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EFFECT OF IRRIGATION DEPTHS ON SOYBEAN FORAGE YIELD (Glycine max (L.) Merr.) cv. CIGRAS 06

EFEITO DAS LÂMINAS DE IRRIGAÇÃO SOBRE A PRODUTIVIDADE DE FORRAGEM DE SOJA (Glycine max (L.) Merr.) cv. CIGRAS 06

EFECTO DE LAS LÁMINAS DE RIEGO SOBRE EL RENDIMIENTO DEL FORRAJE DE SOYA (Glycine max, L. Merr.) cv. CIGRAS 06

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ABSTRACT
This study evaluated the effect of different irrigation depths on the biomass production and water use efficiency of soybean forage (Glycine max (L.) Merr.) cv. CIGRAS 06. The experiment was conducted at the "Manuel Salvador Yépez" Experimental Station, located in Lara State, Venezuela, under tropical dry forest conditions. A controlled sprinkler irrigation gradient design was used, with four replications, evaluating five irrigation depths equivalent to 18%, 30%, 60%, 100%, and 150% of crop evapotranspiration (ETc). Crop water requirements were estimated using the Class A pan method. The results showed a significant increase in biomass production with increasing irrigation depth. The highest dry matter yield (6628 kg ha^{-1}) was obtained under the 150% ETc treatment, while the 100% ETc treatment presented the highest water use efficiency (732 L kg^{-1} of dry matter). Water availability significantly influenced plant morphological composition. The highest proportion of pods and seeds (54.7%) was observed under intermediate irrigation depths (60% and 100% ETc). The findings indicate that irrigation depths between 100% and 150% of ETc, combined with adequate agronomic management, may represent a viable strategy to optimize soybean forage production under tropical conditions.

KEYWORDS: Water use efficiency. Irrigation management. Dry matter. Forage crops

RESUMO
Neste estudo avaliou-se o efeito de diferentes lâminas de irrigação sobre a produção de biomassa e a eficiência do uso da água em forragem de soja (Glycine max (L.) Merr.) cv. CIGRAS 06. O experimento foi conduzido na Estação Experimental "Manuel Salvador Yépez", no estado Lara, Venezuela, sob condições de floresta tropical seca. Foi adotada uma abordagem experimental com gradiente controlado de irrigação por aspersão, com quatro repetições, avaliando cinco níveis de irrigação equivalentes a 18%, 30%, 60%, 100% e 150% da evapotranspiração da cultura (ETc) . A estimativa da demanda hídrica foi realizada pelo método do tanque Classe A. Os resultados demonstraram aumento significativo da produção de biomassa com o incremento das lâminas de irrigação.

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A maior produção de matéria seca (6628 kg ha^{-1}) foi obtida no tratamento com 150% da ETc, enquanto o tratamento com 100% da ETc apresentou maior eficiência no uso da água (732 L kg^{-1} de matéria seca). A disponibilidade hídrica influenciou significativamente a composição morfológica das plantas, sendo observadas maiores proporções de vagens e sementes (54,7%) nos níveis intermediários de irrigação (60% e 100% da ETc). Conclui-se que lâminas de irrigação entre 100% e 150% da ETc, associadas ao adequado manejo agronômico, constituem estratégia viável para otimizar a produção de forragem de soja em condições tropicais.

PALAVRAS-CHAVE: Eficiência do uso da água. Manejo da irrigação. Matéria seca. Forrageiras

RESUMEN
Este estudio evaluó el efecto de diferentes láminas de riego en la producción de biomasa y la eficiencia en el uso del agua de la soya forrajera (Glycine max (L.) Merr.) cv. CIGRAS 06. El experimento se realizó en la Estación Experimental "Manuel Salvador Yépez", ubicada en el estado Lara, Venezuela, bajo condiciones de bosque seco tropical. Se utilizó un sistema experimental con gradiente controlado de riego por aspersión, con cuatro repeticiones, evaluando cinco láminas de riego equivalentes al 18 %, 30 %, 60 %, 100 % y 150 % de la evapotranspiración del cultivo (ETc). Los requerimientos hídricos del cultivo se estimaron utilizando el método de tanque Clase A. Los resultados mostraron un incremento significativo en la producción de biomasa con el aumento de la lámina de riego. El mayor rendimiento de materia seca (6628 kg ha^{-1}) se obtuvo bajo el tratamiento de 150% ETc, mientras que el tratamiento de 100% ETc presentó la mayor eficiencia del uso del agua (732 L kg^{-1} de materia seca). La disponibilidad de agua influyó significativamente en la composición morfológica de la planta. La mayor proporción de vainas y semillas (54,7 %) se observó bajo láminas de riego intermedias (60 % y 100 % de ETc). Los resultados indican que las láminas de riego entre el 100 % y el 150 % de ETc, combinados con un manejo agronómico adecuado, representan una estrategia viable para optimizar la producción de forraje de soja en condiciones tropicales.

