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ASPECTOS AGRONÔMICOS DA FORMAÇÃO DA INFLORESCÊNCIA DA COUVE-FLOR SOB DIFERENTES CONDIÇÕES HÍDRICAS

ANDRE FELIPE BARION ALVES ANDREAN[1]; ROBERTO REZENDE[2]; GUSTAVO SOARES WENNECK [1]; ANDERSON TAKASHI HARA[1]; CLAUDIA SALIM LOZANO MENEZES[1] E DANIELE DE SOUZA TERASSI[1]

[1]Discente do Programa de Pós-graduação em Agronomia, Universidade Estadual de Maringá (UEM), Av. Colombo, 5790, Zona 7, CEP:87020-900, Maringá, Paraná, Brasil. E-mail: andre_andrian@hotmail.com; gustavowenneck@gmail.com; haratakashi1987@gmail.com; claudia.lozano93@hotmail.com; daniele_terassi@hotmail.com

[2]Professor do Departamento de Agronomia, Universidade Estadual de Maringá (UEM), Av. Colombo, 5790, Zona 7, CEP:87020-900, Maringá, Paraná, Brasil. E-mail: rrezende@uem.br

1 RESUMO

Compreender o comportamento da couve-flor em diferentes condições de disponibilidade hídrica pode ser uma importante ferramenta de auxílio ao produtor, que poderá tomar as melhores decisões quanto a época de plantio e a escolha da cultivar, além disto, mesmo que os materiais vegetais possuam a mesma classificação de época de plantio e sazonalidade, o desempenho e os meios fisiológicos de produção muitas vezes não são os mesmos. Objetivou-se avaliar os aspectos agronômicos da formação da inflorescência de duas cultivares de couve-flor, em ambiente protegido, sob diferentes níveis de irrigação com base na aferição de sua evapotranspiração. O arranjo experimental foi em blocos casualizados, com quatro repetições, em esquema fatorial de 2 x 3, sendo dois híbridos e três regimes hídricos. Houve resposta significativa do fator híbrido Barcelona e as diferentes lâminas de irrigação para a variável massa fresca da inflorescência. O híbrido Viena apresentou melhor desempenho produtivo, não variando sua massa fresca de inflorescência mesmo com as alterações de disponibilidade hídrica. A massa fresca das folhas possui forte correlação com a massa fresca da inflorescência, principalmente, para o híbrido Barcelona. O número de folhas acima de 15 contribui positivamente para o crescimento do diâmetro da inflorescência em couve-flor.

Palavras-chave: *Brassica oleracea var.botritys,* lâminas de irrigação, fonte-dreno.

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AGRONOMIC ASPECTS OF THE FORMATION OF THE INFLORESCENCE OF CAULIFLOWER UNDER DIFFERENT WATER CONDITIONS

2 ABSTRACT

Understanding the behavior of cauliflower under different water availability conditions can be an important tool to assist farmers, that will be able to make the best decisions regarding the planting time and the choice of the cultivar, in addition, even if the plant materials have the same classification of planting time and seasonality, performance and physiological means of

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production are often not the same. The objective was to evaluate the agronomic aspects of the formation of the inflorescence of two cauliflower cultivars, in a greenhouse under different levels of irrigation based on the measurement of their evapotranspiration. The experimental arrangement was in randomized blocks with four replications in a 2 x 3 factorial scheme, two hybrids and three water regimes. There was a significant response from the hybrid factors Barcelona and the different irrigation depths for the variable fresh mass of the inflorescence. The Viena hybrid showed better productive performance, with its fresh inflorescence mass not varying even with changes in water availability. The fresh weight of the leaves has a strong correlation with the fresh weight of the inflorescence, mainly for the Barcelona hybrid. The number of leaves above 15 contributes positively to the growth of the diameter of the cauliflower inflorescence.

Keywords: *brássica olerácea var. botritys,* irrigationplates, souce-sink.

