Ciências Agrárias
SEMINA

DOI: 10.5433/1679-0359.2025v46n4p1261

Sowing date and relative maturity groups of soybean cultivars grown in lowland soils

Época de semeadura e grupo de maturação relativa de cultivares de soja em terras baixas

Eduardo Anibele Streck[1]*; Mauro Silveira da Silveira[2]; Camila Bisognin Meneghetti[2]; Felipe Tascheto Bolzan[3]; Kellen da Silveira Freitas[4]; Ana Caroline Garbin[5]; Otávio Diesel Köhler[4]; Rafael Tobias Lang Fronza[6]; Weliton de Almeida Lansana[4]; Ivan Carlos Maldaner[7]

Highlights

La Niña seasons favor early sowing, whereas El Niño seasons favor later sowing.
Medium- or late-maturing cultivars are recommended for early sowing.
Certain soybean cultivars exhibit greater adaptability and flexibility in lowland.
Cultivar choice is determined by sowing date and relative maturity groups (RMGs).

Abstract

Soybean cultivation has expanded considerably in the southern half of Rio Grande do Sul state, Brazil, where irrigated rice has traditionally been grown. However, these lowland soils exhibit low hydraulic conductivity and subsurface compaction, presenting challenges for root development. Therefore, understanding genotype-environment interactions is crucial to achieving high yields. Thus, the present study evaluated the effect of sowing date on the yield of soybean cultivars with different relative maturity groups in lowland areas. The study was conducted during the 2018/19 and 2019/20 crop seasons, in the experimental floodplain teaching field of the Instituto Federal Farroupilha, Campus São Vicente do Sul. Three sowing dates and several cultivars were tested in a randomized block design with split-plots

[1] Prof. Dr., Instituto Federal de Educação, Ciência e Tecnologia Farroupilha, Campus São Vicente do Sul, IFFar, São Vicente do Sul, RS, Brazil. E-mail: streck.eduardo@gmail.com

[2] Agricultural Engineer, IFFar, Campus São Vicente do Sul, São Vicente do Sul, RS, Brazil. E-mail: msilveiraa.98@gmail.com; meneghetti402@gmail.com

[3] MSc., Researcher, DonMario Seeds, RS, Brazil. E-mail: felipebolzan93@hotmail.com

[4] Students of the Master's Degree in the Postgraduate Program in Agronomy, Universidade Federal de Santa Maria, UFSM, Santa Maria, RS, Brazil. E-mail: kellysilveirafreitas@gmail.com; otaviokohler269@gmail.com; welitonlansana96@gmail.com

[5] Graduate Student in Agronomy, IFFar, Campus São Vicente do Sul, São Vicente do Sul, RS, Brazil. E-mail: ana29garbin@gmail.com

[6] Doctoral Student of the Post Graduate Program in Plant Science, Universidade Federal de Viçosa, UFV, Viçosa, MG, Brazil. E-mail: rfronza33@gmail.com

[7] Prof. Dr., Colégio Politécnico, UFSM, Santa Maria, RS, Brazil. E-mail: ivan.maldaner@ufsm.br

* Author for correspondence

Received: May 10, 2024 Approved: Aug. 19, 2025

and three replicates. Plant height, number of pods per plant, number of grains per pod, 1,000-grain weight, and yield were measured. Analysis of variance showed that sowing date significantly affected yield and other variables analyzed in both seasons. Soybean performance in lowland soils is strongly influenced by sowing date and water availability. In crop seasons with excess water, early sowing (late October to November) was more productive, and mid- or late-season cultivars are recommended. By contrast, under water deficit, late sowing favored higher yields. The cultivars BMX Delta, BMX Garra, and BMX Ícone demonstrated good adaptation to excess-water conditions, while BMX Garra, HO Pirapó, DM 66i68, and NS 6601 excelled under water deficit, demonstrating high yield potential and adaptability to late sowing. Agronomic traits such as plant height, thousand-grain weight, and number of pods and grains per plant were significantly affected by sowing date and seasonal weather conditions.
Key words: *Glycine max.* Crop rotation. Yield.

Resumo

A cultura da soja tem apresentado elevada expansão de cultivo na metade Sul do Rio Grande do Sul, tradicionalmente cultivadas com arroz irrigado. No entanto, essas áreas apresentam solos com baixa condutividade hidráulica e compactação subsuperficial, torna-se desafiador para o desenvolvimento do sistema radicular das plantas. Logo, o conhecimento da interação genótipo x ambiente é fundamental para a obtenção de altas produtividades. Nesse sentido, objetivou-se avaliar o efeito da época de semeadura na produtividade de cultivares de soja com diferentes grupos de maturidade relativa em terras baixas. O trabalho foi realizado nas safras agrícolas de 2018/19 e 2019/20, utilizando três épocas de semeadura distintas e diferentes cultivares, onde avaliou-se a altura de planta, número de legumes por planta, número de grãos por legume, peso de mil grãos e produtividade. A pesquisa foi conduzida no campo didático experimental de várzea do Instituto Federal Farroupilha campus São Vicente do Sul. Foi utilizado o delineamento experimental de blocos ao acaso, em esquemas de parcelas subdivididas com três repetições, foram mensurados componentes produtivos e a produtividade da cultura. Os dados obtidos foram submetidos a análise de variância, que evidenciou que a época de semeadura afetou significativamente a produtividade e demais variáveis analisadas em ambas as safras agrícolas. A época de semeadura influencia diretamente o desempenho da soja em terras baixas sob diferentes condições hídricas. Em safras com excesso hídrico, semeaduras antecipadas, entre a segunda quinzena de outubro e novembro, são mais produtivas, e deve ser preconizado o posicionamento de cultivares de ciclo médio ou tardio. Já em safras com déficit hídrico, as semeaduras tardias favoreceram maiores produtividades. As cultivares BMX Delta, BMX Garra e BMX Ícone mostraram boa adaptação ao ambiente de terras baixas sob excesso de água. Enquanto BMX Garra, HO Pirapó, DM 66i68 e NS 6601 se destacaram em condições déficit hídrico, demonstraram altos potenciais produtivos e adaptação a semeaduras tardias. Características agronômicas como altura de plantas, peso de mil grãos e número de legumes e grãos por planta são altamente afetadas pela época de semeadura e pelas condições climáticas da safra.
Palavras-chave: *Glycine max.* Rotação de culturas. Produtividade.