PALABRAS CLAVE: *Eficiencia en el uso del agua. Manejo de riego. Materia seca. Forrajeras*

INTRODUCTION

Forage production constitutes the primary basis for feeding ruminants in extensive livestock systems, representing a low-cost and widely available resource (Bautista *et al.*, 2020). However, in tropical regions, forage availability and quality are strongly affected by seasonal rainfall patterns. During the dry season, forage production may decrease by up to 90%, accompanied by reductions in digestibility and crude protein content (Garay-Martínez *et al.*, 2021), which negatively impacts animal performance, especially when protein levels are below 7% (Belachew *et al.*, 2013).

In this context, the incorporation of leguminous species into forage systems has been recognized as an effective strategy to improve protein supply and overall diet quality (Enríquez *et al.*, 2011). Among these, soybean (Glycine max (L.) Merr.) has emerged as a promising forage alternative due to its high biomass production, elevated protein content, and adaptability to tropical environments.

Previous studies have reported dry matter yields ranging from 4.8 to 8.8 t ha^{-1} at approximately 100 days after sowing (Tobía *et al.*, 2004; Devi *et al.*, 2011; Ávila *et al.*, 2014), highlighting its potential as a supplement during periods of forage scarcity. Additionally, soybean

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forage has demonstrated positive effects on animal performance, including increased weight gain and improved feed conversion efficiency (Torres-Salado *et al.*, 2020).

Despite its agronomic potential, soybean productivity is highly dependent on environmental conditions, particularly water availability. Climate variability and irregular rainfall distribution in tropical regions have intensified the need for efficient irrigation management strategies. Water deficit is considered one of the main limiting factors for biomass accumulation (Han & Hee, 2000), while excess water may also negatively affect plant development.

Soybean water requirements typically range between 450 and 700 mm throughout the crop cycle, depending on climatic conditions, cultivar characteristics, and management practices (Doorenbos & Kassam, 1979; Almanza, 2006). The crop presents distinct water demands across its phenological stages, with the highest requirements occurring during flowering and pod filling (Almanza, 2006).

Water availability directly affects soybean physiological processes, including stomatal conductance, photosynthesis, nutrient transport, and assimilate partitioning between vegetative and reproductive organs (Taiz *et al.*, 2017; Desclaux & Roumet, 1996). Under water deficit, reduced carbon assimilation may limit biomass accumulation and alter source–sink relationships, compromising reproductive development and forage yield (Barros *et al.*, 2023).

Harvest stage is also critical for forage quality. The R6 stage is considered particularly suitable for soybean forage because it combines high biomass production with increased accumulation of pods and seeds, which contribute positively to crude protein concentration and overall nutritional value (Fehr & Caviness, 1977; Pedersen & Lauer, 2004). In contrast, greater allocation to stem fractions may reduce forage digestibility due to increased structural fiber content (Hintz & Albrecht, 1994; Ávila *et al.*, 2014).

Although soybean has been extensively studied for grain production, comparatively less information is available regarding its use as a forage crop under contrasting irrigation regimes, particularly under tropical dry conditions. Previous studies have demonstrated the forage potential of cultivar CIGRAS 06; however, information remains limited concerning its productive response, dry matter partitioning, and water use efficiency under a broad irrigation gradient.

Evaluating irrigation depths ranging from severe water deficit (18% ETc) to supra-optimal water supply (150% ETc) is agronomically relevant, as it allows the identification of both limiting and excessive water conditions, contributing to the optimization of irrigation strategies for forage production systems in water-constrained tropical environments.

Therefore, this study aimed to evaluate the effect of different irrigation depths on biomass production, water use efficiency, and dry matter partitioning of soybean forage (Glycine max (L.) Merr.) cv. CIGRAS 06 harvested at the R6 growth stage.