3 INTRODUCTION

Cauliflower (*Brassica oleracea var. brotris*) belongs to the *Brassicaceae family* and originated on the Mediterranean coast and expanded throughout Europe in the 17th century (SERUDO; DA SILVA FILHO, 2018). Currently, this vegetable is present in more than 100 countries, with China as its largest producer, harvesting approximately 10 million tons in 2018 (FOOD AND AGRICULTURE ORGANIZATION, 2019). Nationally, in 2016, Brazil registered 329,047 thousand tons of cauliflower, with the main producing centers located in the South and Southeast Regions (CONFEDERAÇÃO DA AGRICULTURA E PECUÁRIA DO BRASIL, 2017).

Cauliflower is traditionally grown in the field. However, protected cultivation is gaining worldwide acceptance, as it allows for cultivation in relatively small areas, increasing its efficiency. It also allows for greater control over climate factors and reduces pest and disease attacks, which consequently improves product quality.

Notably, irrigation, when used appropriately, is one of the main factors for success in vegetable production, especially for cauliflower, which is a water-demanding crop. This crop provides 93% water, so adequate irrigation can positively influence production quality (TANGUNE et al., 2016).

The ability of some plants to better utilize water, especially when water is in short supply, is desirable from an agronomic perspective since water savings lead to reduced production costs. Nadeen et al. (2019) highlighted several factors and tolerance mechanisms that some plants may express under unfavorable conditions, whereas Bianchi and De Almeida (2016) described how plants perform osmotic adjustments to adapt to adverse conditions, causing biochemical changes in their physiology that influence gas exchange, stomatal opening, photosynthesis, and, consequently, leaf growth and expansion.

Conversely, applying too much water can trigger physiological disorders in plants, in addition to creating an ideal environment for disease. According to Kirda et al. (2003), overirrigation can compromise the quality and productivity of cauliflower, potentially increasing production costs. Nitrogen absorption can also be compromised, as this element can be easily leached when large amounts of water are applied to the soil (SMITH et al., 2016).

According to Taiz et al. (2017), even when subjected to suboptimal growing conditions, plants have the ability to self-regulate their physiological activities to minimize losses in development and production. The authors also point to the source–sink relationship as an example of this, a dynamic process that can be altered according to environmental adversities. Research by Tomassoni et al. (2013) demonstrated that varying amounts of water can alter cauliflower development, influencing the fresh weights of leaves, flowers, and other parameters. The best yields for large-scale crops are achieved through successful regulation of source–sink relationships.

Knowledge about plant behavior in response to water adversities can contribute to adapting technical cultivation recommendations, indicating the best cultivar for regions with low or high precipitation. Some crops with the same climatic requirements, planting periods, or similar phenotypic characteristics may exhibit different developmental behaviors due to adverse environmental conditions (ALMEIDA et al., 2018).

The need to evaluate cauliflower varieties for their adaptability to different growing conditions and agronomic characteristics is of utmost agricultural importance. Therefore, this study aimed to evaluate the agronomic aspects of cauliflower inflorescence formation under three irrigation levels.

4 MATERIALS AND METHODS

The experiment was carried out at the Irrigation Technical Center (CTI) of the State University of Maringá (UEM) in the municipality of Maringá, PR. The climate of the region is classified as subtropical mesothermal Cfa, with an average annual temperature of 21.8 °C and average precipitation of 1300 to 1600 mm (MONTANHER; MINAKI, 2020).

The experiments were carried out in a protected arch-type environment with no temperature control, which had the following dimensions: 25 m long, 7 m wide and 3.5 m high. Its roof was coated with low-density polyethylene film (150 μm thick), and the sides were wrapped with an anti-aphid screen, both of which were white.

The experimental design adopted was randomized blocks (DBC), with four replications, in a 2 × 3 factorial scheme, where the first factor consisted of two cauliflower hybrids (Barcelona and Viena) and the second factor was the different irrigation depths (75, 100 and 125%) based on crop evapotranspiration (ETc).

