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EFICIÊNCIA DO USO DA ÁGUA E COEFICIENTE DE CULTIVO PARA LISIANTHUS DE CORTE CULTIVADO EM AMBIENTE PROTEGIDO

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1 RESUMO

O lisianthus é considerado uma das espécies de maior relevância econômica no mercado nacional e internacional. Contudo, para alcançar a qualidade que o mercado exige, é necessário um manejo hídrico eficiente durante o período de produção. Uma das alternativas capaz de otimizar a eficiência no uso da água é a adição de hidrogel ao substrato, associada à irrigação. Nesse sentido, o objetivo desse trabalho foi determinar peso fresco, consumo hídrico, eficiência do uso da água e os coeficientes de cultura do lisianthus de corte, sob o efeito combinado entre diferentes manejos de irrigação e doses de hidrogel, em ambiente protegido, em duas épocas de cultivo. O delineamento adotado foi o inteiramente casualizado, com esquema fatorial 5x4, sendo cinco lâminas de irrigação: 40, 60, 80, 100 e 120% da capacidade de retenção do vaso, e quatro doses de hidrogel (0, 3, 6 e 9 gramas por vaso). Foram utilizadas quatro repetições para cada tratamento, totalizando 80 vasos. Em conclusão, o peso fresco, consumo hídrico e a eficiência do uso da água, foram significativamente afetadas pela interação entre lâminas de irrigação e doses de hidrogel nas duas épocas de cultivo.

Palavras-chave: *Eustoma grandiflorum,* consumo hídrico, evapotranspiração, otimização de uso da água.

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EFFICIENCY OF WATER USE AND CROP COEFFICIENT FOR LISIANTHUS AS CUT FLOWER CULTIVATED IN GREENHOUSE

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2 ABSTRACT

Lisianthus is considered one of the most economically important species in the national and international market. However, to achieve the quality demanded by the market, efficient water management during the production period is necessary. An alternative capable of optimizing the water use efficiency is the addition of hydrogel to the substrate, associated with irrigation. In this sense, the objective of this work was to determine fresh weight, water consumption, water use efficiency and crop coefficients of cut lisianthus under the combined effect of different irrigation management and hydrogel doses in a protected environment in two growing seasons. The design adopted was completely randomized, with a 5x4 factorial distribution, with five irrigation depths, namely: 40, 60, 80, 100, and 120% of the pot's holding capacity, and four doses of hydrogel (0, 3, 6, and 9 grams per pot). Four replicates were used for each treatment, totaling 80 pots. In conclusion, fresh weight, water consumption and water use efficiency were significantly affected by the interaction between irrigation depths and hydrogel doses in the two growing seasons.

Keywords: *Eustoma grandiflorum,* water consumption, evapotranspiration, optimization of water.

3 INTRODUCTION

The production of flowers and ornamental plants is related to high water consumption (GARCÍA-CAPARRÓS; LAO, 2018). Thus, improving water use efficiency has become a priority given the current scarcity of this resource (DAMKJAER; TAYLOR, 2017; ZURITA et al., 2018). In this sense, cultivation in a protected environment is an alternative for the efficient management of water resources, in addition to influencing the quality standard of cut flowers. (SLATHIA et al., 2018).

To achieve the quality that the market demands, irrigation is considered an essential input for the cultivation of high value-added crops in a protected environment (CANAJ et al., 2020), as is the case for Lisianthus (RODRÍGUEZ-SERRANO et al., 2020).

In addition, in addition to efficient irrigation management, which allows for better decision-making, aiming at yield, water savings and improved water use efficiency, another promising technique in protected environments is soilless cultivation (MONTESANO et al., 2018). In this system, the substrate retains water and nutrients, ensuring their availability to the plant roots (ULLAH et al., 2017).

Another alternative capable of optimizing water use efficiency is the addition of a hydrogel to the substrate, which is associated with irrigation. Its use is capable of promoting more efficient water management, reducing costs and increasing irrigation intervals since water is gradually released into plants (MENDONÇA; QUERIDO; SOUSA, 2015; ABOBATTA, 2018).

Although hydrogels are widely used in agriculture, especially in studies focused on their applicability in the forestry and fruit growing segment, the technical and economic consequences of their use in the cultivation of ornamental plants require studies (LJUBOJEVIĆ et al., 2017), mainly in protected environments.