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MATERIALS AND METHODS

Experimental site, soil, and irrigation system characterization

The experiment was conducted at the “Manuel Salvador Yépez” Experimental Station, located in Simón Planas municipality, Lara State, Venezuela, at an altitude of approximately 265 m above sea level. According to Holdridge (1978), the experimental area is classified as tropical dry forest (TDF), with an average annual rainfall of 1428 mm, mean air temperature of 24 °C, and relative humidity of approximately 90%.

The soil was classified as silty clay loam, with pH 6.2 and electrical conductivity of 0.1 dS m^{-1}. Prior to the experiment, soil infiltration characteristics were determined using a double-ring infiltrometer, resulting in the infiltration equation:

$ia = 2.092\, T^{0.68}$

where ia is cumulative infiltration (cm) and T is time (min). The basic infiltration rate was 15.4 mm h^{-1}, indicating suitability for sprinkler irrigation.

Plant material

Soybean seeds of cultivar CIGRAS 06 were used (Villalobos & Camacho, 2003). This cultivar was developed by the Grain and Seed Research Center of the University of Costa Rica and is well adapted to tropical conditions, presenting a semi-determinate growth habit and high nodulation capacity when inoculated with Bradyrhizobium japonicum.

Irrigation management

Sprinkler irrigation was applied using a lateral line equipped with three sprinklers spaced 16 m apart and positioned 1.5 m above ground level. The system operated with a flow rate of 7.3 L s^{-1} and pressure of 78 PSI, while each sprinkler delivered 1.3 L s^{-1} at 50 PSI.

Irrigation scheduling was performed weekly based on crop evapotranspiration (ETc), estimated using the Class A pan method (Allen *et al.*, 1998). Reference evapotranspiration (ETo) was calculated as:

$ETo = Epan \times Kp$

where Epan is Class A pan evaporation and Kp is the pan coefficient (0.80), according to Palacios (2002).

Crop evapotranspiration was determined as:

$ETc = ETo \times Kc$

where Kc corresponds to the crop coefficient according to the phenological stage, following Doorenbos and Kassam (1979): 0.30–0.40 during the initial stage (20–25 days), 0.70–0.80 during

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crop development (25–35 days), 1.00–1.15 during the mid-season stage (45–65 days), and 0.70–0.80 during the late-season stage (20–30 days).

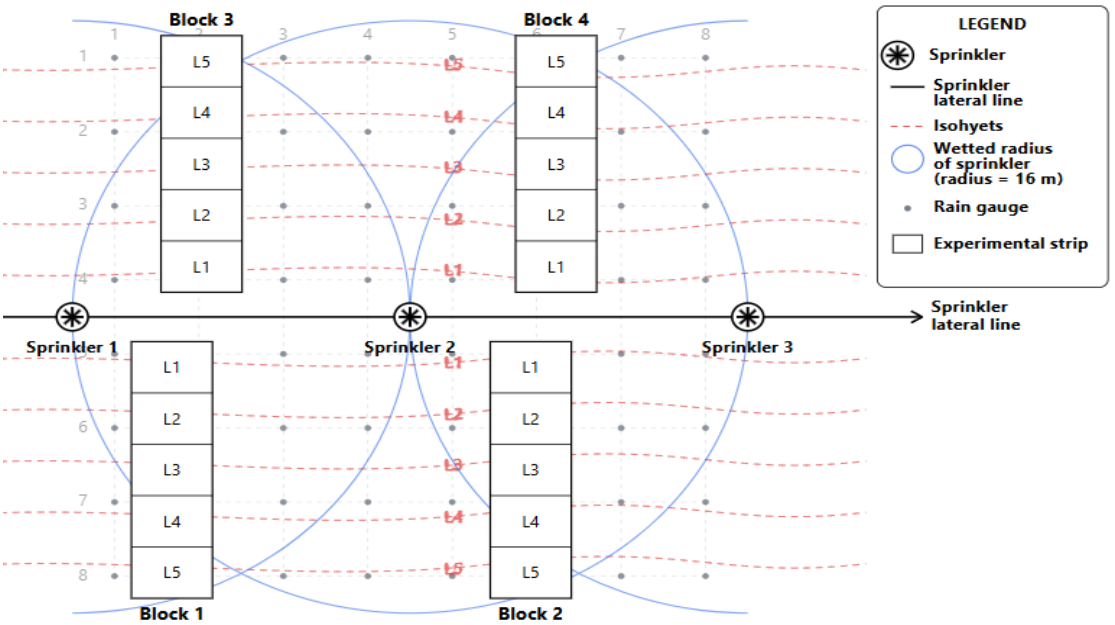
Irrigation management was maintained until the crop reached the R6 reproductive stage (approximately 90 days after sowing), when forage evaluations were performed, according to the phenological criteria of Fehr and Caviness (1977). Because forage harvest occurred at R6, irrigation scheduling considered crop coefficients only up to the period of maximum crop water demand (Kc = 1.15), whereas late-season crop coefficients were not applied.

