COMPARISON OF WATER PERFORMANCE OF SOYBEAN - *GLYCINE MAX* (L.) - AT EARLY AND LATE SOWING DATES IN BAIXO ACRE REGION, AC

Rafael Carlos Barbosa[1], Jefferson Vieira José[2], Kelly Nascimento Leite[2], Thiago Alves Santos de Oliveira[1], Otávio Neto Almeida Santos[3], Marília Alves Brito Pinto[4]

ABSTRACT: This study aimed to compare the water performance of soybean cultivation at early and late sowing dates in the Baixo Acre Region, Acre, to support management strategies and minimize climatic risks. Water balances and the Water Requirement Satisfaction Index (ISNA) were simulated using daily climate data from 1961 to 2020, considering two representative dates: August 1st (early) and November 1st (late). Results showed that early sowing presented a higher risk of water deficit during critical development phases, especially during phase III (flowering and grain filling), with average deficit values exceeding 60 mm. Late sowing (November) showed favorable water conditions, with no deficit and a high occurrence of excess water, indicating greater water supply security but a potential risk of waterlogging. The choice of sowing date directly affects water availability throughout the cycle, influencing yield and crop management. The results contribute to adjusting agricultural zoning and highlight the importance of considering regional climatic scenarios in agricultural planning.
KEYWORDS: agricultural zoning, water balance, management

COMPARAÇÃO DO DESEMPENHO HÍDRICO DA SOJA - (*GLYCINE MAX* (L.) - EM DATAS DE SEMEADURA PRECOCES E TARDIAS NA REGIONAL DO BAIXO ACRE, AC

RESUMO: O presente trabalho objetivou comparar o desempenho hídrico da cultura da soja em datas de semeadura precoces e tardias na Regional do Baixo Acre, Acre, visando apoiar estratégias de manejo e minimizar riscos climáticos. Para tanto, foram simulados balanços

[1] Graduando em Agronomia, UFAC, Cruzeiro do Sul, AC
[2] Professor Doutor, UFAC, Cruzeiro do Sul, AC
[3] Professor, UESB, Estr. Bem Querer, Km-04 - 3293, 3391, CEP 45083-900, Vitória da Conquista, BA. Fone (77) 3424-8650. e-mail: otavio.santos@uesb.edu.br
[4] Pesquisadora, UESB, Vitória da Conquista, BA

hídricos e o Índice de Satisfação da Necessidade de Água (ISNA) com base em dados climáticos diários de 1961 a 2020, considerando duas datas representativas: 1º de agosto (precoce) e 1º de novembro (tardia). Os resultados evidenciaram que a semeadura precoce apresentou maior risco de déficit hídrico durante as fases críticas de desenvolvimento, principalmente na fase III (floração e enchimento de grãos), com valores médios de déficit superiores a 60 mm. Já a semeadura tardia (novembro) apresentou condições hídricas favoráveis, com eliminação do déficit e ocorrência de elevado excesso hídrico, indicando maior segurança de suprimento de água, porém com potencial risco de encharcamento. A escolha da data de plantio impacta diretamente a disponibilidade hídrica ao longo do ciclo, influenciando o rendimento e o manejo da cultura. Os resultados contribuem para o ajuste do zoneamento agrícola e reforçam a importância de considerar cenários climáticos regionais no planejamento agrícola.
PALAVRAS-CHAVE: zoneamento agrícola, balanço hídrico, manejo

INTRODUCTION

Soybean (*Glycine max* (L.) Merrill) holds a strategic position in Brazilian agribusiness, standing out as the main agricultural commodity and contributing significantly to the sector's Gross Domestic Product (GDP) (MAPA, 2023). Brazil has established itself as the world's largest producer and exporter of soybeans, a result of the significant expansion of cultivated areas and improvements in management practices, including the selection of adapted cultivars and the efficient use of water resources (CONAB, 2023).

The expansion into new agricultural frontiers, such as the Cerrado and northern regions of the country, has introduced additional challenges related to climate variability, especially concerning irregular rainfall distribution and the occurrence of dry spells during the rainy season (Melo et al., 2020). Successful soybean production depends directly on synchronizing crop phenology with the water regime, with Agricultural Zoning for Climate Risk (ZARC) being an essential tool for guiding optimal sowing windows and mitigating risks associated with water deficits or excesses (Sentelhas et al., 2015; Cunha et al., 2001).

The definition of the sowing date has a strong influence on soybean productive performance, as it allows the crop to avoid exposure to critical periods of water deficit, especially during flowering and grain filling stages, which are considered the most sensitive to water stress (Berlato & Fontana, 1999; Farias et al., 2007).

The Water Requirement Satisfaction Index (WRSI) stands out as a robust indicator for assessing water supply in relation to crop demand, enabling the estimation of production risks across different sowing periods and regions (Cunha et al., 2001; Aparecido et al., 2021).