Introduction

Soybean (Glycine max) is Brazil's leading agricultural commodity, playing a key role in the national economy. According to surveys by the National Supply Company [CONAB, 2025], yields during the 2024/2025 crop season exceeded initial estimates in nearly all states, except for Rio Grande do Sul (RS) and Mato Grosso do Sul (MS). In RS, as in the 2021/22 and 2022/23 seasons, production was once again affected by drought, resulting in highly heterogeneous yields ranging from less than 500 kg ha^{-1} to approximately 3,600 kg ha^{-1}. Grain quality was also below expectations, with small, light, and damaged seeds, albeit still compliant with industrial standards. However, despite yield losses caused by adverse climate conditions, preliminary data indicate a 1.3% increase in cultivated area compared to the previous season.

During the first decade of the 21st century, significant changes occurred in soybean production systems in Rio Grande do Sul. These included: (I) the consolidation of no-tillage systems and the use of crop rotation and cover crops (Empresa Brasileira de Pesquisa Agropecuária [EMBRAPA], 2020); (II) the introduction of early-maturing cultivars with higher genetic potential and glyphosate resistance; and (III) increased soybean cultivation in lowland areas traditionally used for irrigated rice (Carmona, 2020).

The expansion of soybean in rotation with irrigated rice is associated with increasing weed pressure in rice fields and the need to diversify production systems while adopting advanced agricultural technology. Crop rotation in floodplain soils cultivated with irrigated rice can help manage weeds (Bortoluzzi et al., 2020), primarily red rice, improve soil use and quality, optimize machinery and labor, diversify income, break pest and disease cycles, and increase land profitability. Although soybean has improved in well-drained soils in Brazil, it originates from flood-prone areas of northern China, making adaptation to lowland soils a critical consideration.

According to Zhou et al. (2020), temporary waterlogging is a global problem that adversely affects plant development and growth by reducing oxygen availability in the rhizosphere. Excess soil moisture alters the root environment, causing carbon dioxide and ethylene accumulation in the soil, which compromise mitochondrial function and nutrient uptake. This hypoxic environment can also hinder iron (Fe) and manganese (Mn) absorption, increasing their concentrations to toxic levels for plants (Manghwar et al., 2024).

Wu et al. (2025) reported that waterlogging at the onset of reproductive stages can reduce grain yield by approximately 17.4% per level of water damage. Depending on the growth stage and genotype, yield losses range from 33% to 51% between tolerant and sensitive cultivars. Waterlogging reduces plant development, decreases the number of nodes with buds, and causes flower, pod, and grain abortion due to limited nutrient availability. However, yield loss ultimately depends on the genotype's tolerance to flooding, phenological stage, and the duration of waterlogging.

Factors that can improve yield include adopting early or late sowing dates to avoid drought stress, selecting cultivars tolerant to excess water, and incorporating modern genetic technologies. Sowing dates directly influence the development of different soybean genotypes by affecting bud formation, phenology and nutrient absorption efficiency (Islam et al., 2023).

Another factor that aims to optimize crop yield is aligning critical phenological stages with the most favorable environmental conditions, minimizing stress during the most vulnerable stages. Studies on climate variables and sowing dates are therefore crucial to productive success. According to Oliveira et al. (2021), rainfed soybeans are more affected by sowing date than those in irrigated environments, with maximum yield achieved by sowing in October, while delays can reduce yields by approximately 30 kg ha^{-1} day^{-1}. Zanon et al. (2016) reported maximum soybean yields with sowings from October to November 4th, after which delays resulted in losses of 26 kg ha^{-1} day^{-1}.

Given that crop phenology and meteorological factors largely determine adaptation and yield potential across different production areas (Stochero et al., 2020), studies evaluating soybean cultivars under different sowing dates regions of RS are essential.

Materials and Methods

This study was conducted during the 2018/2019 and 2019/2020 crop seasons at the experimental area of the Instituto Federal Farroupilha in São Vicente do Sul, located in the central depression of Rio Grande do Sul, Brazil (29° 41' 30" S, 54° 40' 46" W, Altitude: 129 m). The floodplain soil is classified as Arenic Haplic Eutrophic Planosol (Streck et al., 2008).

Field experiments consisted of three sowing dates in each season. In 2018/2019, sowing occurred on 10/19, 11/29 and 12/29, with six cultivars evaluated, and in 2019/2020, sowing was performed on 10/24, 11/19 and 12/17, assessing eight cultivars (Table 1).

A randomized block design with split-plot arrangements and three replicates was used. Sowing dates comprised the main plot, and the cultivars the subplots. Each experimental unit consisted of a plot with six 5-meter-long rows spaced 0.45 m apart. Sowing density targeted 10 plants per linear meter at a depth of 0.03 m. Seeds were treated with fungicides and insecticides and inoculated with a strain of Bradyrhizobium japonicum. The trials followed standards established by the Ministry of Agriculture through the National Cultivar Protection Service.