The soil was classified as Dystroferric Red Nitosol, characterized by having a nitic B horizon (SANTOS et al., 2019). On the basis of the chemical analysis of the soil (Table 1) and the recommendations of Pauletti and Motta (2017), base fertilization was carried out with nitrogen (N) in the form of urea and phosphorus (P) in the form of simple superphosphate and potassium (K) in the form of potassium chloride. For topdressing, N and K were applied at 15, 30, 45 and 60 days after transplanting (DAT). Foliar fertilization was carried out at 15 and 30 DAT via boric acid (1 g/L) and ammonium molybdate (0.5 g/L).

Table 1. Chemical analysis of the soil in the 0.0–0.2 m layer of the experimental area.

Parameter	Unit	Result
pH $CaCl_2$	-	6.6
pH H_2O	-	7.4
Organic matter	g dm $^{-3}$	25.2
Carbon	g dm $^{-3}$	14.62
Match	mg dm $^{-3}$	149.02
Potassium	cmol $_c$ dm $^{-3}$	0.72
Magnesium	cmol $_c$ dm ^{3}	2.24
Calcium	cmol $_c$ dm ^{3}	7.55
Hydrogen + aluminum	cmol $_c$ dm ^{3}	2.45
Cation exchange capacity	cmol $_c$ dm ^{3}	12.95
Base saturation	cmol $_c$ dm ^{3}	81.08
Copper	mg dm $^{-3}$	17.77
Zinc	mg dm $^{-3}$	33.94
Iron	mg dm $^{-3}$	169
Manganese	mg dm $^{-3}$	103.7
Sodium	mg dm $^{-3}$	32.25
Boron	mg dm $^{-3}$	4.1

After turning the soil and incorporating the top dressing, 24 beds measuring 3 m long and 0.45 m wide were constructed. The irrigation lines were distributed over these beds, consisting of a drip irrigation system with 12 self-compensating drippers spaced 0.25 m apart, with a flow rate of 4 L h $^{-1,}$ and operated at a pressure of 10 mca.

The plant materials used were Barcelona and Vienna cauliflower hybrids, both classified as midseason cauliflowers. Although they are produced by different companies, these hybrids can reach an average weight of 1.5 kg, a head diameter of 18–24 cm, and good tolerance to temperature fluctuations (FELTRIN 2019; SEMINIS 2019).

The seedlings were grown in 128-cell expanded polystyrene trays with a commercial substrate composed of carbonized pine and rice husks. Transplanting took place at the end of April when the seedlings had four permanent leaves.

The seedlings were placed in the beds, totaling six plants per bed: three Barcelona hybrids and three Vienna hybrids. To ensure minimal environmental interference, only the four central plants were evaluated, with the remaining plants located at the edge of the bed being considered borders.

Irrigation was carried out daily on the basis of the measurement of cauliflower evapotranspiration (ETc) provided by three constant water table lysimeters installed inside the protected environment, where data collection was carried out daily at 7:00 a.m. In each lysimeter, two cauliflower plants were transplanted, similar to reproducing the conditions of the beds.

The lysimeters were constructed with 380-L PVC water tanks. First, a layer of gravel and geotextile was placed inside the tanks to prevent water obstruction by soil particles. The tanks were then filled with soil, following the same order of layers as in the natural conditions of the area. The tanks were coupled to supply tanks with floats similar to those used in residential water tanks. As water loss occurred in the system through evapotranspiration, water was automatically replenished by capillary action, and irrigation was carried out following the methodology of Lozano et al. (2017).

The harvest was carried out on July 30, 95 days after sowing, and the plant diameter (PD) was measured from the tip of the leaf to the tip of the opposite leaf, forming an angle of 180°. Plant height (AP) from the soil surface to the highest point of the inflorescence, inflorescence diameter (ID) and inflorescence height (AI) were evaluated via a graduated ruler. The fresh inflorescence mass (MFI) and fresh leaf mass (MFF) were measured via a digital scale (0.001 g). The number of leaves (NF) was quantified via manual counting, and the leaf area (AF) was estimated via LICOR 3100c equipment.

The data were subjected to analysis of variance via the F test (p > 0.05) to verify the effects of the factors individually, as well as the interactions of the evaluated variables. The Tukey mean test was subsequently applied at the 5% significance level via Sisvar statistical software (FERREIRA, 2019).

