WATER INDICES AND EVAPOTRANSPIRATION OF FORAGE PLANTS GROWN IN SEMI-ARID ENVIRONMENTS: A REVIEW

ÍNDICES HÍDRICOS E EVAPOTRANSPIRAÇÃO DE PLANTAS FORRAGEIRAS CULTIVADAS EM AMBIENTE SEMIÁRIDO: UMA REVISÃO

ÍNDICES HÍDRICOS Y EVAPOTRANSPIRACIÓN DE PLANTAS FORRAJERAS CULTIVADAS EN AMBIENTES SEMIÁRIDOS: UNA REVISIÓN

https://doi.org/10.56238/edimpacto2025.080-006

Pedro Paulo Santos de Souza[1], Lara Rosa de Lima e Silva[2], Márcia Bruna Marim de Moura[3] , Klébia Raiane Siqueira de Souza[4], Gustavo Laurindo da Silva[5], Luciana Sandra Bastos de Souza[6], Alexandre Maniçoba da Rosa Ferraz Jardim[7], Cleber Pereira Alves[8], Lady Daiane Costa de Sousa Martins[9], Wagner Martins dos Santos[10], Elania Freire da Silva[11], Thieres George Freire da Silva[12]

[1] Master's student in Plant Production. Universidade Federal Rural de Pernambuco (UFRPE).
E-mail: pedro.paulossouza057@gmail.com Orcid: 0009-0001-1403-0169
Lattes: http://lattes.cnpq.br/7010919912848920.
[2] Master's student in Plant Production. Universidade Federal Rural de Pernambuco (UFRPE).
E-mail: lara.rosa@ufrpe.br Orcid: 0009-0000-3312-1800
Lattes: http://lattes.cnpq.br/2018292846131861
[3] Master's student in Biodiversity and Conservation. Universidade Federal Rural de Pernambuco (UFRPE).
E-mail: marciabruna78@gmail.com Orcid: 0000-0002-4255-0735
Lattes: http://lattes.cnpq.br/9275493400169999.
[4] Master's student in Biodiversity and Conservation. Universidade Federal Rural de Pernambuco (UFRPE).
E-mail: klebia.raiane@ufrpe.br Orcid:0009-0000-6263-017X
Lattes:http://lattes.cnpq.br/0240299184262533.
[5] Undergraduate student in Agronomy. Universidade Federal Rural de Pernambuco (UFRPE).
E-mail: gustavo.laurindo2023@gmail.com Orcid: 0009-0008-3117-9732
Lattes: http://lattes.cnpq.br/9575496490499349.
[6] Professor. Universidade Federal Rural de Pernambuco (UFRPE). E-mail: Luciana.sandra@ufrpe.br
Orcid: 0000-0001-8870-0295 Lattes: http://lattes.cnpq.br/1186468548787818.
[7] Dr. in Agricultural Engineering. Universidade Federal Rural de Pernambuco (UFRPE).
E-mail: cleberp.agro@gmail.com Orcid: 0000-0002-8796-6945
Lattes: http://lattes.cnpq.br/4951590346280646.
[8] Dr. in Agricultural Engineering. Universidade Federal Rural de Pernambuco (UFRPE).
E-mail: alexandremrfj@gmail.com Orcid:0000-0001-7094-3635
Lattes: http://lattes.cnpq.br/9981205244282499.
[9] Doctoral student in Agricultural Engineering. Universidade Federal Rural de Pernambuco (UFRPE).
E-mail: wagnnerms97@gmail.com Orcid: 0000-0002-3584-1323
Lattes: http://lattes.cnpq.br/4506292783833761.
[10] Doctoral student in Agricultural Engineering. Universidade Federal Rural de Pernambuco (UFRPE).
E-mail: lady.daiane@ufrpe.br Orcid:0000-0002-0942-4673
Lattes: http://lattes.cnpq.br/0248842512558444.
[11] Doctoral student. Universidade Federal Rural do Semi-Árido (UFERSA).
E-mail: elania.silva@alunos.ufersa.edu.br Orcid: 0000-0002-7176-3609
Lattes:http://lattes.cnpq.br/6644267105942189.
[12] Professor. Universidade Federal Rural de Pernambuco (UFRPE). E-mail: thieres.silva@ufrpe.br.
Orcid: 0000-0002-8355-4935 Lattes: http://lattes.cnpq.br/0213450385240546

ABSTRACT

The semi-arid environment is characterized by adverse edaphoclimatic conditions, such as low and irregular rainfall, high evapotranspiration, and low-fertility soils, imposing severe limitations on agricultural and livestock production. In this context, adaptive strategies for water management and the use of forage species adapted to these conditions become essential to ensure productivity and sustainability. This review aims to analyze and discuss the relationship between water indices, evapotranspiration, and water management strategies—including irrigation with brackish water (biosaline agriculture)—in the sustainable production of the BRS Capiaçu cultivar under semi-arid conditions. The study addresses the characterization of the semi-arid region and its limitations, the main morphological and productive characteristics of BRS Capiaçu, and the relevance of water management in mitigating water stress. Drip irrigation is highlighted as an efficient technique for the rational use of water, and biosaline agriculture as a promising alternative in the face of scarce good-quality water resources. In addition, the concepts of evapotranspiration and water use efficiency (WUE) are discussed as essential parameters for irrigation planning and management. It is concluded that the combination of adapted genetic materials, water management practices, and the use of brackish water constitutes a sustainable strategy to increase forage production and ensure the economic and environmental viability of livestock farming in the Brazilian semi-arid region, emphasizing the importance of BRS Capiaçu as a high-yield and drought-resilient alternative.