Table 1
Soybean cultivars, relative maturity group (RMG), and growth habit during the 2018-2019 and 2019-2020 crop seasons

Cultivar	RMG	Growth Habit
2018/19 crop season		
BMX Raio IPRO	5.0	Indeterminate
BMX Elite IPRO	5.5	Indeterminate
BMX Delta IPRO	5.9	Indeterminate
BMX Garra IPRO	6.3	Indeterminate
BS IRGA 1642 IPRO	6.4	Indeterminate
BMX Ícone IPRO	6.8	Indeterminate
2019/20 crop season		
BMX DELTA IPRO	5.9	Indeterminate
BMX GARRA	6.3	Indeterminate
SYN 1263 RR	6.3	Indeterminate
HO PIRAPÓ IPRO	6.4	Indeterminate
NS 6601 IPRO	6.6	Indeterminate
DM 66I68 IPRO	6.6	Indeterminate
FPS 1867 IPRO	6.7	Indeterminate
BMX ICONE IPRO	6.8	Indeterminate

The experimental area was previously leveled in a zero-contour system typical of the region. A textural B Horizon, characteristic of Planosols, indicates subsurface compaction below 15 cm, which impairs soil hydraulic conductivity and drainage. Soil management included leveling with a harrow and blade, pre- and post-sowing desiccation, and construction of drainage channels. Soil physicochemical properties indicated 1.7% organic matter, 16% clay content, pH 6.10 in water, effective cation exchange capacity (CEC) of 11.91 cmol_c/kg, and no aluminum saturation. Fertilization followed soil recommendations for each crop season.

Plant height, number of pods per plant, number of seeds per pod, and thousand-grain weight were measured at physiological maturity. Treatment means were calculated by assessing four randomly selected plants per experimental unit. Grain was harvested from the central 2 meters of the three middle rows (2.7 m²), eliminating border effects. Samples were weighed, and moisture content corrected to 13% to estimate grain yield free of impurities.

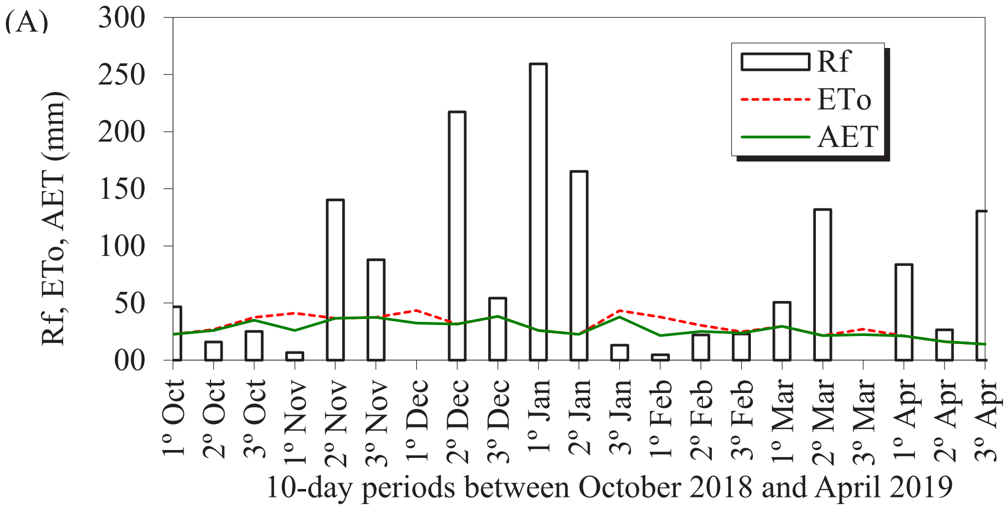
Sequential water balance was estimated using an available soil water capacity (AWC) of 70 mm, average monthly rainfall, and reference evapotranspiration (ETo), calculated via the Penman-Monteith equation. Meteorological data, including temperature and rainfall, were obtained from an automatic weather station of the National Institute of Meteorology (INMET), located less than 500 m from the experimental site.

Statistical analyses were performed using Sisvar software. Analysis of variance (ANOVA) was applied to evaluate differences among variables, and means were compared using Tukey's test at a 5% probability level.

Results and Discussion

Its high spatial and temporal variability makes rainfall a key climactic factor in agriculture, directly affecting all stages of plant development. Radin et al. (2017) identify rainfall as the primary factor responsible for soybean yield variability, with both prolonged droughts and excessive rainfall significantly influencing crop performance.

During the 2018/2019 crop season, a weak El Niño event produced intermittent rainfall, with 10 to 15 days of precipitation alternating with 10 to 15 days of predominantly sunny weather until mid-December. In January, however, higher and more persistent rainfall characteristic of El Niño occurred (Figure 1A). The sequential water balance (Figure 1B) indicates surplus of 150- 233 mm during late December and January, coinciding with the soybean reproductive stage, which is highly sensitive to water availability.



