ISSN 1808-8546 (ONLINE) 1808-3765 (CD-ROM)

PHENOLOGY, CONSUMPTION AND WATER USE EFFICIENCY OF *GYPSOPHILA PANICULATA* GROWN ON RICE HUSK-BASED SUBSTRATES

DANIELA HÖHN[1]; ROBERTA MARINS NOGUEIRA PEIL[2]; PRISCILA MONALISA MARCHI[3]; PAULO ROBERTO GROLLI[4] E LAÍS PERIN[5]

[1]* State University of Maringá *(Avenida Colombo, 5790, Zona 7, C.P. 87020-900, Maringá – Paraná, Brazil) dani.hohn.sc@gmail.com*
[2] *Department of Plant Sciences, Federal University of Pelotas (Avenida Eliseu Maciel – s/n Jardim América, C.P. 96160-000, Capão do Leão, Rio Grande do Sul, Brasil) rmp@gmail.com*
[3] *College Santo Angelo (R. do Seminário, 188, Vera Cruz, 98807-296, Santo Ângelo – Rio Grande do Sul, Brasil) priscilammarchi@yahooo.com.br*
[4] *Department of Plant Sciences, Federal University of Pelotas (Avenida Eliseu Maciel – s/n Jardim América, C.P. 96160-000, Capão do Leão, Rio Grande do Sul, Brasil) prgrolli@gmail.com*
[5] *Department of Plant Sciences, Federal University of Pelotas (Avenida Eliseu Maciel – s/n Jardim América, C.P. 96160-000, Capão do Leão, Rio Grande do Sul, Brasil) laisp.agro@gmail.com*

1 ABSTRACT

The knowledge of the main characteristics of the cultivation medium and the water demand of the crop according to the phenological period is fundamental for the most adequate water management in soilless cultivation. The objective was to evaluate the plant phenology related to thermal summation, water consumption and the water use efficiency (WUE), of gypsophila plants that were cultivated in different substrates. Were four substrate evaluated media Carbonized rice husk and raw rice husk used alone, and the mixes of both materials with commercial organic medium S10 (Beifort®) in the ratio of 15%. The total accumulated thermal sum during the crop cycle was 981.3°C and the phases II (bloom induction) and III (elongation and initial bloom) comprised, 34.2 and 34.1% of the total sum. The amount of water consumed by plants cultivated in both carbonized and raw rice husk pure material in phase III represented about 51% of the total consumption in the whole crop cycle and in the cases of the substrates with addition of commercial organic medium, these figures were 48%. The addition of organic medium improved water holding capacity of both carbonized and raw rice husk and enabled better water use efficiency for to fresh matter production.

Keywords: Thermal sum, irrigation, flowering, soilless cultivation.

HÖHN, D.; PEIL, R. M. N.; MARCHI, P. M.; GROLLI, P. R.; PERIN, L. PHENOLOGY, CONSUMPTION AND WATER USE EFFICIENCY OF *GYPSOPHILA PANICULATA* GROWN ON RICE HUSK-BASED SUBSTRATES

2 RESUMO

O conhecimento das principais características do meio de cultivo e da demanda hídrica da cultura de acordo com o período fenológico é fundamental para o manejo mais adequado da água no cultivo sem solo. O objetivo foi avaliar a fenologia vegetal relacionada à soma térmica, consumo de água e eficiência do uso da água (EAU), de plantas de *gypsophila* cultivadas em

Recebido em 25/07/2022 e aprovado para publicação em 28/02/2023
DOI: http://dx.doi.org/10.15809/irriga.2023v28n1p176-189

diferentes substratos. Foram avaliados quatro substratos: casca de arroz carbonizada e casca de arroz crua utilizada isoladamente, e as misturas de ambos os materiais com meio orgânico comercial S10 (Beifort®) na proporção de 15%. A soma térmica total acumulada durante o ciclo da cultura foi de 981,3°C e as fases II (indução da floração) e III (alongamento e floração inicial) representaram, 34,2 e 34,1% da soma total. A quantidade de água consumida pelas plantas cultivadas tanto em matéria pura de casca de arroz carbonizada quanto crua na fase III representou cerca de 51% do consumo total em todo o ciclo da cultura e nos casos dos substratos com adição de meio orgânico comercial, esses valores foram 48%. A adição de meio orgânico melhorou a capacidade de retenção de água da casca de arroz carbonizada e crua e possibilitou uma melhor eficiência no uso da água para a produção de matéria fresca.

Palavras-chave: Soma térmica, irrigação, floração, cultivo sem solo.

3 INTRODUCTION

Cut flowers have been one of the most profitable segments in the Brazilian floriculture (SEBRAE, 2015). Production of gypsophila has stood out since it is one of the most traded cut flowers in Brazil. Gypsophila belongs to the family Cariophyllceae and is native from Europe and Asia (Petry, 2008). Its production has mainly aimed at bouquets and flower arrangements, besides decoration since its flowers beautify and harmonize any environment.

Success in commercial production of gypsophila depends on the use of techniques that optimize workforce, rationally water use and income of the production. Growing gypsophila on substrate allocated in suspended gutters – which makes crop management easier – may be an interesting alternative cultivation system (Gaspari; Khatounian, 2016).

Carbonized rice husk has been commonly used as a pure substrate or as a constituent in horticulture growing media mixtures for several plant species in southern Brazil (Kratz *et al*., 2013). Availability in large quantity together with to its resistance to degradation, and low density as well as to its low water holding capacity and high porosity, making it difficult to over-water and easy to provide oxygen, make it a very suitable growing medium constituent. However, the rice husk carbonization process presents some difficulties, mainly related to its empiricism, low yield – a 50% decrease in husk volume – and air pollution (Giménez; Andriolo; Godoi; 2008).