Furthermore, the water conservation approach requires accurate information on crop water use (FERNÁNDEZ-PAVÍA; TREJO-TÉLLEZ, 2019). In this sense, the crop coefficient is a parameter for estimating the water use required for efficient irrigation management.

The water demand of plants varies according to their phenological phase, thus requiring a specific crop coefficient for each phase (SILVA et al., 2017). However, there is currently no description of this parameter in the scientific literature, considering the simultaneous effects of irrigation and hydrogel management on lisianthus cuttings.

This parameter is the ratio of crop evapotranspiration (ETc), which can be determined directly via lysimeters, to reference evapotranspiration (ETo), which can be obtained via applied methods or empirical equations (LIMA et al., 2020).

Considering the importance of expanding and improving studies on the water requirements of species of economic interest in floriculture, the objective of this work was to determine the cultural coefficients of cut lisianthus and evaluate the efficiency of water use under the combined effects of different irrigation management practices and hydrogel doses in a protected environment.

4 MATERIALS AND METHODS

The experiment was carried out in the Floriculture Sector of the Polytechnic College of the Federal University of Santa Maria in a semiclimate-controlled greenhouse with an area of 600 m2 (20x30 m) that was 3.5 meters high and covered with transparent polyethylene (150 microns) in two growing seasons. The first growing season (147 days) occurred between March and July 2019, and the second season (88 days) occurred from August to December 2019.

According to the Köppen classification, the region's climate is Cfa, humid subtropical, with hot summers and no defined dry season (HELDWEIN; BURIOL; STRECK, 2009). The average air temperature in the first growing season ranged from 10°C to 28°C, whereas the relative humidity ranged from 58% to 95%. In the second season, the average air temperature ranged from 16 to 31°C, and the relative humidity ranged from 65 to 95%.

The crop used was Lisianthus-*Eustoma grandiflorum* (Raf).) Shinn, 'Mariachi blue', purple in color. The seedlings were purchased from the Úrsula flower shop, located in the city of Nova Petrópolis/RS, which receives seeds from the company Sakata Seed Corporation, headquartered in São Paulo.

A 5x4 factorial design was adopted, with five irrigation depths of 40, 60, 80, 100 and 120% vessel retention capacity (CRV) and four doses of hydrogel. (0, 3, 6 and 9 grams per pot). Four replicates were used for each treatment, totaling 80 pots. The pots had a capacity of 8 liters and had the following dimensions: 22.5 cm in height, 23 cm in upper diameter, and 19 cm in lower diameter.

The chemical composition of the substrate used to fill the pots was hydric peat, pine bark-based substrate and commercial Carolina substrate at a ratio of 2.5:1:1. All the pots had 4 holes in the bottom for drainage and aeration of the root system.

The characteristics of the hydrogel used are described in Hydroplan-EB®, and it was prepared following the manufacturer's recommendations for the substrate (1000 grams for every 200 liters of water), with formulations of 3, 6, and 9 g of the product for every 1.2, 2.4, and 3.6 liters of water, respectively. For each treatment, the pots received the dosage of the expanded gel and were subsequently homogenized with the substrate, followed by transplanting the seedlings.

For these treatments, five water replacement levels were used in relation to the CRV: 40, 60, 80, 100 and 120%.

The determination of the CRV was performed according to the methodology described by (KÄMPF; TAKANE;

SIQUEIRA, 2006). For this purpose, the mathematical sentence below was used, adapted from (SCHWAB et al., 2013):

$$PV\,\% = (PV_{crv} - PV_{seco}).\, CRV + PV_{seco} \quad (1)$$

where PV% is the weight of the pot for each of the treatments; PV_{crv} is the water retention capacity; PV_{dry} is the weight of the pot filled with completely dry substrate; and CRV is the water replacement depth.

After each irrigation, the water storage of the substrate was quantified via the water balance method, which accounts for water inflows and outflows from the pot. The variation in pot water storage was determined by weighing the pots on a 50-kg scale. Irrigation was performed manually via a 20-liter plastic bucket placed in each pot with a graduated beaker. Because the experiment was conducted in a protected environment, the only water input was through irrigation at seven-day intervals.

Among the various methods for calculating evapotranspiration, the Penman–Monteith method, recommended by the FAO, stands out. However, the use of this equation was limited by the lack of measurement of some input variables. Therefore, because the experiment was carried out in a greenhouse and to facilitate use by floriculturists, the reference evapotranspiration (ETo) was determined via Equations 2, 3, 4, 5 and 6. Crop evapotranspiration (ETc) was obtained by weighing lysimetry.