Correlations were verified between the variables AF, DI, MFI, and MFF via Pearson's correlation analysis. Cluster analysis was also performed, adopting the methodology of De Albuquerque and De Oliveira (2020), aiming to classify the variables into groups so that they are related by similarities, or even dependencies, in addition to separating different cluster elements, that is, highlighting distinct elements. Water use efficiency (WUE) was calculated on the basis of productivity in relation to the amount of water applied, according to Levidow et al. (2014).

5 RESULTS AND DISCUSSION

The water depth factor was significant for the variables plant height, plant diameter, inflorescence fresh weight, leaf fresh weight, leaf area, and number of leaves, as shown in Table 2. The hybrid factor was significant for all variables except plant height. Regarding the interaction between the factors, no significance was observed for any of the variables.

Table 2. Analysis of variance for the morphological variables of the Barcelona and Viena cauliflower hybrids subjected to different water depths in a protected environment.

FV	GL	AP	DP	MFI	MFF	DI	THERE	AF	NF
		cm		g		cm		cm ^{2}	-
BL	3	0.00*	0.00*	0.00*	0.00*	0.00*	0.00*	0.00*	0.81 ^{NS}
L	2	0.00*	0.02*	0.04*	0.00*	0.23 ^{NS}	0.11 ^{NS}	0.02*	0.02*
Heb	1	0.06 $_{NS}$	0.02*	0.00*	0.00*	0.03*	0.00*	0.00*	0.00*
L* Hb	2	0.92 $_{NS}$	0.45 $_{NS}$	0.37 $_{NS}$	0.30 $_{NS}$	0.56 ^{NS}	0.53 ^{NS}	0.58 ^{NS}	0.50 ^{NS}
CV (%)		14.27	12.95	29.75	28.83	10.69	13.24	21.43	25.56

BL, block; L, water blade; Hb, hybrid; AP, plant height; DP, plant diameter; MFI, fresh mass of inflorescence; DI, inflorescence diameter; AI, inflorescence height; AF, leaf area; NF, number of leaves; NS, not significant at the 5% level; *, significant at the 5% level; GL, degrees of freedom; CV, coefficient of variation.
Source: Andrean et al. (2021)

The breakdown of the inflorescence fresh mass variable is presented in Table 3. For the Barcelona hybrid, the 100% and 125% ETc blades provided greater inflorescence mass than did the deficient blade.

Table 3. Breakdown of the variable fresh mass (g) of the inflorescence of the Barcelona and Viena hybrids.

Hybrid	**Water depths (% ETc)**		
	75	**100**	**125**
Barcelona	482.75 Bb	599.87 Ba	649.31 Ba
Vienna	810.93 Aa	783.18 Aa	880.00 Aa

Means followed by the same letter, lowercase in the row and uppercase in the column, do not differ from each other according to the Tukey test. **Source:** Andrean et al. (2021)

Oliveira et al. (2019), with the Barcelona hybrid, obtained an average of 859 g of MFI at a depth of 132% of ETc. It is assumed that this plant material requires larger amounts of water for better performance, in addition to demonstrating sensitivity to different water availability, since there was a 35% increase in the MFI of the largest irrigation depth in relation to the smallest.

The Viena hybrid showed no significant difference in MFI in relation to the different irrigation depths, in addition to outperforming the Barcelona hybrid at all levels of water availability. Blum (2017) reported that some plant species, or even plants of the same species, can develop a high degree of osmotic adjustment in response to water deficit or other adversities. These physiological reactions can be expressed through the different water regimes offered to the plants. Similarly, Risco et al. (2018) reported similar results, showing that there was no difference in the fresh mass of the inflorescence or leaf area of the Avanger hybrid cauliflower subjected to three water depths (50, 100, and 150% of ETc).

The water demand of the crop (Vienna and Barcelona hybrid cauliflower) used in the present study was 214 mm, considering an evapotranspiration of 100% of the ETc with a cycle duration of 95 days. The water replacement of 75% of the ETc corresponded to 160.5 mm, and the surplus sheet corresponded to 267.5 mm. Research carried out by Refai et al. (2018) revealed higher values in two periods of the year, namely, 322 mm and 367 mm.