Keywords: *Pennisetum purpureum cv*. BRS Capiaçu. Supplemental Irrigation. Biosaline Agriculture. Water Use Efficiency.

RESUMO

O ambiente semiárido é caracterizado por condições edafoclimáticas adversas, como baixa e irregular precipitação, alta evapotranspiração e solos de baixa fertilidade, impondo severas limitações à produção agropecuária. Diante desse cenário, estratégias adaptativas de manejo hídrico e o uso de espécies forrageiras adaptadas tornam-se fundamentais para garantir a produtividade e a sustentabilidade. Este trabalho de revisão tem como objetivo analisar e discutir a relação entre os índices hídricos, a evapotranspiração e as estratégias de manejo de água, incluindo a irrigação com água salobra (agricultura biossalina), na produção sustentável da cultivar BRS Capiaçu em condições semiáridas. O estudo aborda a caracterização do semiárido e suas limitações, as principais características morfológicas e produtivas do BRS Capiaçu, e a relevância do manejo hídrico na mitigação do estresse hídrico. Destaca-se a irrigação por gotejamento como técnica eficiente no uso racional da água e a agricultura biossalina como alternativa promissora frente à escassez de recursos hídricos de boa qualidade. Além disso, são discutidos os conceitos de evapotranspiração e eficiência do uso da água (EUA) como parâmetros essenciais para o planejamento e gestão da irrigação. Conclui-se que a combinação entre materiais genéticos adaptados, práticas de manejo hídrico e uso de águas salobras constitui uma estratégia sustentável para elevar a produção de forragem e assegurar a viabilidade econômica e ambiental da pecuária no semiárido brasileiro, ressaltando-se a importância do BRS Capiaçu como alternativa de alto rendimento e resiliência ao estresse hídrico.

Palavras-chave: *Pennisetum purpureum cv*. BRS Capiaçu. Irrigação Complementar. Agricultura Biossalina. Eficiência do Uso da Água.

RESUMEN

El ambiente semiárido se caracteriza por condiciones edafoclimáticas adversas, como precipitación baja e irregular, alta evapotranspiración y suelos de baja fertilidad, lo que impone severas limitaciones a la producción agropecuaria. Ante este escenario, las estrategias adaptativas de manejo hídrico y el uso de especies forrajeras adaptadas se vuelven fundamentales para garantizar la productividad y la sostenibilidad. Este trabajo de revisión tiene como objetivo analizar y discutir la relación entre los índices hídricos, la evapotranspiración y las estrategias de manejo del agua—incluyendo el riego con agua salobre (agricultura biosalina)—en la producción sostenible de la cultivar BRS Capiaçu en condiciones semiáridas. El estudio aborda la caracterización del semiárido y sus limitaciones, las principales características morfológicas y productivas del BRS Capiaçu, y la relevancia del manejo hídrico en la mitigación del estrés hídrico. Se destaca el riego por goteo como una técnica eficiente en el uso racional del agua y la agricultura biosalina como una alternativa prometedora frente a la escasez de recursos hídricos de buena calidad. Además, se discuten los conceptos de evapotranspiración y eficiencia en el uso del agua (EUA) como parámetros esenciales para la planificación y gestión del riego. Se concluye que la combinación de materiales genéticos adaptados, prácticas de manejo hídrico y el uso de aguas salobras constituye una estrategia sostenible para incrementar la producción de forraje y asegurar la viabilidad económica y ambiental de la ganadería en el semiárido brasileño, resaltando la importancia del BRS Capiaçu como una alternativa de alto rendimiento y resiliencia al estrés hídrico.

Palabras clave: *Pennisetum purpureum cv*. BRS Capiaçu. Riego Complementario. Agricultura Biosalina. Eficiencia del Uso del Agua.

1 INTRODUCTION

The semi-arid environment is characterized by a combination of challenging edaphoclimatic factors, including irregular rainfall distribution, water scarcity, high evapotranspiration rates, and low fertility soils. These conditions impose severe limitations on agricultural production, especially with regard to the cultivation of forage species, essential for animal feed (Salvador *et al*., 2021).

These environments require the development of adaptive strategies that ensure the rational use of water and the maintenance of productivity, especially in the face of climate change scenarios and increased global climate variability (Araújo júnior *et al*., 2024). In view of the scenario of water stress and the growing demand for productive resilience, the search for management strategies and the development of adapted cultivars become imperative. Thus, forage species with high water efficiency, such as the *Pennisetum purpureum* cv. BRS Capiaçu, have stood out as promising alternatives for the sustainable production of biomass and animal feed in adverse conditions (Salvador *et al*., 2021; Saints *et al*., 2025).