Experimental design and irrigation treatment definition

The experiment was conducted using a controlled irrigation gradient approach based on the principles of the line-source sprinkler methodology originally described by Hanks *et al.* (1976) and subsequently applied under Brazilian conditions by Stone and Moreira (2000). This approach differs from conventional irrigation experiments with independently assigned fixed treatments, as irrigation depths are generated through the spatial water distribution pattern of the sprinkler system. Therefore, the objective was not to achieve uniform water application across the entire experimental area, but rather to generate controlled and measurable differences in accumulated irrigation depth.

Four experimental blocks were established perpendicular to the sprinkler line so that each block intersected the irrigation gradient generated by the sprinkler system (Figure 1).

Figure 1. Schematic representation of the experimental design showing the line-source sprinkler irrigation gradient, cumulative isohyets, and distribution of experimental strips across four blocks



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During each irrigation event, water application was monitored using rain gauges distributed in a regular grid across the experimental area. A reference strip was selected to represent the irrigation level corresponding to 100% of crop evapotranspiration (ETc). Irrigation was interrupted whenever the rain gauge installed in this reference strip collected the target water depth corresponding to 100% ETc.

Consequently, other portions of the irrigated area received irrigation depths below or above the reference depth according to the sprinkler distribution pattern. At the end of the irrigation period, the accumulated irrigation depths recorded in all rain gauges were summed, and an isohyet map (contour map of equal accumulated irrigation depth) was constructed.

Based on this cumulative water distribution map, harvest plots corresponding to five irrigation treatments were identified within each block, resulting in four replications per treatment and a total of 20 experimental units. The treatments corresponded to 150% ETc (L1 = 630.2 mm), 100% ETc (L2 = 415.9 mm), 60% ETc (L3 = 254.8 mm), 30% ETc (L4 = 121.5 mm), and 18% ETc (L5 = 77.2 mm).

Therefore, statistical analyses were based on measured accumulated irrigation depths rather than merely spatial position within the field.

Crop management

Soybean was sown in rows spaced 0.60 m apart. During the first two weeks, establishment irrigations totaling 77.2 mm were applied to ensure uniform germination.

Fertilization consisted of 100 kg ha^{-1} of nitrogen (urea) and 350 kg ha^{-1} of a 10-20-20 formulation.

A foliar nitrogen application was performed at 63 days after sowing.

Weed control was carried out using imazetapyr herbicide (8 days after sowing), followed by manual weeding. No significant pest or disease incidence was observed.

Data collection

Evaluations were performed at 90 days after sowing, corresponding to the R6 growth stage (Fehr & Caviness, 1977).

Each experimental unit consisted of three soybean rows spaced 0.60 m apart. Biomass samples were collected by harvesting the central row over a 2 m length, corresponding to a useful harvest area of 1.20 m^2. Plants were cut at approximately 10 cm above ground level, and fresh biomass was weighed immediately in the field.

Dry matter determination followed A.O.A.C. (1990). Samples were dried at 60 °C for 72 hours to determine dry matter content and subsequently dried at 105 °C for total dry matter determination.

Dry matter percentage was calculated as:

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DM (%) = (dry weight / fresh weight) × 100

Plant material was manually separated into leaf, stem (including petioles), and pod fractions to determine dry matter partitioning.

Statistical analysis

Data were analyzed using analysis of variance (ANOVA) under the General Linear Model (GLM) procedure. Prior to analysis, data normality was assessed using the Shapiro–Wilk test, and all variables met the normality assumption ($P > 0.05$). Means were compared using Tukey's test at the 5% significance level. Regression analyses were performed to evaluate relationships between irrigation depth and response variables. All analyses were conducted using SAS software (version 8.0).