In the Northern region and the state of Acre, the use of water balance analyses to support agricultural planning becomes even more relevant, given the high intra- and interannual rainfall variability, combined with the vulnerability of rainfed production systems (José et al., 2025). Furthermore, the recent expansion of soybean cultivation into areas traditionally occupied by pastures or native vegetation requires detailed studies to ensure water sustainability and reduce economic and environmental risks (Andrade & Collicchio, 2022).

Thus, the present study aimed to compare the water performance of soybean under different sowing dates (early and late), using climatic water balance and the Water Requirement Satisfaction Index as tools to evaluate the risks of water deficit and excess throughout the crop cycle.

MATERIAL AND METHODS

The study was conducted in the Baixo Acre region, in the state of Acre, covering the municipalities of Acrelândia, Capixaba, Plácido de Castro, Porto Acre, Rio Branco, and Senador Guiomard, characterized by a hot and humid climate, with an average annual precipitation exceeding 1,900 mm (INMET, 2020). For climatological characterization and definition of sowing dates, historical data on precipitation, reference evapotranspiration (ETo), and temperature were obtained from the National Institute of Meteorology (INMET) and the National Water and Sanitation Agency (ANA), using a historical series of at least 20 years.

The climatic water balance was calculated using the method proposed by Thornthwaite and Mather (1955), considering a soil available water capacity (AWC) of 100 mm, consistent with the physical characteristics of the predominant soils in the region (EMBRAPA, 2020). Two representative sowing dates were defined for analysis: an early sowing date (early August) and a late sowing date (early November), corresponding to the extreme scenarios commonly adopted by local farmers and included in the official Agricultural Zoning for Climate Risk (ZARC).

The Water Requirement Satisfaction Index (WRSI) was calculated for each phenological stage of soybean (from emergence to vegetative development, flowering, grain filling, and physiological maturity), following the methodology described by Farias et al. (2007), allowing the quantification of water adequacy throughout the crop cycle. For each sowing date, cumulative water deficits, surpluses, and critical periods were evaluated, enabling a direct comparison between early and late sowing strategies.

The data were organized in electronic spreadsheets and analyzed in percentage terms, highlighting the occurrence of water deficit or excess in each phase, based on historical average behavior. This procedure allowed the identification of potential loss risks depending on the sowing date, providing technical support for regional crop management.

RESULTS AND DISCUSSION

For the sowing date of August 1st, precipitation values ranged from 538.5 mm (Porto Acre) to 558.1 mm (Plácido de Castro), while the reference evapotranspiration (ETo) was approximately 487.2 mm for the region. The crop evapotranspiration (ETc) was slightly lower than the ETo, indicating that the soil retained sufficient moisture to meet the crop's water demand. The water surplus varied between 146.1 mm (Capixaba) and 170.4 mm (Acrelândia), whereas the highest water deficit was observed in Porto Acre (70.4 mm), reflecting a moderate water balance but with potential deficit risks (Table 1).

Table 1. Mean values of rainfall (Ppt), reference evapotranspiration (ETo), crop evapotranspiration (ETc), water surplus (EXC), and water deficit (DEF) for soybean in two sowing dates in the Baixo Acre region, Acre State, from 1961 to 2020.

Sowing	Municipality	Ppt	ETo	ETc	EXC	DEF
August 1st	Acrelândia	557.4	486.9	456.3	170.4	70.2
	Bujari	544.9	486.2	455.6	152.9	65.1
	Capixaba	542.2	485.2	454.6	146.1	59.5
	Plácido de Castro	558.1	488.7	458.0	166.8	67.5
	Porto Acre	538.5	487.3	456.5	151.1	70.4
	Rio Branco	542.6	488.8	458.0	148.4	65.1
	Senador Guiomard	544.5	487.1	456.4	148.9	62.0
	Regional do Baixo Acre	546.9	487.2	456.5	154.9	65.7

Sowing	Municipality	Ppt	ETo	ETc	EXC	DEF
November 1 st	Acrelândia	1139.5	445.8	411.9	716.0	0.0
	Bujari	1120.0	445.4	411.6	698.8	0.0
	Capixaba	1072.8	445.6	411.8	648.9	0.0
	Plácido de Castro	1129.9	447.6	413.6	704.4	0.0
	Porto Acre	1126.7	446.1	412.2	705.4	0.0
	Rio Branco	1113.9	447.7	413.7	690.4	0.0
	Senador Guiomard	1099.6	446.4	412.6	676.5	0.0
	Regional do Baixo Acre	1114.6	446.4	412.5	691.5	0.0

For the sowing date of November 1st, an increase in rainfall was observed, reaching values above 1,000 mm. The water surplus increased significantly, exceeding 700 mm in

Acrelândia, Plácido de Castro, and Porto Acre, and the water deficit was completely eliminated (Table 1), reinforcing the hypothesis that late sowings provide greater water security for the crop.