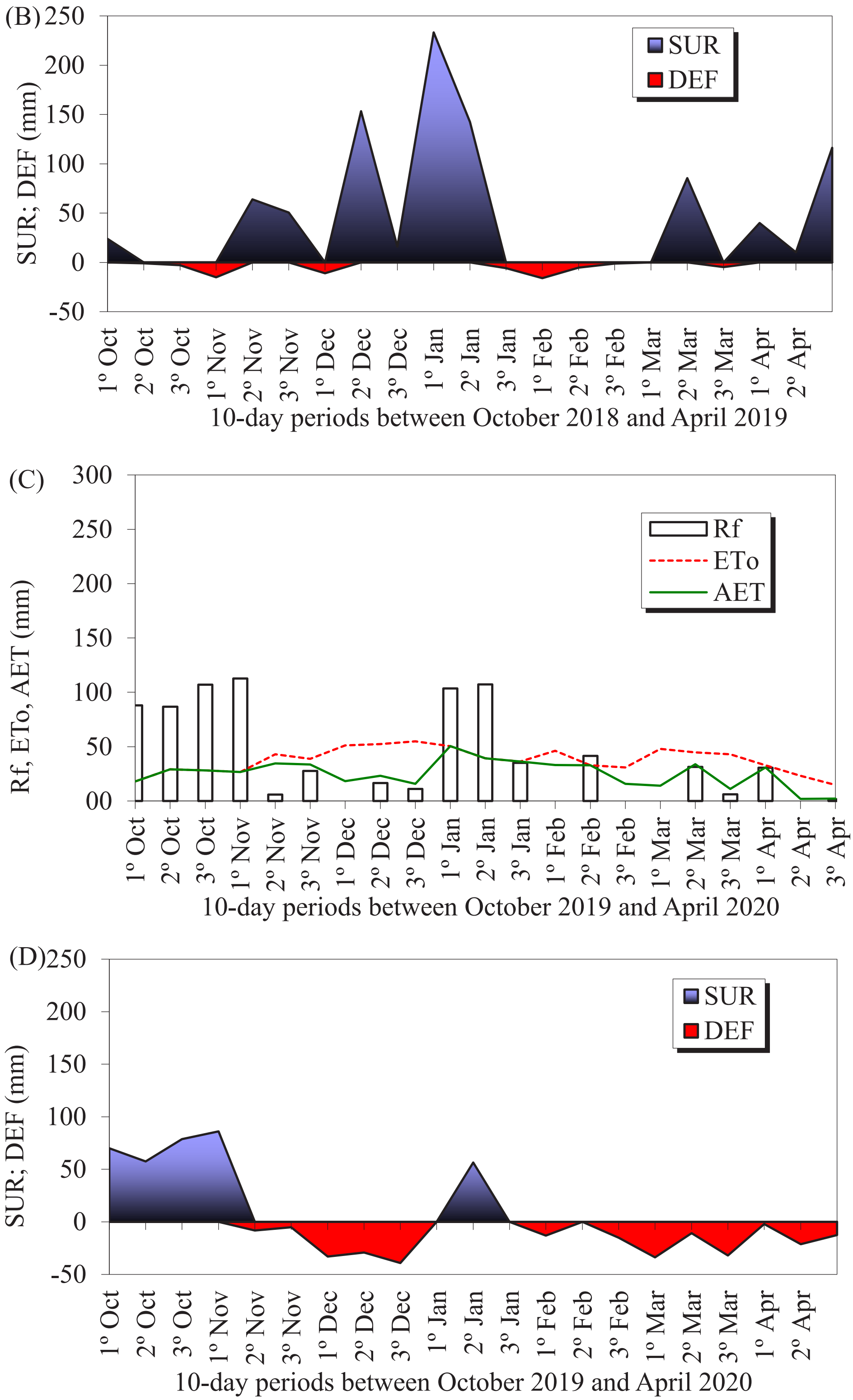


Figure 1. Rainfall (Rf), reference evapotranspiration (ETo), actual evapotranspiration (AET), and sequential water balance (surplus and deficit) for the 2018/19 (A and B) and 2019/20 (C and D) crop seasons in the municipality of São Vicente do Sul – RS.

By contrast, the 2019/2020 season exhibited two distinct phases, initial excessive rainfall during crop establishment, followed by severe water deficit during the reproductive phase (Figures 1C and 1D). During the ten-day periods of October, cumulative rainfall exceeded 250 mm, with surpluses of 58-86 mm persisting until late November, which hindered sowing and crop establishment. However, from December to March, rainfall was low, with deficits of up to 39 mm, compromising emergence and development, primarily in late-sown cultivars. Zanon et al. (2016) found that rainfall during January, February, and March is essential to ensure high soybean yield potential because most fields are in the reproductive stage (flowering and grain filling), when the crop is most sensitive to water stress.

ANOVA revealed that sowing date significantly affected yield and other traits in both crop seasons.

During the 2018/19 season, continuous excess water stress favored early sowings in the first two periods (10/19 and 11/29), resulting in higher yields. Sowing after November 29 reduced yield by 23.4 kg ha^{-1} day^{-1} (Figure 2A). Early sowings allowed plants to develop fully before entering the reproductive phase, benefiting from favorable temperature and solar radiation during critical stages (Zanon et al., 2018). However, late sowings at the end of December (11/29) resulted in lower average yields due to a shortened vegetative phase and lower solar radiation during the critical flowering period, underscoring the importance of the sowing date for maximizing soybean yield (Amorim et al., 2011).

By contrast, in the 2019/20 season, characterized by drought stress during the vegetative and reproductive periods, later sowings increased the average yield of the cultivars. Yields improved by approximately 9 kg ha^{-1} day^{-1} compared to the first sowing date (10/24) (Figure 2B). Additionally, high rainfall in October compromised crop establishment which, when combined with drought stress during flowering, reduced the average yield potential. This stress affects yield components differently depending on when it occurs: early flowering stress reduces the number of pods per plant, while stress during grain filling reduces grain size (Oya et al., 2004).

It is important to note that the timing of critical phenological stages and adaptation to lowland soils vary among cultivars. In this context, Figures 3A and 3B illustrate cultivar-specific yield responses to sowing date in the two crop seasons.