Benevides and Lopez Method (1970):

$$ETo_{(BL)} = 1{,}21 \times 10^{\left(\frac{7{,}45 \times T_{med}}{234{,}7 + T_{med}}\right)} (1 - 0{,}01 \times UR_{med}) + 0{,}21\, x\, T_{med} - 2{,}30 \quad (2)$$

where $ETo_{(BL)}$ is the reference evapotranspiration according to the Benevides–Lopes method, mm day $^{-1}$; T_{med} is the average air temperature, °C; and RH_{med} is the average daily relative humidity, %.

Camargo Method (1971):

$$ETo_{(Cam)} = K \times R_a \times T_{med} \times ND \quad (3)$$

where $ETo_{(Cam)}$ is the reference evapotranspiration according to the Camargo method, mm day $^{-1}$; K is an adjustment factor that varies with the average annual temperature of the location, °C; Ra is the extraterrestrial solar radiation, mm day $^{-1}$; T_{med} is the average air temperature, °C; and ND is the number of days in the period.

Linacre Method (1977):

$$ETo_{(L)} = \frac{700 \times \frac{T_m}{(100 - \varphi)} + 15 \times (T_{med} - T_d)}{(80 - T_{med})} \quad (4)$$

where $ETo_{(L)}$ represents the reference evapotranspiration according to the method of Linacre, mm day $^{-1}$; T_{med} represents the mean daily temperature, °C; T_m represents T_{med} + 0.006z, z represents the altitude (m); T_d represents the dew point temperature, °C; and φ represents the local latitude (degrees), °.

Haise method (1963):

$$ETo_{(JH)} = R_S \times (0{,}025 \times T_{med} + 0{,}078) \quad (5)$$

where $ETo_{(JH)}$ is the reference evapotranspiration according to the Jensen–Haise method, mm day $^{-1}$; R_S is the global solar radiation converted into units of evaporated water, mm day $^{-1}$; and T_{med} is the average daily temperature, °C.

Hargreaves Method (1974):

$$ET_{o(H)} = 0,408 \times 0,0023 \times (T_{med} + 17,8) * (T_{máx} - T_{min})^{0,5} * R_a \quad (6)$$

where $ET_{o\ (H)}$ is the reference evapotranspiration according to the method of Hargreaves, mm day $^{-1}$; T_{max} is the maximum air temperature, °C; T_{min} is the minimum air temperature, °C; T_{med} is the average daily temperature, °C; and R_a is the extraterrestrial solar radiation, mm day $^{-1}$.

Reference evapotranspiration was estimated via different equations to reduce the variation in estimates from existing methodologies and increase the reliability of the results. The meteorological variables required to calculate ETo were measured inside the protected environment via a digital thermohygrometer to verify the maximum and minimum temperatures and relative humidity. Readings were taken daily at a standard time. Other data, such as insolation and solar radiation data, were obtained from the automatic station of the National Institute of Meteorology (INMET), located at the UFSM.

To evaluate the crop coefficient (Kc), the limit of 80% of the CRV was used. Kc was calculated from the ETc estimated via lysimetry, and ETo was estimated via different equations via Equation 7.

$$Kc = \frac{ETc}{ETo} \quad (7)$$

where Kc is the crop coefficient for potted lisianthus; ETo is the reference evapotranspiration (mm day $^{-1}$); and ETc is the crop evapotranspiration (mm day $^{-1}$).

Water use efficiency (WUE) was determined via Equation 8, which is related to the fresh mass of the stems (Y) and the total water depth applied during the crop cycle (ETc).