Maintaining productivity in such environments requires the optimization of water management practices, with emphasis on complementary irrigation, which is essential to mitigate the effects of water deficit and high atmospheric demand. However, the limitation of good quality water drives the adoption of biosaline agriculture, which uses brackish groundwater in conjunction with the cultivation of salinity-tolerant species, as a sustainability strategy in regions where freshwater scarcity is critical (Silva *et al*., 2023).

In this context, in-depth knowledge about water demand and water use efficiency is crucial, as these water indices allow for more accurate irrigation planning and management, maximizing biomass productivity per unit of applied water. The main objective of this review work is to analyze and discuss the relationship between water indexes, evapotranspiration and water management strategies, including irrigation with brackish water (Biosaline Agriculture) for the sustainable production of the cultivar BRS Capiaçu under semiarid conditions.

2 CHARACTERIZATION OF THE SEMI-ARID REGION AND CLIMATE CHANGE

The production of forage species, as well as other crops of economic importance, is strongly influenced by meteorological conditions, which play a decisive role in agricultural systems. This influence is even more significant in semi-arid regions, where water scarcity requires the adoption of more resilient and efficient management strategies. Currently, arid and semi-arid regions represent about 55% of the planet's land, covering countries in Latin

America and the Caribbean, such as Mexico, Chile, Argentina and Brazil, totaling approximately 313 million people. (Hussain *et al.,* 2018).

In Brazil, the semi-arid region is recognized for its vulnerability to droughts and economic problems, although most of these regions are occupied by agricultural production areas. According to SUDENE (2021), this region has approximately a territorial extension of 1.35 million km², constituting 15% of the national territory, in which a large part is located in the Northeast region, occupying about 1,477 municipalities distributed in nine states (Ceará, Bahia, Sergipe, Alagoas, Minas Gerais, Paraíba, Piauí, Rio Grande do Norte and Pernambuco) (Figure 1). This locality has about 28,000,000 million people who are subject to vulnerability to the spatio-temporal variation of rainfall and increase in temperatures.

Figure 1

Delimitation of the Brazilian semi-arid region

Source: SUDENE, 2021/IBGE

The semi-arid climate is well characterized by irregularly distributed rainfall, scarce (< 800 mm per year^{-1}), accumulated in a short period of time (on average, three months) and average annual temperatures of 27°C (Sudene, 2021). In addition, most regions are a subtype classified by dry climate, with dry lands and high aridity index (<0.5), in which most soils are sandy in texture, with low fertility and organic carbon (Pinheiro *et al.,* 2021).

This edaphoclimatic characteristic can reduce water availability, directly affecting the yield of forage species and compromising agricultural and livestock production, which will be affected both by the annual amount of water required by the crop, and can be influenced by water quality by salinization, which can lead to desertification in some regions. According to the National Water Agency (ANA), the semi-arid region is the most vulnerable region in Brazil with regard to water availability. In addition, other predominant aspects must be considered in the semi-arid region, such as semi-flat relief, intense surface runoff that favors the leaching process, deciduous native vegetation rich in cacti that have morphological characteristics that are determinant for development in environments with abiotic and natural stresses (Lucena; Ferrer; Guilhermino, 2021).

3 BRS CAPIAÇU: A HIGH-YIELDING CULTIVAR OF IMPORTANCE AS A FORAGE PLANT ADAPTED TO THE SEMI-ARID

a. *Origin and development*

The advancement of technological packages and resilient practices has proven to be solutions in rural areas, aiming to improve the production of forage plants that can tolerate abiotic conditions during periods of scarcity, thus contributing to the supply of quality food for animal consumption (Bekele, 2025). In January 2015, an elephant grass cultivar, BRS Capiaçu (*Pennisetum purpureum*, Schumach.) by the Brazilian Agricultural Research Corporation (Embrapa), through the improvement program of the Embrapa Cattle and Milk department (Pereira *et al.,* 2016). Through the Active Germplasm Bank (BAGCE), the best progenies were obtained through crosses between elephant grass accessions, these materials were cloned, evaluated and conducted in 17 Brazilian states by the National Network of Elephant Grass Trials (RENACE), from 1999 to 2008 (Pereira *et al.,* 2016).