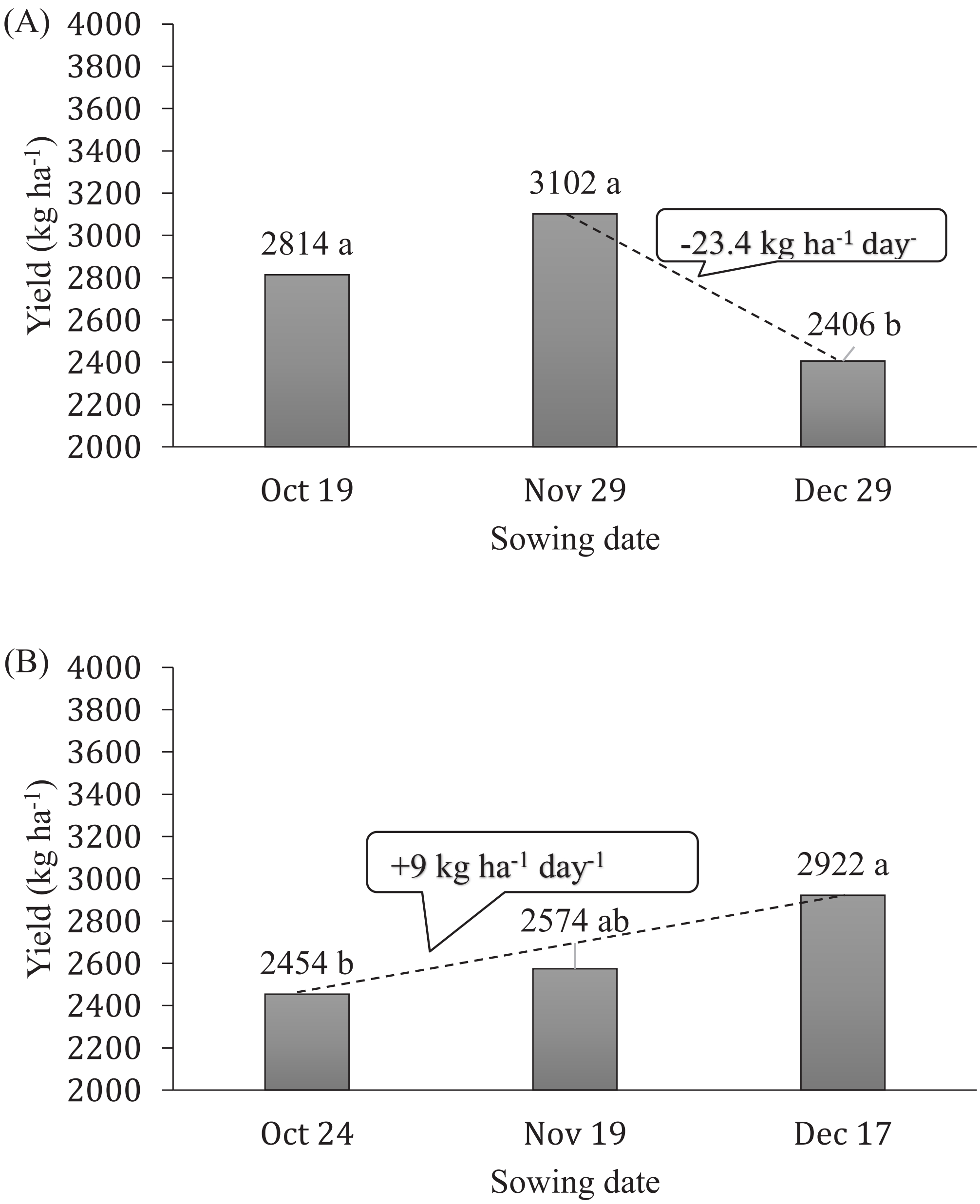


Figure 2. Effect of sowing date on soybean yield across three sowing dates during the 2018/19 (A) and 2019/20 (B) crop seasons in the municipality of São Vicente do Sul – RS. *Means followed by the same letter do not differ statistically according to Tukey's test at 5% probability.