$$EUA = \frac{Y}{ETc} \quad (8)$$

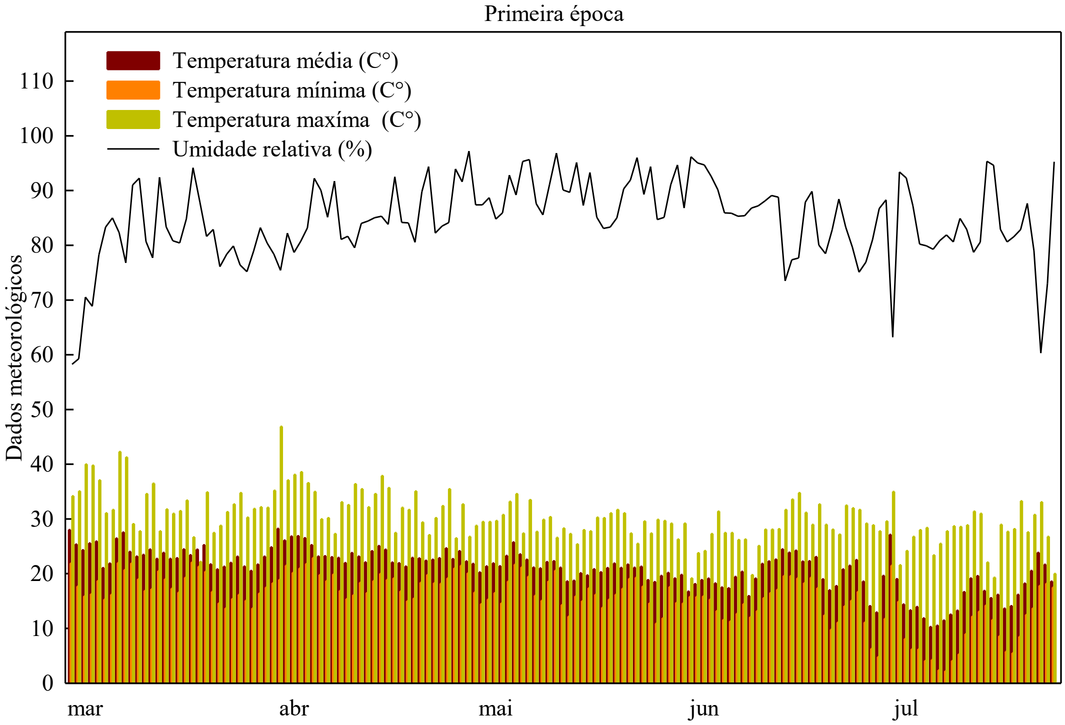
where EUA represents the water use efficiency (g.mm $^{-1}$), Y represents the fresh mass of the stems (g), and ETc represents the crop evapotranspiration (mm cycle $^{-1}$).

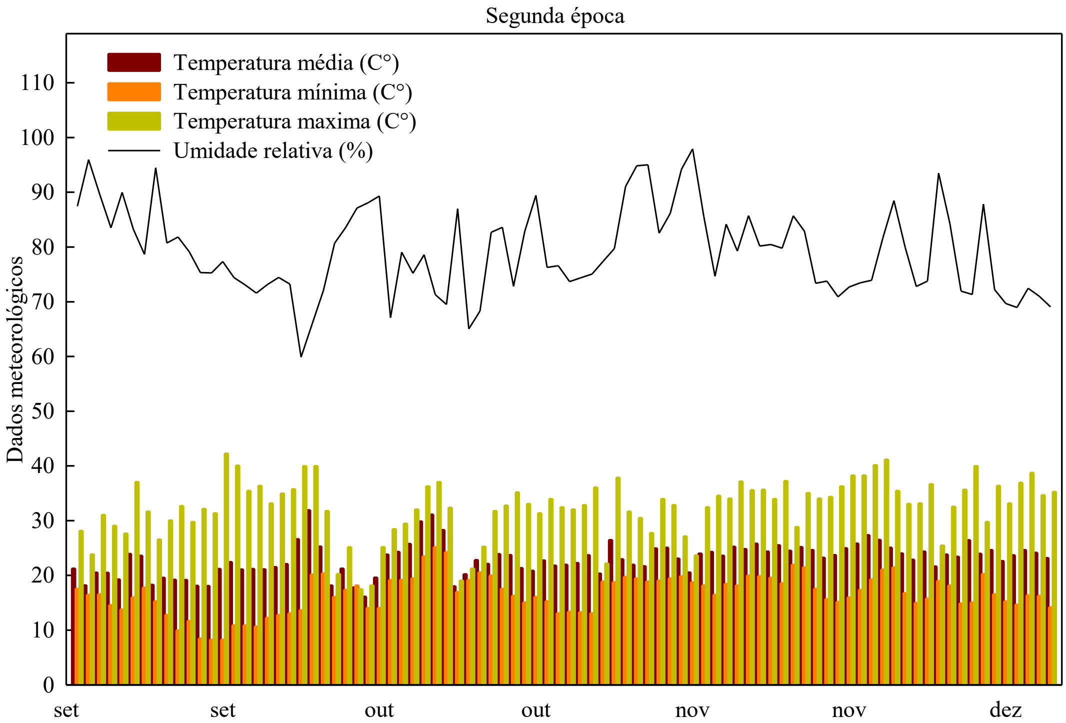
Wilk normality test and the Levene test for homogeneity of variance were used. Finally, the data were subjected to analysis of variance with a maximum probability of type I error of 5% via SISVAR 5.6 statistical software (FERREIRA, 2011). When a significant interaction was observed between the irrigation depth and hydrogel dose, response surface graphs were produced via the SigmaPlot 12.5 program.