With this, the clone CNPGL 92-79-2 was obtained, originated from the cross between the Guaco IZ2 (BAGCE 60) and Roxo (BAGCE 57) accessions, which stood out in several locations and environments when submitted to several years of evaluation. Thus, due to its high yield potential and tall size, the cultivar named BRS Capiaçu (capiaçu means "big grass" in Tupi-Guarani), began to be registered with the Ministry of Agriculture, Livestock and Supply (MAPA) (Pereira *et al.,* 2021). Currently, this cultivar has great acceptability in the regions of the country, as it has different uses in animal feed, being provided as a complement in the ruminant's diet, as well as in a *Fresh* presenting high nutritional value and yield.

b. *Main characteristics of BRS Capiaçu*

In view of all the existing cultivars of elephant grass, although each of them has specific characteristics, BRS Capiaçu stands out in its productive and nutritional potential in relation to the others. The cultivar has late flowering, tall size (reaching up to five meters in height), vertical clumps (with many tillers), its roots are rhizomatous, the leaves with long blades (on average 1.25 m), wide (4 to 5 cm) and green, cylindrical stems of thick diameter, yellowish elongated internodes (which can exceed 20 cm); it has green/yellowish ligule and sheath and good resistance to tipping (Pereira *et al.,* 2016; Faithful *et al.,* 2020). To achieve the productive potential of the cultivar, it is necessary to adopt appropriate management from implantation, a determining factor for the success of the crop.

Therefore, planting should be recommended at the beginning of the rainy season, with the propagation medium via stem distributed in furrows of approximately 20-30 cm deep and the spacing between rows of 0.80 to 1.20 m. Foundation fertilization and the use of correctives should be applied based on the results of the soil analysis, in order to reach 60% of base saturation. Due to the high production of biomass, the application of phosphate fertilization with 120 kg ha is recommended at planting^{-1} of P2O5 and soils with levels of less than 50 ppm of K at a dose of 80 to 100 kg ha^{-1} of KCl at the bottom of the grooves (Pereira *et al.,* 2016). Also according to the authors, when the plants reach an average height of 50 cm, topdressing/maintenance fertilization is recommended, following the recommendation of fractional application of 1,200 kg ha^{-1} year^{-1}o of the NPK formulation (20-05-20) after each cut with moist soil.

In addition, the cultivar has favorable characteristics for tolerance to water stress, which leads to be considered as an alternative for rotation in corn-producing areas in regions with high risk of occurrences of dry spells. The productive potential of this cultivar exceeds that of sugarcane and corn, with an average of 50 Mg ha^{-1} year^{-1} of dry matter, standing out as a high-yielding species for animal feed and considered the cultivar with the highest yield, with 33% higher than that of Camarões and Mineiro (on average of 33.3 Mg ha^{-1} year^{-1}) and in relation to other cultivars of the same species (Monção *et al.,* 2019).

The cutting age of BRS Capiaçu directly influences the yield and quality of the forage, therefore, the earlier the cut, the lower the transformation in the morphological characteristics of the crop, on the other hand, the later it is, the greater this transformation, that is, leaf-stem ratio, thus resulting in a reduction in nutritive values (Maroneze *et al.,* 2014). To Lima *et al.* (2010), the values of fiber present in its composition are influenced by the cutting age, which is visualized through the leaf-stem relationship, in which the younger the plant, the lower the increase in neutral detergent fiber (NDF) and acid detergent fiber (ADF) contained in the composition, the opposite occurring the later. The average chemical-bromatological composition of the cultivar BRS Capiaçu is shown in Table 1.

Table 1

Characteristic of the chemical-bromatological composition of BRS Capiaçu

Variables	Quantities (%)	References
Crude Protein	5,1 - 9,0	
Ether Extract	1,5 - 3,5	Paula *et al.* (2020)
Total Digestible Nutrients	45 - 55	Cosmo; Galeriani (2021)
Dry matter	9,3 – 20	Rose *et al.* (2019)
Acid Detergent Fiber	40 – 50	Pear tree *et al.* (2016)
Neutral Detergent Fiber	60,5 – 70	

Thus, the use of this cultivar has been standing out in several tropical and subtropical regions of the world. In the period of prolonged drought in which the supply of food for the animals is limited, this cultivar of elephant grass is used as a strategy for roughage supplementation in the diet of ruminants (Pereira *et al.,* 2016).

In addition to the characteristics already mentioned, BRS Capiaçu has adaptability to regions with hot and dry climates, which is linked to structural and morphological changes that allow the development of this species in adverse conditions. In addition to the species having a well-developed root system, capable of enabling growth and development in shallow soils and low fertility, it tends to curl the leaves at times with higher air temperatures, contributing to the reduction of leaf area, minimizing solar incidence on the leaves and, consequently, a reduction in transpiration and a reduction in transpiration.

4 THE USE OF IRRIGATION AS A STRATEGY FOR FORAGE PRODUCTION IN A SEMI-ARID ENVIRONMENT

Due to poor water distribution in arid and semi-arid regions, high atmospheric demand and high air temperatures for most of the year, water deficit becomes one of the aggravating factors for crop development in ecosystems and plant productivity. In this context, it is necessary to use irrigation system practices to minimize the effect of water stress, which limits crop growth, causing great losses in production, as this same practice can cause excess water (compromising soil aeration through nutrient saturation and leaching), revealing the importance of using irrigation in the agricultural environment.