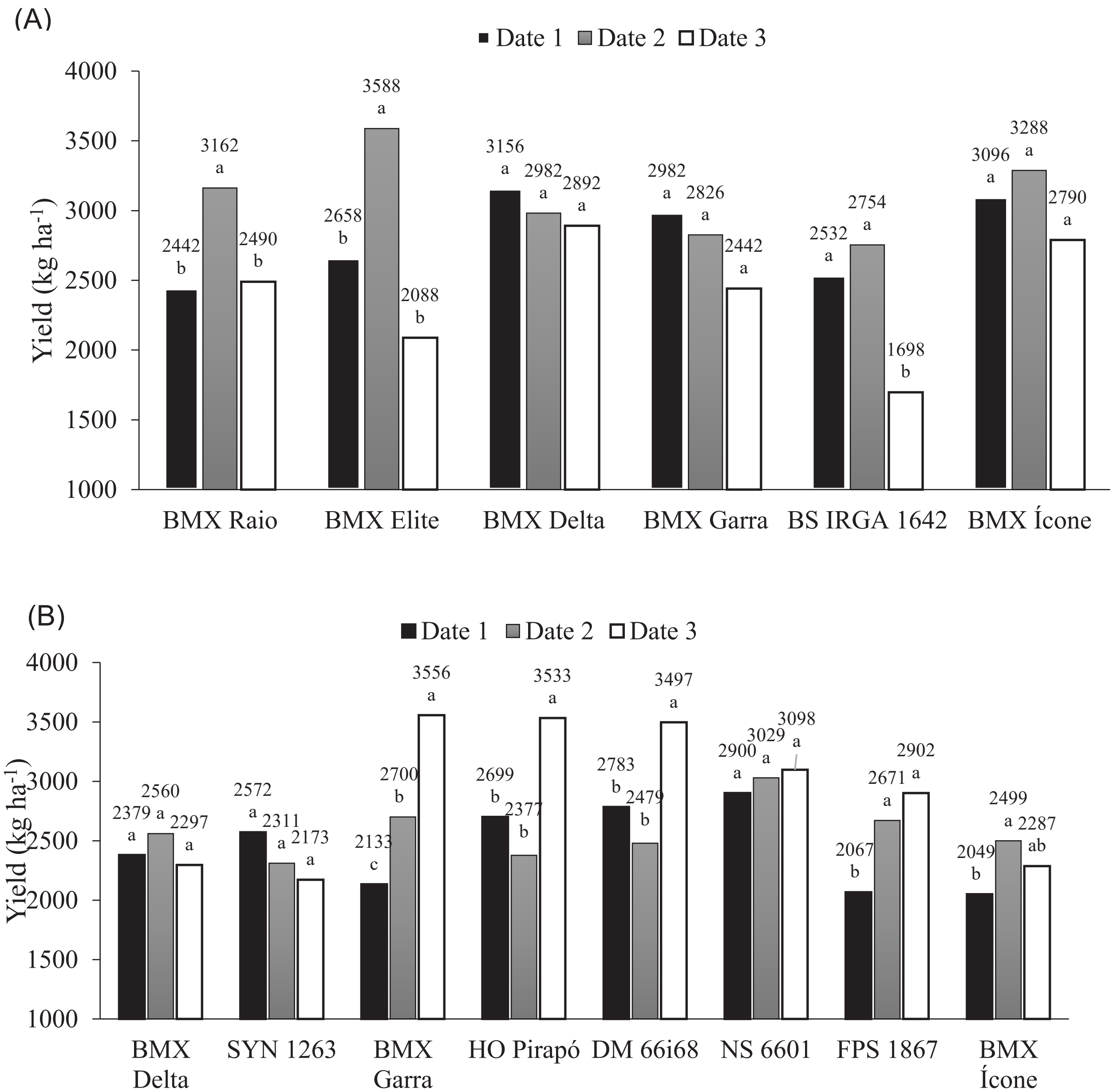


Figure 3. Interaction between sowing date and cultivar on soybean yield during the 2018/19 (A) and 2019/20 (B) crop seasons in the municipality of São Vicente do Sul – RS. *Means followed by the same letter do not differ statistically within sowing dates for each cultivar, according to Tukey's test at 5% probability.

Under excess water stress (2018/19 season), earlier cultivars (with low relative maturity groups), such as BMX Raio and BMX Elite, performed better with November sowings (period 2). Cultivars BMX Delta, BMX Garra, and BMX Ícone showed broad adaptation to the lowland environment under excess water stress, allowing a longer sowing window. Under drought stress (2019/20 season), BMX Garra, HO Pirapó, DM 66i68, and NS 6601 showed high yield potential and adapted well to later sowings.

These variations in cultivar yield responses across different crop seasons and sowing dates can be attributed to differences in relative maturity groups (RMGs), as illustrated in Figures 4A and 4B. Thus, for early sowing, especially in crops exeriencing drought stress from excess moisture such as during El Niño years, medium- or late-maturing cultivars (RMG > 5.5) are recommended. This is because early-maturing cultivars tend to flower prematurely, have reduced plant height, and consequently lower yield (Stochero et al., 2020). Conversely, the same authors emphasize that delaying the sowing date for cultivars with larger RMGs shortens the reproductive phase (R1-R8) and overall development period (EM-R8). Therefore, early sowing extends the crop cycle, while late sowing shortens it, with consistent effects across all RMGs, directly affecting final yield (Zanon et al., 2015).

In the 2019/20 season, cultivars with larger RMGs achieved the highest yield, especially when sown at later dates. This may be due to their greater adaptability to different sowing dates and improved capacity to recover from short-term stress events such as drought, waterlogging, or high temperatures (Zanon et al., 2015).

Plant height varied with sowing date in both crop seasons. In 2018/19, the first sowing date (10/19) produced the tallest plants, not significantly different from the second date (11/29), while the third date (12/29) resulted in the shortest average plant height (49 cm). In 2019/20 season, the tallest plants were recorded at the second sowing date (11/19), followed by the first (10/24). This is attributed to the increasing photoperiod in October and November, allowing greater vegetative growth before the reproductive stage (Barros & Sediyama, 2009). Delayed sowing gradually reduced plant height, likely due to a shortened reproductive period sensitive to climate variations (Amorim et al., 2011). Weber (2017) identified an optimal plant height of 105 cm for reaching a yield potential of 6.0 Mg ha^{-1}. This relationship between plant height and grain yield also affects weed control and can minimize losses during mechanized harvesting.

