURI, MH Socioeconomic importance of soybeans. EMBRAPA. Available at: https://www.agencia.cnptia.embrapa.br/gestor/soja/arvore/CONTAG01_12_271020069131.html . Access on: September 2, 2020.

ALLEN, RG *et al*. **Crop evapotranspiration - Guidelines for computing crop water requirements.** Rome: FAO, 1998, 300p. (Irrigation and Drainage Paper, 56). Available at: <http://www.fao.org/docrep/X0490E/X0490E00.htm>. Accessed: September 6, 2020.

BERLATO, M.A., FONTANA, D. C. Interannual variability of rainfall and soybean yield in Rio Grande do Sul. **Brazilian Journal of Agrometeorology** , Serra Talhada, v.7, n.1, p.119–125, 1999.

BRACCINI, AL *et al*. Agronomic characteristics and yield of soybean seeds in sowing carried out in the off-season period. **Bragantia** , Campinas, v. 63, n. 1, p. 81-92, 2004.

CÂMARA, GMS **Soybean: Production Technology II** . Piracicaba, 450p, 2000.

CORRÊA, MF *et al*. Effect of sprinkler irrigation on yield and physiological potential of soybean seeds. Journal of **Agroveterinary Sciences** , Lages, v.18, n. 4, p. 482-488, 2019

CHUNFENG *et al*. Effects of drip irrigation on spring soybean (*Glycine Max* L.Merr) growth and soil physical indices of Heilongjiang province of China. **Bangladesh Journal Botany** , **Bangladesh ,** vol. 48(1), p. 95-103, 2019.

CONAB. **Eleventh survey of the 2019/20 harvest** . n. 11 - v. 7, 2020. Available at: https://www.conab.gov.br/info-agro/safras/graos/boletim-da-safra-de-graos . Accessed on: September 6, 2020a.

CONAB. **Sixth harvest survey 2019/20.** n. 6 - v. 7, 2020. Available at: https://www.conab.gov.br/info-agro/safras/graos/boletim-da-safra-de-graos . Accessed on: September 6, 2020b.

Emater/RS- Ascar . **Informative conjunctural.** No. 1600, April 2, 2020. Available at : http://www.emater.tche.br/site/arquivos_pdf/conjuntural/conj_02042020.pdf . Accessed on: September 6, 2020.

BRAZILIAN AGRICULTURAL RESEARCH CORPORATION – EMBRAPA. **Soybean ecophysiology** . Technical Circular, Paraná, p.9, ISSN 1516-7860, 2007.

BRAZILIAN AGRICULTURAL RESEARCH CORPORATION – EMBRAPA. **Brazilian soil classification system** . Brasília, 3rd ed., p.353, 2013.

FARIAS, JRB; NEPOMUCENO, A. L; NEUMAIER, N. **Soybean knowledge tree** . EMBRAPA. Available at: https://www.agencia.cnptia.embrapa.br/gestor/soja/arvore/CONT000g0tk1p1302wx5ok026zxpgwjmpe2f.html. Accessed on: September 2, 2020.

FARIAS, JRB; NEUMAIER, N.; NEPOMUCENO, AL **Soybean knowledge tree** . EMBRAPA. Available at : https://www.agencia.cnptia.embrapa.br/gestor/soja/arvore/CONT000fzr67crj02wx5ok0cpoo6aietiwl0.html#:~:text=A%20necessidade%20total%20de%20%C3%A1gua,da%20dura%C3%A7%C3%A3o%20do%20seu%20ciclo. Access on : September 2, 2020.

GAJIĆ, B *et al*. Effect of irrigation regime on yield, harvest index and water productivity of soybean grown under different precipitation conditions in a temperate environment. **Agricultural Water Management** , Elsevier, v. 210, p. 224-23, 2018.

JAYBHAY, S. A *et al*. Response of Soybean [*Glycine max* (L.) Merrill] to Irrigation at Different Growth Stages. **Agricultural Science Digest** , vol. 39, p.132-135, 2019 .

, A.G. Environmental and genetic control of the phenology of soybean cultivation: impacts on the performance and adaptation of genotypes. **Revista da Facultad de Agronomía UBA** , Buenos Aires, v. 28, p. 63-88, 2008.

MATZENAUER, R.; BARNI, NA; MALUF, JRT Estimation of relative water consumption for soybean crops in the State of Rio Grande do Sul. **Ciência Rural** , Santa Maria, v.33, n.6, p.1013-1019, 2003.

MUNDSTOCK, CM; THOMAS, AL Soybean: **Factors affecting growth and grain yield.** Engraf . Department of Crop Plants of the Federal University of Rio Grande do Sul, p.31, 2005.

PEDROTTI, MC **Soybean and corn productivity as a function of sowing time under irrigated and rainfed conditions** . Dissertation (Master's in Agronomy) - Federal University of Grande Dourados, Dourados, 2014.

POPP, MO *et al*. Planting date, cultivar, and tillage system effects on dryland soybean production. **Agronomy Journal** , v.94, p.81-88, 2002.

REICHARDT, K. **Water in agricultural systems** . São Paulo: Manole, 188p, 1987.

RICHTER, GL *et al*. Estimation of leaf area of old and modern soybean cultivars by nondestructive method. **Bragantia** , Campinas, v. 73, n. 4, p.416-425, 2014.

RODRIGUES, O. *et al*. **Soybean grain yield in response to sowing season** . [Sl .]: Embrapa Trigo, p. 3. (Online Release, 65), 2001.

RODRIGUES, O. *et al*. **Soybean grain yields in late sowing.** [Sl .]: Embrapa Trigo, p. 26 (Online Research and Development Bulletin, 66), 2008.

SENTELHAS, P. C *et al*. The Soybean Yield Gap in Brazil - Magnitude, Causes and Possible Solutions for a Sustainable Production. **Journal of Agricultural Science,** Cambridge, vol. 153, p. 1394-1411, 2015.

SETIYONO, T. D *et al*. Understanding and modeling the effect of temperature and daylength on soybean phenology under high-yield conditions. **Field Crops Research** , v.100 , p. 257-271, 2007.

STRECK, NA Do we know how plants sense a drying soil?. **Rural Science** . Santa Maria, v . 34, p.581-584. 2004.

STÜLP, M. *et al*. Agronomic performance of three soybean cultivars at different sowing dates in two harvests. **Science and Agrotechnology** , Lavras , v. 33, p. 1240-1248, 2009.

SUBEDI, PP, WALSH, KB, OWENS, G. Prediction of mango eating quality at harvest using shortwave near infrared spectrometry, **Postharvest Biology and Technology** , v. 43, p. 326-334, 2007

TAIZ, L.; ZEIGER, E. **Plant physiology** . 5th ed. Porto Alegre:Artemed , p. 954, 2013.

ZANON, AJ *et al*. Contribution of branching and the evolution of the leaf area index in modern soybean cultivars. **Bragantia** , Campinas, v.74, p.279-290, 2015.

ZANON, AJ *et al*. **Soybean ecophysiology - Aiming for high productivity** . 1st ed. Santa Maria: [ns .], ISBN: 978-85-54856-14-4, p.136, 2018.

ZANON, AJ; STRECK, NA; GRASSINI, P. Climate and management factors influencing soybean yield potential in a subtropical environment. **Agronomy Journal** , vol. 108, p.1447-1454, 2016.