In addition, to ensure productive stability in large areas of the semi-arid region, it is essential to use complementary irrigation, due to the high atmospheric demand. However, most of the water resources used in agriculture in the semi-arid region come from groundwater from wells, and in many cases it is the only source of water available (Mbarki *et al.,* 2017).

Considering that in most cases, groundwater in semi-arid regions has inferior quality, that is, with large concentrations of impurities and salts, combined with high air temperatures, it can cause the process of secondary salinization and, causing desertified areas (Pessoa *et al*., 2022). In most cases, the waters with high concentrations of salts, resulting from irrigation and lack of drainage have contributed to the increase of salinization in regions of agricultural production, in addition, almost 20% of the irrigated areas, approximately 45 million hectares, are already salinized (Shrivastava; Kumar, 2015). In view of this, projections indicate for future scenarios that good quality waters will become less accessible in ecosystems, making it necessary to implement efficient systems that contribute to reducing impacts on terrestrial life (To give *et al.,* 2017; Garden, 2019).

The great challenge for the next scenarios will be to increase the production of food with less water, in order to meet the great demand worldwide (Silva *et al.,* 2018). For a better use of water resources, it is essential to optimize the use of water applied in agriculture with quantities and frequency of water application in irrigation based on the real need of the crop and water indexes, revealing the importance of these parameters to maximize irrigation water management and, thus, ensure optimal management for crops.

In this context, the traditional pressurized drip irrigation method is characterized by high efficiency in water availability (>90%) for crops and with all water being applied directly to the root zone of the crop. The method has low service pressure and flow, high frequency to keep humidity at a value close to that of the field capacity, contributing economically to electricity costs, and can generate savings of up to 65% of the water applied in relation to other conventional irrigation methods (Mostafa *et al.,* 2018; Matsunaga *et al.*, 2022).

In addition, understanding how much water content in the soil is essential and allows us to visualize information about the interaction of the crop with the environment, that is, in the soil-plant-atmosphere system, in addition to humidity being one of the physical-hydric attributes that directly influence the development of cultivated species in general and can be interfered with by factors such as soil texture, topography and cultivation, with great variability in time and space (Araújo Primo, 2013; Alves, 2021).

5 BIOSALINE AGRICULTURE: USE OF BRACKISH WATER AS A STRATEGY IN FORAGE PRODUCTION IN THE SEMIARID REGION

The great limitation of fresh water at a global level has driven the search for other alternatives that meet the need to ensure agricultural production and food security, particularly in arid and semi-arid regions (Araújo; Silva; Campos, 2021). In these regions, most of the agricultural production in the semi-arid region is irrigated, that is, using groundwater which, in turn, often has lower quality due to the presence of ions from sedimentary rocks and other materials present in the soil, resulting in high concentrations of salts (Lessa *et al*., 2023).

Salinity in tropical semi-arid regions is aggravated by several natural factors that increase the risk to agriculture and sustainability, such as high temperatures, poorly developed soils, high evapotranspiration and prolonged drought (Lessa *et al*., 2007). The excessive presence of salts available to plants can seriously compromise the development and growth of economically important crops, in addition to causing soil degradation, making it unproductive and undervalued (Alves *et al*., 2022).

From this perspective, the adoption of forage species with high water efficiency and good performance under conditions of salt stress emerges as a viable alternative to meet the growing demand for agricultural production in the semi-arid region. This essential mitigation practice, such as the use of tolerant plants, combined with integrated management, is crucial to avoid significant losses in their yield, ensuring the supply of food for ruminants (Araújo; Silva; Campos, 2021). Some forage species have high tolerance to salinity because they have a morphophysiological structure capable of accumulating salt in their leaves, such as saltgrass (*Atriplex* spp.), and some varieties of alfalfa (*Medicago sativa*), among others. Certain species can continue to develop even in environments under salinity levels above (>25 - 40 dS m^{-1}). On the other hand, more sensitive crops may have their vegetative growth compromised when subjected to (5 - 15 dS m^{-1}) (Masters; Benes; Norman, 2007).

For this, these species that are highly tolerant to high concentrations of salts are called halophytes. They express different specific physiological mechanisms that allow them to withstand the toxic and osmotic effects caused by salinity. Sensitive species, known as glycophytes, do not have these adaptations, being unable to properly absorb water and nutrients in saline environments, which compromises their growth and development.

Despite the limitations regarding access to good quality water resources and the challenges associated with soil salinization, it is essential to adopt new strategies capable of optimizing and enhancing agricultural and livestock production. Biosaline agriculture has stood out as a promising alternative to increase the production of forage of economic interest in semi-arid regions, through the use of brackish water combined with appropriate management practices (Lessa *et al*., 2023). This approach contributes significantly to strengthening agricultural production and promoting environmental sustainability. Santos, Henrique, Rodrigues. (2019), when studying the effect on the biomass production of forage species at different levels of electrical conductivity in irrigation water, they found that sorghum and elephant grass were not affected, neither in quality nor quantity, with electrical conductivity of up to 2.5 dS m^{-1} in a semi-arid environment.