The initial phase of germination and emergence is crucial for crop establishment, as plants are more vulnerable to adverse conditions, such as water shortage, during this period. According to the presented data, it was observed that in both sowing dates, Phase I did not show significant water deficit (Figure 1).

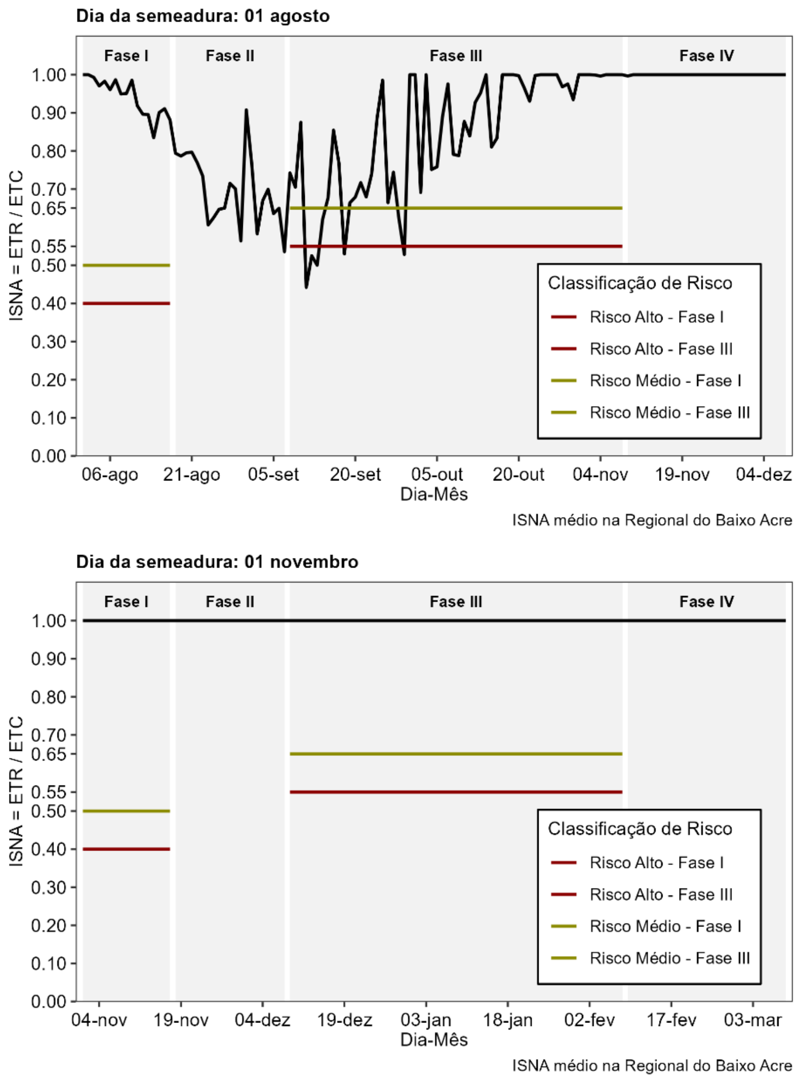

Figure 1. Variation of the Water Requirement Satisfaction Index (WRSI) throughout the soybean crop cycle for sowings in Phases I and III, carried out in August and November in the Baixo Acre region.

In the sowing carried out in August, during Phase III, the WRSI indicated a water deficit on 5 days with high risk and 2 days with moderate risk. For the November sowing, Phase III did not show any water deficit, with WRSI values remaining above 0.65, indicating favorable water conditions for crop development (Figure 1). Recent studies have shown that WRSI values above 0.65 indicate low climatic risk, while values below 0.55 represent high productivity risk and may lead to a drastic reduction in yield potential (Melo et al., 2020; Farias et al., 2024).

Phase III, which encompasses the flowering and grain filling period, is considered the most critical stage for soybean cultivation. According to Farias et al. (2024), severe deficits during this stage can compromise pod set, reduce the number of seeds per pod, and impair final grain filling, resulting in significant yield losses.

This trend is also reflected in the historical frequency of water deficit occurrence by phenological stage, presented in Table 2, which shows a markedly higher incidence of stress during reproductive stages in early sowing scenarios.

Table 2. Relative frequency (%) of water deficit occurrence in each phenological stage of soybean (I – Emergence/Vegetative Development; II – Pre-flowering; III – Flowering/Grain Filling; IV – Maturation), for two sowing dates between 1961 and 2020 in the Baixo Acre region, Acre State, Brazil.