RESULTS AND DISCUSSION

Biomass production and water use efficiency

Biomass production was significantly affected by irrigation depth ($P < 0.01$), increasing progressively as irrigation depth increased (Table 1). Fresh biomass increased from 3191 kg FM ha^{-1} under severe water deficit (18% ETc) to 28905 kg FM ha^{-1} under supra-optimal irrigation (150% ETc), representing an approximately ninefold increase. The relationship between irrigation depth and fresh biomass was best described by a quadratic model ($y = -0.0075x^2 + 53.612x - 1628.1$; $R^2 = 0.955$; $P < 0.01$), indicating a strong positive response of soybean forage biomass to increasing water availability (Figure 2).

Table 1. Fresh biomass, total dry matter, dry matter yield, and water use efficiency of the entire soybean plant harvested at the R6 stage under different irrigation depths

rigation depths	Fresh biomass (kg FM ha^{-1})	TDM (%)	DMY (kg DM ha^{-1})	WUE (L kg^{-1} DM)
L1 (630.2 mm ≈ 150%)	28905^{a} ± 1783	23.0^{b} ± 0.7	6628^{a} ± 371	951
L2 (415.9 mm ≈ 100%)	20326^{b} ± 1422	28.0^{a} ± 0.4	5682^{a} ± 416	732
L3 (254.8 mm ≈ 60%)	10694^{c} ± 1149	29.1^{a} ± 0.9	3084^{b} ± 254	826
L4 (121.5 mm ≈ 30%)	4211^{d} ± 133	29.8^{a} ± 0.8	1258^{c} ± 73	966
L5 (77.2 mm ≈ 18%)	3191^{d} ± 349	29.4^{a} ± 1.0	932^{c} ± 84	828

FM = fresh matter; TDM = total dry matter; DMY = dry matter yield; WUE = water use efficiency. Values are means of four replications ± standard error. Means followed by different letters within the same column differ significantly according to Tukey's test ($P \leq 0.05$).

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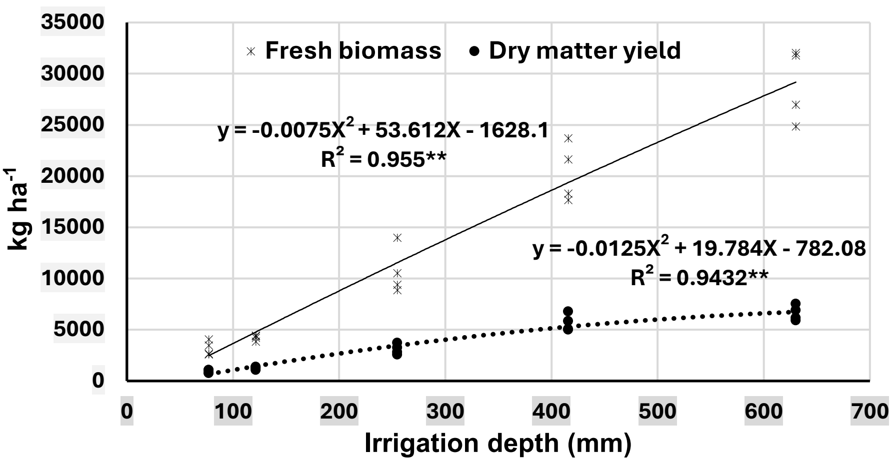
Figure 2. Relationship between irrigation depth and fresh biomass and dry matter yield of soybean cv. CIGRAS 06



The soybean cultivar CIGRAS 06 accumulated substantial fresh biomass when irrigation depth exceeded its estimated evapotranspiration requirements. This response may be associated with the semi-determinate growth habit of this cultivar, which allows continued vegetative growth and biomass accumulation under favorable moisture conditions. Similar responses have been reported in forage soybean studies, where increased water availability promoted higher biomass accumulation, whereas water deficit significantly reduced plant growth due to limitations in photosynthesis, assimilate transport, and reproductive development (Barros *et al.*, 2023; Gokkus *et al.*, 2025).

Total dry matter concentration (TDM) was also significantly influenced by irrigation depth ($P < 0.05$). The lowest TDM value was observed under the highest irrigation depth (L1 = 150% ETc), with 23.0%, whereas treatments from L2 to L5 showed significantly higher values ranging from 28.0% to 29.8% (Table 1). The reduction of 17.9% in TDM concentration between L2 and L1 suggests a dilution effect caused by increased tissue water content under excessive irrigation.