6 IMPORTANCE OF EVAPOTRANSPIRATION AND WATER USE EFFICIENCY IN FORAGE PLANT PRODUCTION IN THE SEMI-ARID REGION

In view of the entire photosynthetic process of plants, it is known that carbon concentrations are factors that limit photosynthesis, consequently causing different responses in the production of biomass and organic matter. According to the IPCC (2020), global carbon emissions tend to increase for the next future scenarios, if there is no elaboration of global plans and projects capable of mitigating the gases generated.

As a result of these impacts, in addition to contributing to changes in meteorological processes, such as rainfall distribution and CO2 concentration, they affect the balance of the plant/environment system interaction. The plants that are able to carry out their photosynthetic process when they are subjected to limitations in the concentrations offered are those with C4 metabolism, in which they are more naturally evolved (Braga *et al.,* 2021). In addition to optimizing carbon assimilation, C4 metabolism contributes to greater efficiency in water use, which influences the evapotranspiration patterns of these species.

Evapotranspiration (ET) is one of the fundamental elements in the hydrological cycle, in which it contributes to the local or global estimate with great precision, collaborating to determine the use of water in several different areas of action. This component presents a pertinent mechanism that the water concentrated in the soil and plants to the atmosphere, playing a continuous movement and revealing a fundamental role in the regulation of the hydrological cycle and water availability for the agricultural sector. ET is very relevant in the agricultural sector of BRS Capiaçu, because in regions where commercial production under rainfed conditions, all scientific information and knowledge is crucial to contribute to the optimization and improvements in the supply and requirement of water in order to reduce the impacts of water stress on irrigation systems (Inamn-bamber; Smith, 2005).

In addition, several factors such as: environmental conditions; agricultural management, irrigation system; Cutting age and variety can influence evapotranspiration. According to Kings (2022), which evaluated the evapotranspiration in class A tanks of two different varieties, tifton-85 and BRS Capiaçu, submitted to the same cutting age, found significant values of BRS Capiaçu higher than tifton-85 due to plant morphology, about 27.93% and 45.89% higher in the first and second cycles, respectively.

Monsoon *et al.* (2019), in a study related to productivity and nutritional value with the cutting age, in the north of Minas Gerais, it was found that as the cutting age of BRS Capiaçu increased, the dry matter productivity increased in the same proportion, recommending the age between 90 and 120 days of regrowth. Faithful *et al.* (2020a) Evaluating the correlations between the productive and nutritional traits, it was stated that the equilibrium point between yield and nutritional value occurs at the height of 3.5 meters, and that the cut for forage is 1.9 meters and for silage between 3 and 4.5 meters in height. On the other hand Faithful *et al.* (2020b) found that elephant grass cultivars, such as Napier; Purple Cameroon; BRS Canará; BRS Kurumi and BRS Capiaçu, when subjected to an increase in the cutting age, reduce the nutritional quality and with a lesser magnitude for the cv. BRS Kurumi.

In addition to previously understanding the water needs of crops, it is essential to evaluate the efficiency of the production system, considering both the management of water resources and the economic benefits (Araújo Júnior *et al.,* 2024). Understanding and optimizing water use efficiency (EUA) in forage crops is therefore critical to ensuring economic viability and environmental sustainability.

Thus, EUA is a very important parameter for planning and decision-making in the proper management of water throughout the crop cycle. However, this agenda has been discussed by several researchers (Molden *et al.,* 1998), proposing indicators capable of assessing EUA. This index quantifies the amount of water that the crop uses to produce dry matter in relation to the volume of water inserted, through parameters of the production system, such as the final productivity of the crop or total biomass produced (Fernández *et al.,* 2020; Saints *et al.,* 2024)

These indicators are crop water productivity (PAc), which expresses the relationship between productivity with the water depth applied or consumed by the plant, economic water productivity (PEA), which allows analyzing the gross economic return as a function of the amount of water applied, and irrigation water productivity (PAI), which reveals the yield gain due to the increase of water in the production system, revealing a result capable of optimizing and evaluating the effectiveness of water management. (Silva *et al.,* 2018; Oak *et al.,* 2020; Fernández *et al.,* 2020).

Saints *et al.* (2020) provided a convincing analysis in their study with sorghum (cv. Sudan IPA 4202), in Serra Talhada, Pernambuco. The authors evaluated the efficiency of water use in different water regimes with saline water, and revealed that even the crop subjected to water regime variation (i.e., 50 and 125% ET0), the smallest depth applied presented higher yield, which did not imply a significant effect on the efficiency of water use by the crop. Other studies have shown similar results for other forage species, demonstrating the importance of adapting irrigation practices to specific conditions. Mezzomo *et al*. (2020) studied the water use efficiency of Sudanese sorghum (*Sudanese Sorghum* (Piper) Stapf) submitted to four cutting frequencies (50, 80, 110 and 140 days after sowing) with five irrigation depths (60%, 80%, 100%, 120% and 140% of the difference between reference evapotranspiration and effective rainfall-PE). The authors found greater efficiency of water use, in the sum of the four cuts, for the treatment with 100% of the ET0-EP, and when submitted to the treatment with 60% of the ET0-EP, it was also noted that the depths above 100% showed a decrease in efficiency, indicating that the excess of irrigation negatively affects the efficiency in the use of water by the crop and also increases the costs.