With respect to water use efficiency, on the basis of the average inflorescence weight and water demand, both hybrids presented better water use efficiency at the deficit irrigation depth (75% of ETc), as shown in Table 4.

Table 4. Water use efficiency of cauliflower hybrids, Barcelona and Viena, subjected to different water depths (75, 100 and 125% of ETc) in a protected environment.

Water replacement (% of ETc)	Hybrid	
	Barcelona	Vienna
	(g mm $^{-1}$)	
75	0.27 to	0.45 to
100	0.25 b	0.32 b
125	0.21 c	0.29 c

*Means followed by the same letter in the same column do not differ from each other according to the Tukey test.
Source: Andrean et al. (2021)

The average EUA values obtained for the Barcelona hybrid were lower than those obtained for the Viena hybrid. This difference in performance is likely linked to genetic material. Oliveira et al. (2018), when studying the performance of cauliflower hybrids in the Baixada Fluminense region, reported that the Barcelona hybrid had an average MFI value of 478.12 g, which was lower than the values obtained for the Bônus and Sharon hybrids.

Through Pearson's correlation analysis, a strong correlation was observed between the leaf area and inflorescence diameter of the Barcelona hybrid at the three applied water depths (Table 5). For the Viena hybrid, as water availability increased, the AF variable began to have a weak correlation with the DI variable, ranging from 0.76 at the 75% water depth to 0.28 at the 125% water depth of ETc; that is, the plant reacts differently to each applied water depth, with changes in the correlation between these variables.

Table 5. Pearson correlation coefficients between the leaf area variables and morphological components of the Barcelona and Viena cauliflower hybrids under different water replacement treatments (75, 100 and 125% of ETc).

Variable	Water depths (% ETc)	Barcelona	Vienna
Inflorescence diameter	75	0.74	0.76
	100	0.74	0.47
	125	0.81	0.28
Fresh mass of inflorescence	75	0.97	0.99
	100	0.98	0.74
	125	0.90	0.55
Fresh leaf mass	75	0.95	0.97
	100	0.97	0.91
	125	0.96	0.68

Source: Andrean et al. (2021)