5 RESULTS AND DISCUSSION

The phenological cycle of cut lisianthus in the first growing season was longer than that in the second growing season, possibly due to different weather conditions, particularly related to the air temperature inside the structure at different times (Figure 1). In particular, higher air temperatures at the beginning of the growing season likely led to slower plant development. The average air temperatures in the first and second growing seasons were 20°C and 23°C, respectively. The ideal air temperature range for lisianthus is 15°C to 25°C, although lisianthus can withstand relatively high temperatures (AHMAD et al., 2017).

Figure 1. Temperature data (minimum and maximum) and average relative humidity in the two growing seasons.





Fresh weight (FW), water consumption (WI), and water use efficiency (WUE) were significantly affected by the interaction between irrigation depth and hydrogel dose in both growing seasons (Figure 2). In this sense, response surface plots were constructed to visualize the interaction between significant variables and their optimal values.

As shown, a decrease in irrigation depth and hydrogel dose was correlated with a reduction in PF and CH. The best response for PF was observed at depths of 84.4 and 86.5% of CRV and with doses of 7.2 and 8.1 g of hydrogel for the first and second growing seasons, respectively, reaching values of up to 60 g in both growing seasons (Figures 2A and 2B).

However, in the second growing season, when temperatures were relatively high, especially at the end of the cycle, when there were 56 days of air temperatures above the ideal temperature for lisianthus cultivation (15–25°C), the hydrogel had a greater influence on fresh weight than did the first growing season, which had 36 days of air temperatures above the ideal temperature. This evaluation demonstrated that the hydrogel directly contributes to water retention in the substrate and, consequently, delays the symptoms of water stress.