7 FINAL THOUGHTS

Forage production in semi-arid environments, such as Brazil's, requires the synergistic combination of adapted genetic materials and efficient water management. The review demonstrated the relevance of cv. BRS Capiaçu as an alternative with high yield and tolerance to water stress, crucial for the sustainability of livestock in these regions. Its morphological characteristics and its C4 metabolism give it an inherent efficiency in the use of water, a vital attribute to maximize biomass production under conditions of scarcity.

It is evident that the practice of irrigation is indispensable to ensure productive stability in the semi-arid region. However, given the increasing limitation of good quality water resources, biosaline agriculture emerges as a promising approach, enabling the strategic use of brackish waters for the cultivation of tolerant species, such as elephant grass. This practice is essential for food security and the strengthening of agricultural production in these areas.

Thus, the determination and monitoring of the crop's water demand and the efficiency of water use are essential to optimize water use, reducing losses and costs, as evidenced by the analyzed studies. The application of water indices allows for precise water management guided by the real needs of the crop, ensuring optimal management for BRS Capiaçu and contributing to economic viability and environmental sustainability in the semi-arid region. Therefore, the future challenges lie in intensifying research on the performance of BRS Capiaçu under different levels of salinity and water regimes, consolidating integrated management protocols to enhance its productivity in a sustainable way.

REFERENCES

Alves, C. P., et al. (2022). How to enhance the agronomic performance of cactus-sorghum intercropped system: Planting configurations, density and orientation. Industrial Crops and Products, 184, Article 114928.

Araujo, G. G. L., Silva, T. G. F., & Campos, F. S. (s.d.). Agricultura biossalina e o uso de águas salobras na produção de forragem. In Agricultura irrigada em ambientes salinos (Vol. 1, pp. 174–211).

Araújo Júnior, G. do N., et al. (2024). Growth dynamic, productivity, evapotranspiration, and water-economic indices of forage cactus under different irrigation depths. Agronomy, 14(4), 1–26.

Bekele, T. (2025). On-farm demonstration of improved forage varieties in selected districts of Southwest Ethiopia. Agriculture, Forestry and Fisheries, 14(2), 44–49.

Braga, F. M., et al. (2021). Revisão: Crescimento de plantas C3 e C4 em resposta a diferentes concentrações de CO2. Research, Society and Development, 10(7), Article e33810716701.

Carvalho, I. C. B. de, et al. (2020). Eficiência de uso da água de mamoneiras nas condições agroecológicas do semiárido / Water use efficiency of castor bean variety in agroecological semiarid conditions. Brazilian Journal of Development, 6(9), 73354–73373.

Cosmo, B. M. N., & Galeriani, T. M. (2021). Composição bromatológica de beterraba, capim elefante e farinha de peixe. Revista Brasileira Multidisciplinar, 24(3), 53–69.

Costa, D. C., Martorano, L. G., et al. (2018). Dinâmica temporal da pegada hídrica por cultivar de soja em polo de grãos no Oeste do Pará, Amazônia. Revista Ambiente & Água, 9(3), 445–458.

Da Silva, T. G. F., et al. (2023). Profitability of using irrigation in forage cactus-sorghum intercropping for farmers in semi-arid environment. Revista Brasileira de Engenharia Agrícola e Ambiental, 27(2), 132–139.

Dar, E. A., et al. (2017). Simulating response of wheat to timing and depth of irrigation water in drip irrigation system using CERES-Wheat model. Field Crops Research, 214, 149–163.

Fernández, J. E., et al. (2020). Water use indicators and economic analysis for on-farm irrigation decision: A case study of a super high density olive tree orchard. Agricultural Water Management, 237, Article 106074.

Hussain, J., et al. (2018). Wheat responses to climate change and its adaptations: A focus on arid and semi-arid environment. International Journal of Environmental Research, 12(1), 117–126.

Inman-Bamber, N. G., & Smith, D. M. (2005). Water relations in sugarcane and response to water deficits. Field Crops Research, 92(2–3), 185–202.

Jardim, A. M. da R. F. (2019). Consórcios de palma (Nopalea sp. e Opuntia sp.) em sistema de plantio adensado com cultivares de sorgo sob uso mínimo e regular de irrigação. Estuarine, Coastal and Shelf Science, 2020(1), 127.

Leal, D. B., et al. (2020a). Correlações entre as características produtivas e nutricionais do capim-BRS capiaçu manejado na região semiárida. Brazilian Journal of Development, 6(4), 18951–18960.

Leal, V. N., et al. (2020b). Produção e valor nutritivo de forragem de cultivares de capim-elefante em diferentes períodos de rebrotação. Research, Society and Development, 9(11), Article e41391110025.