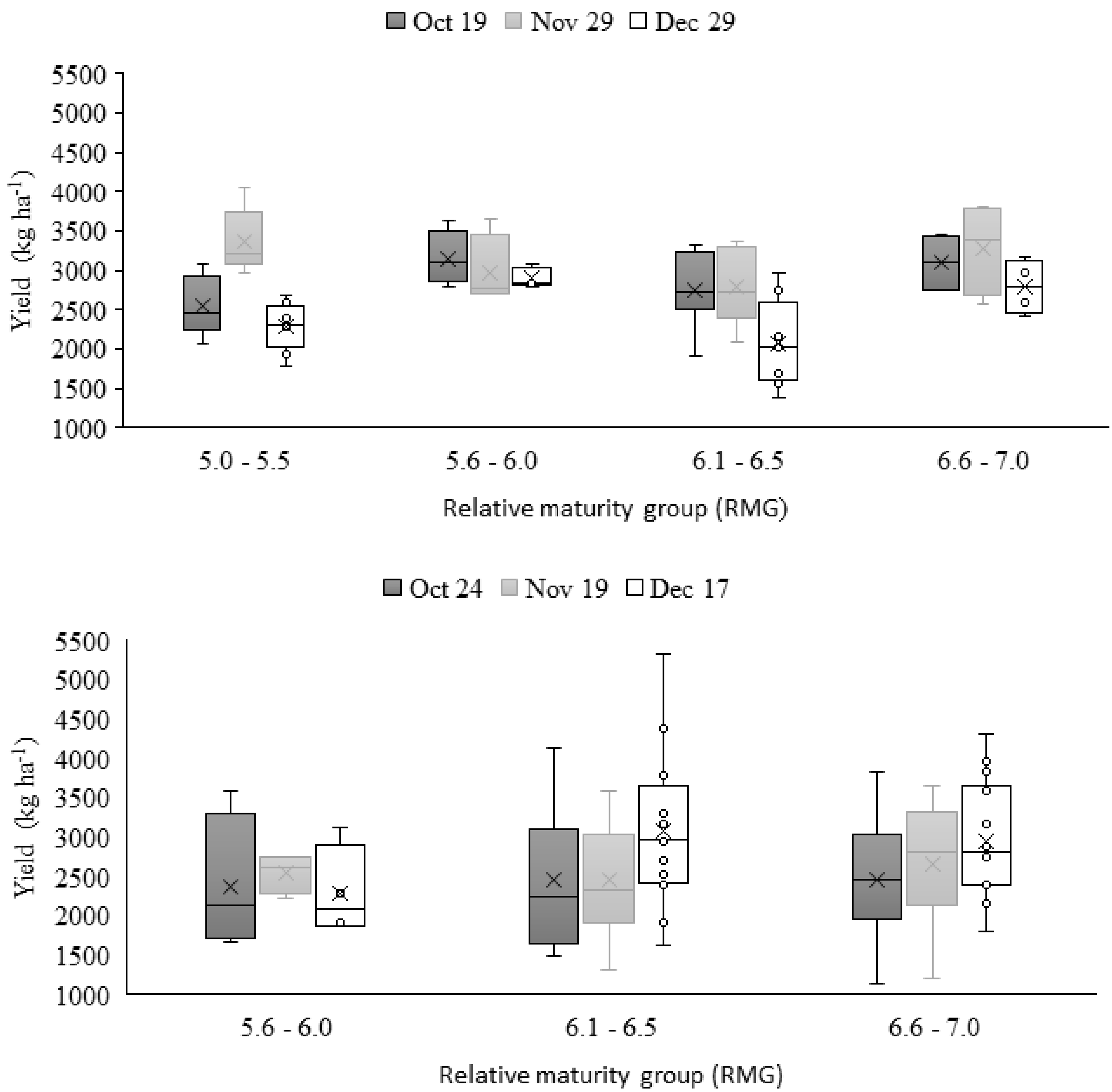


Figure 4. Soybean yield in relation to relative maturity group and sowing date during the 2018/19 (A) and 2019/20 (B) crop seasons in the municipality of São Vicente do Sul – RS.

Grain yield is a complex variable influenced by genetic factors, the environment, and management practices, which can either enhance or limit yield potential (Zanon et al., 2018). To understand these effects, grain yield can be analyzed through its component traits.

Thousand-grain weight (TGW) is genetically determined, but also influenced by environmental factors, including rainfall, sowing density, and pest and disease management (Weber, 2017). Analyzing the cultivars used across both crop seasons reveals that during the 2018/19 season, TGW was higher in early sowings under excess water stress, with losses reaching up to 33 grams in late sowing. By contrast, late sowing improved TGW in 2019/20, which exhibited water deficit during grain filling, causing poor grain formation (Table 2).

Table 2
Soybean yield components at different sowing dates in lowland soils in São Vicente do Sul, Rio Grande do Sul state, Brazil

Sowing date	HP	TSW (g)	NPP	NSP
		2018/19 crop season		
Date 1	69.1 a	163.8 a	61.7 b	149.9 b
Date 2	65.8 a	171.7 a	68.1 a	160.7 a
Date 3	49.1 b	138.8 b	70.0 a	164.5 a
CV (%)	11.08	7.6	13.5	14.7
		2019/20 crop season		
Period 1	86.0 b	128.7 b	101.1 a	243.6 a
Period 2	93.5 a	121.1 c	76.5 b	188.5 b
Period 3	70.6 c	142.7 a	78.6 ab	196.8 ab
CV (%)	9.4	8.1	41.89	40.7

* Means followed by the same letter do not differ statistically, according to Tukey's test at 5% probability. Ht- height plant; TSW-thousand-seed weight, NPP- number of pods per plant, NSP- number of seeds per plant.

For the number of pods and grains per plant, patterns were generally opposite to TGW and yield. Later sowings in 2018/19 produced more pods and grains per plant, with the first and last sowings showing the highest potential. This is primarily due to water stress during the flowering stages, which prevents flower and pod set (Weber, 2017). The number of pods per plant depends directly on the number of flowers successfully set during the reproductive period (Mundstock & Thomas, 2005). This yield component is most sensitive to planting arrangements and management practices, whereas grain number per pod and grain weight are more strongly controlled by genetics and environmental factors (Zanon et al., 2018).

Conclusions

Sowing date was a key factor influencing soybean performance in lowland soils under different water conditions. In crop seasons with excess water, early sowings from the second half of October to November produced the highest yields, making medium-to late-maturing cultivars the preferred choice. Conversely, in seasons with water deficit, later sowings favored higher yields.

Among the cultivars evaluated, BMX Delta, BMX Garra, and BMX Icone showed good adaptation to the lowland environment under excess water conditions. BMX Garra, HO Pirapó, DM 66i68, and NS 6601 excelled under water deficit, demonstrating high yield potential and suitability to later sowing dates.

Agronomic traits such as plant height, thousand-grain weight, and the number of pods and grains per plant are significantly affected by sowing date and seasonal climate.

Acknowledgments

We thank the National Council for Scientific and Technological Development (CNPq) for the research grant, and the Farroupilha Federal Institute - São Vicente do Sul Campus for providing the necessary facilities.