Dry matter yield (DMY) was significantly affected by irrigation depth ($P < 0.01$) and followed a quadratic response ($y = -0.0125x^2 + 19.784x - 782.08$; $R^2 = 0.943$; $P < 0.01$) (Figure 2). DMY increased from 932 kg DM ha^{-1} under severe deficit irrigation (18% ETc) to 6628 kg DM ha^{-1} under 150% ETc. However, despite a numerical increase of 14.3% between L2 (100% ETc) and L1 (150% ETc), no statistically significant difference was observed between these treatments (Table 1).

This result is agronomically relevant because it indicates that irrigation above crop evapotranspiration requirements increased fresh biomass primarily through greater plant water accumulation rather than proportional dry matter production. The significantly lower TDM concentration observed in L1 supports this interpretation, suggesting that supra-optimal irrigation

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promoted tissue hydration rather than effective dry matter accumulation. Therefore, although fresh biomass continued to increase under excessive irrigation, dry matter production showed diminishing returns.

These findings are consistent with Hernández *et al.* (2013), who reported high forage productivity for soybean cultivar CIGRAS 06 under irrigated tropical dry forest conditions, with fresh biomass yields reaching 52333 kg ha^{-1} and dry biomass yields of 17247 kg ha^{-1}. Under humid tropical conditions in Costa Rica, Tobía and Villalobos (2004) reported dry matter yields of 4800 kg ha^{-1} for the same cultivar harvested at the R6 stage, whereas under more favorable conditions yields ranged from 7300 to 8800 kg ha^{-1}. Similarly, Pedersen and Lauer (2004) reported dry matter yields of 7770 kg ha^{-1}, while Muñoz *et al.* (1983) obtained values up to 10100 kg ha^{-1} when soybean forage was harvested between stages R6 and R7.

The reduction in biomass and dry matter production under lower irrigation depths confirms the strong sensitivity of soybean to water deficit during critical growth stages. Although much of the available literature focuses on grain yield, the same physiological mechanisms—including reduced stomatal conductance, impaired photosynthesis, decreased assimilate availability, and restricted reproductive development—also explain the reductions observed in forage biomass under water-limited conditions (Barros *et al.*, 2023; Farias *et al.*, 2024).

Water use efficiency (WUE) was significantly influenced by irrigation level ($P < 0.05$) (Table 1). The highest efficiency was observed under 100% ETc (732 L kg^{-1} DM), indicating the most favorable balance between dry matter production and water consumption. Under the edaphoclimatic conditions of the experimental site, this treatment was 30.0% more efficient than 150% ETc and 13.0% more efficient than 60% ETc.

This result indicates that an irrigation depth corresponding to 100% of crop evapotranspiration demand optimized forage production efficiency, whereas excessive irrigation increased water consumption without proportional gains in dry matter yield. Similar findings were reported by Maduro *et al.* (2012), who observed that although greater irrigation depths increased soybean productivity, maximum water use efficiency occurred when irrigation matched crop water requirements rather than exceeded them.

According to Doorenbos and Kassam (1979), alfalfa hay (*Medicago sativa*) with 15% moisture requires approximately 670 L of water per kg of dry matter, indicating that soybean forage under similar conditions presents slightly lower water use efficiency. This comparison reinforces the relatively high water demand of soybean forage, emphasizing the importance of precise irrigation management to maximize productivity while avoiding inefficient water use.

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Dry matter partitioning

Table 2 presents the distribution of dry matter among leaves (L), stems and petioles (SP), and pods and seeds (PS) fractions of soybean forage harvested at the R6 stage under different irrigation depths.

The leaves fraction was not significantly affected by irrigation treatment (P > 0.05), remaining relatively stable between 20.1% and 25.6% of total dry matter. This stability suggests that leaves biomass allocation was less sensitive to changes in water availability compared with reproductive and structural fractions.

Table 2. Dry matter partitioning in soybean plants harvested at the R6 stage under different irrigation depths

Treatments	Leaves (%)	Stems and Petioles (%)	Pods and Seeds (%)
L1 (630. 2 mm ≈ 150%)	25.6^{a} ± 1.3	28.1^{bc} ± 1.6	46.3^{b} ± 1.7
L2 (415.9 mm ≈ 100%)	21.4^{a} ± 1.0	23.9^{c} ± 1.0	54.7^{a} ± 1.0
L3 (254.8 mm ≈ 60%)	20.1^{a} ± 1.3	25.2^{bc} ± 1.8	54.7^{a} ± 1.1
L4 (121.5 mm ≈ 30%)	23.5^{a} ± 2.8	31.2^{ab} ± 1.9	45.3^{b} ± 2.1
L5 (77.2 mm ≈ 18%)	20.5^{a} ± 0.7	35.9^{a} ± 0.5	43.6^{b} ± 0.4

Values are means of four replications ± standard error. Means followed by different letters within the same column differ significantly according to Tukey's test (P ≤ 0.05).