Lessa, C. I. N., et al. (2007). Potential of brackish groundwater for different biosaline agriculture systems in the Brazilian semi-arid region. Agriculture, Ecosystems and Environment, 119(3–4), 234–248.

Lessa, C. I. N., et al. (2023). Potential of brackish groundwater for different biosaline agriculture systems in the Brazilian semi-arid region. Agriculture (Switzerland), 13(3).

Lucena, R. L., Ferrer, É., & Guilhermino, M. M. (2021). Mitigando os riscos da seca através de ações de recuperação e preservação do bioma caatinga no semiárido brasileiro / Mitigating dry risks through actions for the recovery and preservation of the caatinga biome in the Brazilian semi-arid. Brazilian Journal of Development, 7(4), 36546–36557.

Masters, D. G., Benes, S. E., & Norman, H. C. (2007). Biosaline agriculture for forage and livestock production. Agriculture, Ecosystems and Environment, 119(3–4), 234–248.

Matsunaga, W. K., et al. (2022). Evapotranspiration, crop coefficient and water use efficiency of onion cultivated under different irrigation depths. Revista Brasileira de Engenharia Agrícola e Ambiental, 26(3), 219–225.

Mezzomo, W., et al. (2020). Supplementary irrigation in Sudan grass: Leaf area index, dry matter production and water use efficiency. Científica, 48(2), 85–98.

Molden, D., et al. (s.d.). Indicators for comparing performance of irrigated agricultural systems (Vol. 20).

Monção, F. P., et al. (2019). Yield and nutritional value of BRS Capiaçu grass at different regrowth ages. Semina: Ciências Agrárias, 40(5), 2045–2055.

Mostafa, H., et al. (2018). Drip irrigation management for wheat under clay soil in arid conditions. Ecological Engineering, 121, 35–43.

Paula, P. R. P., et al. (2020). Composição bromatológica da silagem de capim-elefante BRS Capiaçu com inclusão fubá de milho. Pubvet, 14(10), 53–69.

Pereira, A. V., Auad, A. M., Brigent, A. M., Mittelman, A., Gomide, C. de A. M., Martins, C. E., Paciullo, D. S. C., Ledo, F. J. da S., Oliveira, J. S. E., Leite, J. L. B., Machado, J. C., Matos, L. L. de, Morenz, M. J. F., Andrade, P. J. M., Bender, S. E., & Rocha, W. da. (s.d.). BRS Capiaçu e BRS Kurumi: Cultivo e uso (Vol. 59).

Pereira, A. V., et al. (2016). BRS Capiaçu: Cultivar de capim-elefante de alto rendimento para produção de silagem. Comunicado Técnico EMBRAPA, 2(79), 1–6.

Pinheiro, A. G., et al. (2021). Yield gap and cultivation strategies in improving forage production for the Brazilian semi-arid region – Review. Revista Brasileira de Geografia Física, 14(4), 2403–2426.

Reis, M. C. G. (2022). Tanques de evapotranspiração cultivados com forrageiras: Balanço hídrico e de poluentes [Trabalho de conclusão ou dissertação/tese – instituição não informada].

Rosa, P. P., et al. (2019). Pesquisa Agropecuária Gaúcha, 25(1/2), 70–84.

Salvador, K. R. S., et al. (2021). Intensificação de sistemas de produção de palma forrageira por meio de consorciação rotativa com gramíneas, leguminosas e oleaginosas: Uma revisão / Intensification of forage cactus production systems by rotating intercropping with grasses, legumes, and oilseeds: A review. Revista Brasileira de Geografia Física, 14, 2369–2390.

Santos, A. R. M., et al. (2025). Environmental seasonality affects the growth, yield and economic viability of irrigated forage species in dry regions. Irrigation and Drainage, 1–29.

Santos, F. J. D. S., Henrique, B., & Rodrigues, N. (2019). Produção de gramíneas forrageiras irrigadas com água de diferentes condutividades elétricas no semiárido do Piauí / Productivity of forage grasses irrigated with water of different electrical conductivities in the semi-arid region of the north of Piauí. Pubvet, 13(4), 1–9.

Santos, G. C. L., et al. (2020). Crescimento e eficiência do uso da água do sorgo sob distintos regimes hídricos contínuos. Archivos de Zootecnia, 69(268), 164–171.

Santos, J. P. A. de S., et al. (2024). Morphophysiological responses, water, and nutritional performance of the forage cactus submitted to different doses of nitrogen. Field Crops Research, 308, Article 109258.

Shrivastava, P., & Kumar, R. (2015). Soil salinity: A serious environmental issue and plant growth promoting bacteria as one of the tools for its alleviation. Saudi Journal of Biological Sciences, 22(2), 123–131.

Silva, V. de P. R. da, et al. (2018). Evapotranspiration, water use efficiency and crop coefficient of three lettuce varieties grown in a tropical region. Revista de Ciências Agrárias, 41(3), 798–805.

Superintendência do Desenvolvimento do Nordeste. (2021). Delimitação do semiárido – 2021: Relatório final (pp. 1–272).