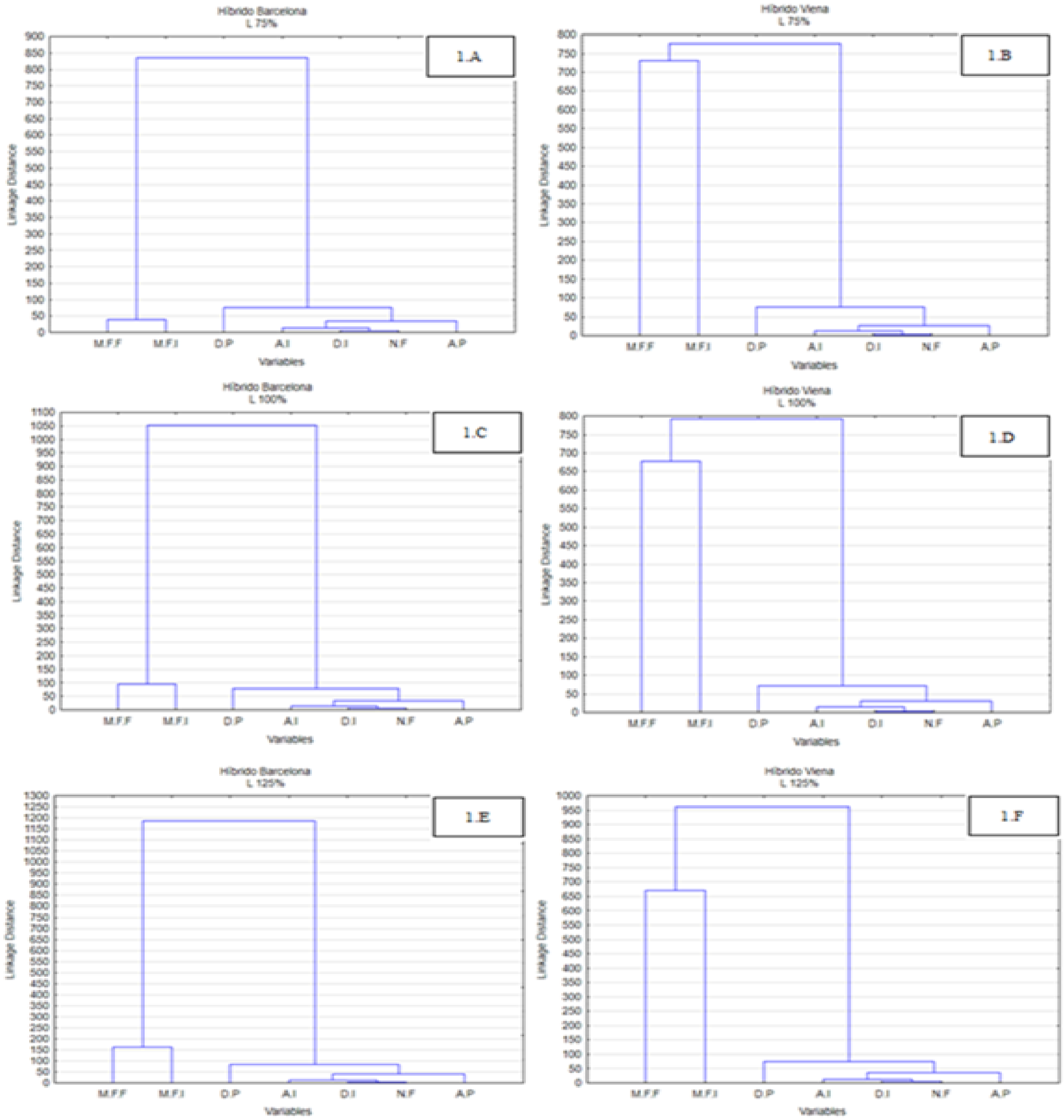
The correlations between the AF and MFI variables were similar to those observed with the DI variable (Table 5). For the Barcelona hybrid, there was a strong correlation at all irrigation levels, unlike what was observed for the Viena hybrid, in which the interactions between these variables ranged from strong to moderate. These findings indicate that, for the Viena hybrid, the leaf area is essential for inflorescence development when the plant is under water deficit, and as this water demand is met, the influence of AF on the inflorescence tends to diminish. Under water deficit conditions, amino acids and sugars accumulate in the leaves, serving as osmotic protectors during cellular dehydration, helping the plant maintain its physiological stability and allowing continued cell growth (ZHONG et al., 2018).

With respect to the MFF variable, only the Viena hybrid presented lower correlation coefficients with AF as water availability increased, from 0.97 to 0.68. These changes indicate that there was better osmotic adjustment for this hybrid, favoring the plant in directing its photosynthetic production to other vegetative parts and providing continuity to its development.

For the Barcelona hybrid, the correlation between MFF and AF remained strong at all irrigation depth levels, demonstrating that even in situations of nonwater deficiency, the plant is stimulated to expand its leaves, which can serve as a drain for photoassimilate sources, compromising the development of the inflorescence or other vegetative parts.

Some variables are essential for the formation and development of the inflorescence. This relationship is associated with the source–sink interaction, in which some vegetative parts become fundamental to other vegetative components of the plant. The cluster analysis, shown in Figure 1, represents the similarity between the variables that contributed, in some way, to the formation and development of the IFM.

Figure 1. Dendrogram based on analysis of the morphological variables of the Barcelona and Viena hybrid cauliflower hybrids.



AP- plant height; DP- plant diameter; MFI- fresh inflorescence mass; MFF- fresh leaf mass; DI- inflorescence diameter; AI- inflorescence height; NF- number of leaves.
Source: Andrean et al. (2021)

Cluster analysis revealed that the groups formed by the variables were the same in the two hybrids under study, as well as in the different water depths (Figure 1). However, there were changes in the degree of similarity (*linkage distance*) between the associations formed, in which the lowest values observed on the Y axis of the graph represent greater proximity between the variables.