Sowing Date		**High**	**Medium**	**Low**
Mês	**Day**	WRSI < **0,55**	**0,55** > WRSI < **0,65**	WRSI > **0,65**
August	1	5	2	55
	15	-	61	1
September	1	-	-	62
	15	-	-	62
October	1	5	2	55
	15	-	-	-
November	1	-	-	62
	15	-	-	62
December	1	-	-	62
	15	-	-	62
January	1	-	-	62
	15	-	-	62
February	1	-	-	62
	15	-	-	62
March	1	-	-	62
	15	7	52	3
April	1	22	4	36
	15	34	6	22
May	1	48	8	6
	15	55	6	1
June	1	55	5	2
	15	46	9	7
July	1	32	11	19
	15	19	10	33

An interannual frequency analysis of water deficit occurrence revealed consistent patterns of climatic risk depending on the sowing date. When sowing was performed on August 1st, Phase III (flowering and grain filling) exhibited water deficit in 76.3% of the years analyzed, while Phase II showed deficits in 53.4% of the years. In contrast, sowing on November 1st reduced the frequency of deficit in Phase III to 18.6%, and practically eliminated water deficit in Phases I and IV (Figure 2). These findings reinforce the interpretation of the WRSI values and highlight the increased vulnerability of reproductive stages to early sowing in the Baixo Acre region.

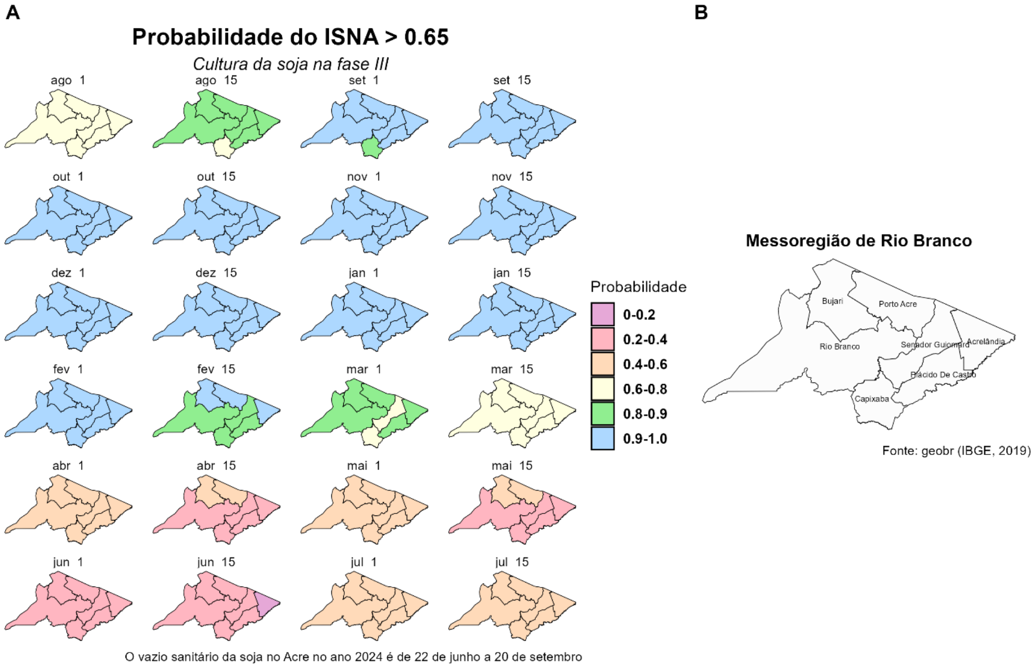

Figure 2. Percentage of years with water deficit occurrence in each soybean phenological stage (I to IV), for sowings in August and November, based on historical data from 1961 to 2020 in the Baixo Acre region.

Such a high recurrence of water stress during critical phenological phases in early sowing scenarios poses a major threat to yield stability, particularly in municipalities like Capixaba, Senador Guiomard, and Porto Acre, where rainfall irregularity is more pronounced. This temporal analysis provides further evidence that aligning sowing schedules with periods of historically lower water déficit, as observed in November, is a key strategy to ensure water adequacy and reduce climate-related yield losses in rainfed soybean systems.

CONCLUSIONS

This study demonstrated that soybean cultivation in the Baixo Acre region offers greater water security when sown in November, a period during which the Water Requirement Satisfaction Index (WRSI) remains above 0.65 throughout the critical flowering and grain filling stage, validating the recommendations of ZARC. On the other hand, early sowings

(August) present significant risks of water deficit, especially in municipalities such as Capixaba and Senador Guiomard, where rainfall variability is more pronounced.

Although the study has limitations, such as its dependence on historical data, its results provide a solid basis for agricultural planning, aligning productivity and resource conservation, and pave the way for future field studies to validate these recommendations.

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