References

Amorim, F. A., Hamawaki, O. T., Sousa, L. B., Lana, R. M. Q., & Hamawaki, C. D. L. (2011). Época de semeadura no potencial produtivo de soja em Uberlândia-MG. *Revista Semina, 32*(4, Sup1), 1793-1802. doi: 10.5433/1679-0359.2011v32n4Sup1p1793

Barros, H. B., & Sediyama, T. (2009). Luz, umidade e temperatura. In T. Sediyama (Ed.), *Tecnologias de produção e usos da soja* (Cap. 3, pp. 17-27). Londrina, PR, Brasil.

Bortoluzzi, M. P., Heldwein, A. B., Trentin, R., Maldaner, I. C., & Rosa da Silva, J. (2020). Risk of occurrence of water deficit in soybean cultivated in lowland soils. *Earth Interactions, 24*(4), 1-9. doi: 10.1175/EI-D-19-0029.1

Carmona, F. C. (2020). *Dificuldades e soluções para o cultivo de soja nas terras baixas da Metade Sul do Rio Grande do Sul.* Plantio Direto e Tecnologia Agrícola. https://www.plantiodireto.com.br/artigos/37

Empresa Brasileira de Pesquisa Agropecuária (2020). *Manejo da soja em terras baixas para alta produtividade.* (Circular Técnica n.º 207). EMBRAPA Clima Temperado. https://www.infoteca.cnptia.embrapa.br/handle/doc/1126892

Islam, M. M., Chen, X., & Liu, G. (2023). Physiological and agronomic responses and nutrient uptake of soybean genotypes cultivated under various sowing dates. *Journal of Soil Science and Plant Nutrition, 23*(4), 1478-1492. doi: 10.1007/s42729-023-01389-y

Manghwar, H., Hussain, A., Alam, I., Khoso, M. A., Ali, Q, & Liu, F. (2024). Waterlogging stress in plants: unraveling the mechanisms and impacts on growth, development, and productivity. *Environmental and Experimental Botany, 224*(1), 105824. doi: 10.1016/j.envexpbot.2024.105824

Mundstock, C. M., & Thomas, A. L. (2005). *Soja: fatores que afetam o crescimento e o rendimento de grãos.* https://www.ufrgs.br/agronomia/plantas/destaques/livro_soja.php

National Supply Company [CONAB] (2025). *Acompanhamento da safra brasileira: grãos, safra 2024/25- 9º levantamento.* CONAB. https://www.gov.br/conab/pt-br/atuacao/informacoes-agropecuarias/safras/safra-de-graos/boletim-da-safra-de-graos/9o-levantamento-safra-2024-25

Oliveira, Z. B., Knies, A. E., Rodrigues, L. R., Schmidt, D. A., & Gonçalves Kury, A. (2021). Produtividade da soja em função da época da semeadura e da irrigação suplementar na região central do RS. *Irriga, 26*(4), 774-786. doi: 10.15809/irriga.2021v26n4p774-786

Oya, T., Nepomuceno, A. L., Neumaier, N., Farias, J. R., Tobita, S., & Ito, O. (2004). Drought tolerance characteristics of Brazilian soybean cultivars: evaluation and characterization of drought tolerance of various Brazilian soybean cultivars in the field. *Plant Production Science, 7*(2), 129-137. doi: 10.1626/pps.7.129

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

Stochero, E. C., Maldaner, I. C., Meneghetti, C. B., Halberstadt, C. M., Bolzan, F. T., & Streck, E. A. (2020). Fenologia de cultivares de soja em diferentes datas de semeadura em terras baixas. *ScientiaTec, 7*(2), 30-46. doi: 10.35819/scientiatec.v7i2.3787

Streck, E. V., Kämpf, N., Dalmolin, R. S. D., Klamt, E., Nascimento, P. C., Schneider, P., Giasson, E., & Pinto, L. F. S. (2008). *Solos do Rio Grande do Sul.* Emater/RS.

Weber, P. S. (2017). *Componentes de rendimento e grupo de maturidade relativa que influenciam o potencial de produtividade em soja.* [Trabalho de Conclusão de Curso, Universidade Federal de Santa Maria, Santa Maria, RS, Brasil].

Wu, C., Zeng, F., & Chen, J. (2025). Impact of flooding at the early reproductive growth stage on soybean yield and seed composition. *Crop Science, 65*(1), 110-123. doi: 10.1002/csc2.21397.

Zanon, A. J., Silva, M. R. da, Tagaliapietra, E. L., Cera, J. C., Bexaira, K. P., Richter, G. L., Duarte Júnior, A., Rocha, T. S. M. da, Weber, P. S., & Streck, N. A. (2018). *Ecofisiologia da soja visando altas produtividades.* Field Crops.

Zanon, A. J., Streck, N. A., & Grassini, P. (2016). Climate and management factors influence soybean yield potential in a subtropical environment. *Agronomy Journal, 108*(4), 1447-1454. doi: 10.2134/agronj2015.0535

Zanon, A. J., Winck, J. E., Streck, N. A., Rocha, T. S., Cera, J. C., Richter, G. L., Lago, I., Santos, P. M., Maciel, L. R., Guedes, J. V., & Marquesan, E. (2015). Desenvolvimento de cultivares de soja em função do grupo de maturação e tipo de crescimento em terras altas e terras baixas. *Bragantia, 74*(4), 400-411. doi: 10.1590/1678-4499.0043

Zhou, C., Zeng, F., & Chen, J. (2020). Plant waterlogging/flooding stress responses: from seed germination to maturation. *Plant Physiology and Biochemistry, 148*(1), 228-236. doi: 10.1016/j.plaphy.2020.01.020