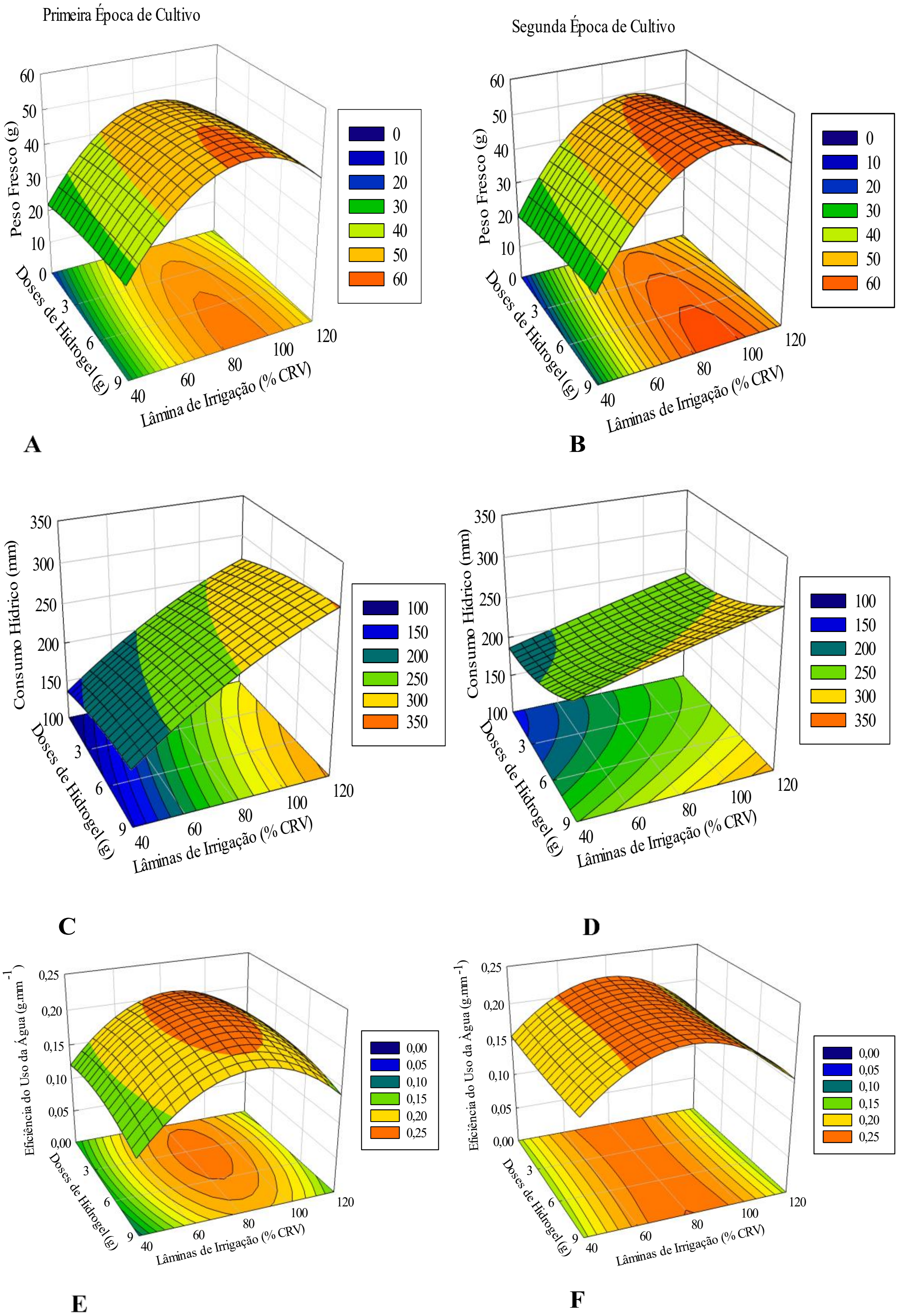
The 110.1 and 117.3% CRV blades and 8.5 and 8.8 g hydrogel doses, respectively, for the first and second crops presented the highest CHs (Figures 2C and 2D). This result is indicative of the contribution of the treatments used in relation to the maintenance of soil moisture, which is of utmost importance for cut flowers, which have a root system limited to the space of the vase and require great water availability.

This result is corroborated by Ju, Yoon and Ju (2021) and Tomadoni et al. (2020), who reported that the addition of hydrogel influenced the moisture retention of the substrate.

With respect to EUA (Figure 2E and 2F), slides containing 82.4 and 85.6% CRV and hydrogel doses of 4.6 and 5.6 g, respectively, presented better results for the first and second cultivation seasons.

Because irrigation was applied directly to the base of the plant, a reduction in evaporative losses of the applied water was observed, even at the smallest replacement depths tested. This increase in water application efficiency influenced the hydrogel response, maximizing the EUA. Similar results were described by Matos Filho, Silva, Bastos (2020), Kassim, El-Koly, Hosny (2017) and Navroski et al. (2015), who obtained greater EUAs with the use of hydrogels.

Figure 2. Response surface graphs of the parameters of fresh weight, water consumption and water use efficiency of the crop as a function of the interactions developed between the irrigation depths and hydrogel doses in the two growing seasons.



Therefore, hydrogels are convenient and economically viable options in water-deficit areas, as water-retaining polymers delay the onset and intensity of water deficit (FELIPPE et al., 2020). However, although hydrogels contributed to improving the variables in this study, the irrigation depths tested were what actually produced the best results.

This behavior is in agreement with that reported by Nascimento et al. (2021), who highlighted that the efficiency of superabsorbent polymers is affected by the amount of applied irrigation water and by the air and soil temperatures.

Crops in protected environments differ in terms of climate and structure. Furthermore, there are numerous limitations in measuring some of the indoor meteorological parameters. Consequently, the performance of ETo estimation methods may differ under any given condition and require local calibration (RAHIMIKHOOB ; SOHRABI; DELSHAD, 2020).

According to Table 1, a variation in Kc was observed throughout the crop cycle, with lower crop coefficient values occurring during the initial development phase, with average Kc values for the different equations of 0.61 and 0.75 (VEG 1) and 1.28 and 1.04 (VEG 2) in the first and second cultivations, respectively. This occurred because of the lower transpiration by the plants during this period and the dependence on environmental factors, especially the evaporation of water from the substrate, which resulted in higher ETo and lower ETc values, resulting in an initially lower Kc than those in other phases (SILVA et al., 2018).