The level of similarity between MFF and MFI at L75% (blade with 75% Etc water replacement) was greater for Barcelona, with 40 *linkage points*. For the Viena hybrid, at the same water depth, the degree of similarity was 725 points (Figure 1B). Thus, it is assumed that the IFM production of the Viena hybrid is not exclusively dependent on the MFF and that a set of factors may have contributed to the production of the inflorescence. This is different from what was observed in the Barcelona hybrid, in which water deficiency resulted in a situation of dependence on the source of photoassimilates (MFF) for the sink, which is the inflorescence.

For water depths of 100 and 125% of ETc (Figures 1C and 1E, respectively), a decrease in the degree of association between MFF and MFI was observed for the Barcelona hybrid, with 100 points at L100% (depth with water replacement of 100% of ETc) and 160 points at L125% (depth with water replacement of 125% of ETc). For Viena, the values were 675 points for L100% and 660 points for L125% (Figures 1D and 1F, respectively). Santhosha, Varalakshmi and Shivashankara (2014) reported strong positive correlations for the variables of fresh leaf mass, number of leaves, and length and width of leaves in relation to the fresh mass of the inflorescence of the cauliflower crop.

At all water availability levels, there was great similarity between DI and NF. The AI variable depends on the association between DI and NF, which together influence the AP variable. DP is similar to AP and the other variables mentioned above. These variables are strongly correlated, as they were recorded below 50 points on the similarity scale at all water depths in both hybrids.

There is evidence that for cauliflower, regardless of water conditions, NF is essentially essential for DI; that is, the number of leaves or their permanence on the plant positively influences the increase in inflorescence diameter. Kumar et al. (2017) reported that the number of leaves imposed a positive indirect effect on the mass of the cauliflower inflorescence.

The number of leaves of the Barcelona hybrid was influenced by water availability, as observed in Table 6. For the Viena hybrid, there was no change in NF at any level of water availability.

Table 6. Breakdown of the number of leaves in the Barcelona and Vienna cauliflower hybrids.

Hybrid	Blade (% ETc)		
	75	**100**	**125**
Barcelona	15.72 Bb	16.50 Bab	17.56 Aa
Vienna	17.81 Aa	18.00 Aa	18.56 Aa

Averages followed by the same lowercase letter in the row and uppercase letter in the column do not differ from each other according to the Tukey test.
Source: Andrean et al. (2021)

It cannot be stated that cauliflower, or at least the tested hybrids, increases its MFI production with a high leaf number, as there may be discrepancies in the source–sink relationship. However, regarding the Barcelona material, the average leaf number of 15.72 obtained at the deficit irrigation depth indirectly represents the lowest MFI recorded for this hybrid. The maximum average leaf number (17.56), obtained at the highest irrigation depth, reflects the highest average MFI for this material, as shown in Table 3. The highest average leaf number for Barcelona (17.56) does not differ statistically from the highest value obtained for the Viena material; therefore, it also does not differ from the other values obtained from the Viena sufficiency and deficit water depths. Therefore, for both hybrids, an average leaf number above 15.72 may positively contribute to increasing inflorescence fresh mass.

Thus, even if hybrids have the same planting classification and similar production, several factors can influence the formation of vegetative parts that are essential and decisive for inflorescence production. Furthermore, what is expected in plant production is a balance in the formation and distribution of photoassimilates, directing them so that they can meet the vegetative areas with the greatest energy demand or commercial interest, such as flowers, fruits, and inflorescences.

6 CONCLUSION

The amount of water applied to Barcelona cauliflower implies changes in the production of vegetative mass and fresh mass of the inflorescence and can reach its maximum productivity under conditions of high water availability.

The Viena hybrid has proven to be tolerant to different water regimes, making it an optional material for regions with irregular rainfall rates.

The production of the inflorescence is determined by the number of leaves and the fresh mass of the leaves, in some cases contributing to the increase in the diameter of the inflorescence.

The presence of more than 15.72 leaves can contribute positively to the development of cauliflower inflorescence diameter.

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