In contrast, the stems and petioles fraction was significantly affected by irrigation depths (P ≤ 0.05). The highest proportion was observed under severe water deficit (L5 = 18% ETc), reaching 35.9%, whereas the lowest value occurred under optimal irrigation (L2 = 100% ETc), with 23.9%. Compared with L2, the SP fraction increased by approximately 50% under L5, indicating that water stress altered biomass partitioning toward structural tissues.

The pods and seeds fraction also showed significant differences among treatments (P ≤ 0.05). The highest proportions (54.7%) were observed under intermediate irrigation depths (L2 and L3), whereas both excessive irrigation (L1) and severe water deficit (L4–L5) significantly reduced reproductive biomass allocation.

These results indicate that both water deficit and excess water negatively affected reproductive dry matter partitioning. Under severe water deficit, reductions in pod and seed biomass may be attributed to restricted assimilate production caused by reduced photosynthetic activity, impaired translocation, and limitations in reproductive development. Conversely, under excessive irrigation, greater vegetative hydration and continued vegetative growth may have reduced assimilate allocation efficiency toward reproductive structures.

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These findings are consistent with Desclaux and Roumet (1996), who reported that drought stress alters soybean phenology and reduces reproductive development by shortening seed filling duration. Similar physiological responses were described by Egli *et al.* (1980) and Zeiher *et al.* (1982), who demonstrated that soybean reproductive growth depends strongly on photoassimilate translocation from vegetative source tissues to reproductive sink organs.

Comparisons with previous studies reinforce these observations. Tobía and Villalobos (2004), working under humid tropical conditions with lower solar radiation, reported dry matter partitioning proportions of 24.4:39.0:36.6% (L:SP:PS), showing substantially lower reproductive allocation than observed in the present study. Likewise, Muñoz *et al.* (1983) reported values of 28.0:36.0:36.0%, whereas Hintz and Albrecht (1994) found proportions close to those observed under optimal irrigation in this study (16.8:28.3:54.9%).

From a forage quality perspective, the higher pods and seeds proportions observed under intermediate irrigation depths are particularly relevant, as reproductive tissues generally contribute greater protein and energy value, whereas excessive stem accumulation tends to increase fiber content and reduce digestibility.

Economic and productive implications

From a practical perspective, the results indicate that irrigation management strongly influences both forage productivity and resource use efficiency. Although the highest fresh biomass and dry matter yield were observed under 150% ETc, this treatment did not differ significantly from 100% ETc in dry matter production, while requiring substantially greater water input. Therefore, from an agronomic and economic standpoint, irrigation at 100% ETc appears to represent the most rational management strategy, as it maximized water use efficiency without compromising productive performance.

From a nutritional perspective, soybean forage produced under irrigation levels between 100% and 150% ETc presents significant supplementation potential for tropical livestock systems due to its elevated dry matter production and favorable biomass partitioning toward reproductive tissues.

Based on the dry matter yield obtained under optimal irrigation, soybean forage could provide a meaningful contribution to crude protein and energy supply, supporting more efficient forage-based feeding systems, particularly in regions where seasonal forage scarcity limits livestock productivity.

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CONCLUSION

Irrigation depth significantly affected biomass production, water use efficiency, and dry matter partitioning in soybean forage cv. CIGRAS 06. Maximum fresh biomass yield was obtained under 150% ETc, whereas the highest water use efficiency was achieved at 100% ETc, indicating that irrigation management should prioritize efficient water use rather than excessive water application. Intermediate irrigation depths (60–100% ETc) promoted greater biomass allocation to pods and seeds, which may positively influence forage nutritional quality. However, because this study was conducted under a single production cycle, in one experimental environment, and with only one soybean cultivar, caution should be exercised when extrapolating these findings to other production conditions. Within the conditions of this study, irrigation management around 100% ETc appears to represent the most efficient strategy for optimizing soybean forage production under tropical dry conditions.

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