Table 1. Cultivation coefficient of cut lisianthus in the two growing seasons.

DAT	PHASE	There is	Here	I read	JH	BL	Amplitude kc	Average	Etc (mm day-1)
First Cultivation Season									
Crop Coefficient									
0-37	VEG I	0.88	0.54	0.55	0.60	0.49	0.16	0.61	1.94
37-73	IF I	1.75	0.96	1.12	1.55	1.03	0.35	1.28	3.18
73-110	PF I	2.13	1.20	1.29	2.15	1.30	0.48	1.61	3.28
110-147	QF I	1.20	0.87	0.80	1.28	0.98	0.21	1.03	1.97
Second Growing Season									
Crop Coefficient									
DAT	**PHASE**	**There is**	**Here**	**I read**	**JH**	**BL**	**Amplitude kc**	**Average**	**Etc (mm day-1)**
0-22	VEG I	0.99	0.69	0.56	0.83	0.68	0.16	0.75	2.26
22-44	IF I	1.61	0.91	0.72	1.11	0.86	0.34	1.04	3.13
44-66	PF I	2.04	1.14	1.04	1.40	1.11	0.41	1.34	4.07
66-88	QF I	1.30	0.85	0.67	0.76	0.73	0.25	0.86	3.06

DAT: days after transplanting, Ha: Hargreaves, Ca: Camargo, Li: Linacre, JH: Jensen Hayse, BL: Benevides Lopez, Kc: cultural coefficient, ETc: average daily crop evapotranspiration, VEG1: beginning to middle of the vegetative phase, VEG2: half to the end of the vegetative phase, PF: full flowering, QF: fall of flowering.

The values of the cultural coefficients (Kc values) increase as the crop develops until the PF phase, where they peak, with average values of 1.61 and 1.34 for the first and second cultivations, respectively.

Owing to the reduction in water demand, the Kc values progressively decreased in the fall flowering phase (QF I), with average Kc values for the first and second seasons of 1.03 and 0.86, respectively. This occurs in response to the reduction in crop water demand. Furthermore, in the first season, the relative humidity and air temperature values were greater, and peaks occurred during certain periods of the crop cycle, which possibly contributed to the increase in Kc values compared with those in the second season.

Corroborating these observations, Silva et al. (2017) reported differences in Kc values estimated by different methodologies and attributed this oscillation to the fact that each methodology considers a different number of variables in estimating the estimated ETo value, which results in heterogeneous Kc values among the methods considered in the work. The sensitivity of the ETo estimate in response to the oscillation of a given meteorological variable is conditioned by the mathematical calculation model considered for the ETo estimate; thus, it is justifiable that there may be a difference in greater or lesser amplitudes of Kc between the growing seasons considered.

In this context, it is important to determine Kc for each crop cycle considered in the different seasons. Furthermore, Piroli et al. (2020) reported that the crop coefficient is a characteristic value of each cultivar, varying according to the study site and the conditions to which the crop is subjected.

Confirming this behavior, dos Santos et al. (2021) reported differences in the Kc values found depending on the method used to estimate ETc and ETo, mainly in response to the climatic conditions of the region considered.

These differences suggest a direct relationship with irrigation management and rational use of water, since the use of Kc values obtained via empirical methods results in applications of irrigation depths in greater or lesser quantities, considering that all of them presented similar values in some phases and different values in other phases.

6 CONCLUSION

The best response for fresh weight, water consumption and water use efficiency for lisianthus crops in the first season was observed with blades with between 82.4 and 110.1% CRV and hydrogel doses between 4.6 and 8.5 g of hydrogel.

In the second period, the best results for the same variables were observed with slides containing between 85.6 and 117.3% CRV and doses between 5.6 and 8.8 g of hydrogel.

The average values of the crop coefficient of cut lisianthus in the vegetative phase for the different equations were 0.61 and 0.75 (VEG 1) and 1.28 and 1.04 (VEG 2) in the first and second cultivations, respectively.

At flowering, Kc reached values of 1.61 and 1.34 for the first and second crops, respectively, and decreased with decreasing flowering, with values for the first and second seasons of 1.03 and 0.86, respectively.

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