Raw rice husk may be an alternative material since it is readily available for use. It has been used for growing fruit vegetables in closed soilless cultivation systems (Peil; Albuquerque Neto, 2014; Carini *et al*., 2018; Neutzling *et al*., 2018). However, due to its too low water holding capacity (Zorzeto *et al*., 2014), extremely high frequency of irrigation is required and makes its own use in commercial cropping systems difficult. Addition of organic compost to raw rice husk may increase the water holding capacity of the medium, which allows lower irrigation frequency and should improve water use efficiency.

Knowledge about main characteristics of substrate and water demand of the crop accordingly the phenological period is fundamental to choose the most appropriate water supply management and plan the soilless cultivation facilities. Furthermore, the improvement of water use efficiency, as the result of frequent irrigation, has become a factor that not only increases yield and decreases risks, but also improves the quality of the floral stems (Souza *et al*., 2010).

Taking into account that little information on water consumption of gypsophila is available in the literature, further studies should be carried out to investigate real needs of this crop and prevent water waste (Girardi *et al*., 2012).

Even though water waste is minimum in soilless closed systems (Marques *et al*., 2014), over-watering may lead to additional problems, such as nutrient leaching, pH control difficulty, sharp decrease in the electrical conductivity of the substrate solution and disease proliferation. On the other hand, water deficit is known to hamper plant growth and development (Andrade *et al*., 2018). Knowledge about the amount of water to be supplied to plants ensures more efficient irrigation management (Carvalho *et al*., 2018) and contributes to water conservation.

Considering that gypsophila cultivation on substrate with recirculation of nutrient solution may represent a water-saving cropping system and information about the water needs of the species is scarce, this study aimed to analyze plant phenology related to thermal sum and evaluate water consumption along crop development as well as determine water use efficiency of gypsophila crop, considering the effects of different rice husk-based media.

4 MATERIAL AND METHODS

Texto do material e métodos. The experiment was conducted in a plastic greenhouse (10 m x 18 m) placed at the Universidade Federal de Pelotas, in Capão do Leão City, RS, Brazil (31º 52'S and 52º 21'W; altitude of 13 m), from October 8th, 2015 to January 12th, 2016. Inside air temperature was monitored daily by a digital thermo-hygrometer, which was installed inside an instrument shelter 1.5 m above the ground. The average medium, maximum and minimum temperatures inside greenhouse during the experimental period were, respectively, 24.1°C, 29.8°C and 18.5°C. Data of incident global solar radiation outside greenhouse were provided by the Estação Agroclimatológica de Pelotas, located about 1000 m from the place of the experiment. Accumulated and daily mean global solar radiation were 1586.83 MJ m-2 and 16.36 MJ m-2 day-1, respectively.

Commercial New Amore® seedlings from Bioplugs (São Paulo, SP) were used. Setting to the soilless system was performed when plants were about 4-5 cm high.

Four substrate media were studied: carbonized rice husk (CRH) and raw rice husk (RRH), used alone; and the mixes of CRH (85%) or RRH (85%) with a commercial organic medium S10® (15%). The last one is a certified medium produced by Beifort® (Garibaldi, RS, Brazil) and it is obtained from composting a mix of grape stalks and pomace with poultry bed (20%), peat moss (60%) and carbonized rice husk (20%). Physical and chemical characteristics of the substrates were determined in the laboratory (Table 1).

Table 1. Physical and chemical characteristics of carbonized rice husk (CRH) and raw rice husk (RRH) after cultivation, used alone and in mix with commercial organic substrato S10 (Beifort®) in Gypsophila paniculata cultivation in gutters with recirculating nutrient solution. Capão do Leão, Rio Grande do Sul, Brasil.

Physical Characteristics	**Media**			
	CRH	**RRH**	**CRH+S10**	**RRH+S10**
Wet Density (g L^{-1})	262	236	343	417
Dry Matter (g 100 g^{-1})	60	38	54	54
Dry Density (g L^{-1})	156	90	186	225
Total Porosity (m^3 m^{-3})	0.76	0.72	0.74	0.77
Air Space (m^3 m^{-3})	0.56	0.58	0.47	0.42
Easily Available Water (m^3 m^{-3})	0.12	0.04	0.12	0.12
WHC* 10 cm (m^3 m^{-3})	0.20	0.14	0.27	0.35
Chemical Characteristics				
Electrical Conductivity (dS m^{-1})	0.11	0.07	0.26	0.51
pH Value (H_2O)	5.06	5.29	5.00	4.69

*WHC: water holding capacity.

The greenhouse contained 12 wood-made gutters (3.50 m long and 0.20 m wide), internally recovery by white polyethylene film to waterproof, collect and recirculate the drain solution. The substratos were allocated individually in the gutters at 0.15 m height layer, corresponding to a volume of 105 liters/gutter, which resulted in 5.8 liters/plant. Gutters were arranged in pairs sloping 3%. The pairs of double rows were 0.80 m apart (0.60 m wide paths) with 0.25 m between-row distance. Spacing plants 0.20 m within-row distance imposed plant density at 10.8 plants/m2 (18 plants per gutter). Each gutter was connected to a nutrient solution catchment tank of 100 liters. The nutrient solution was supplied individually for each gutter during 15 min per hour (from 8 am to 7 pm) through a pump and drip tapes, with drippers spacing 0.20 m (one dripper per plant) and a flow rate of 1.35 liters/h per dripper. The drain nutrient solution was collected and returned to the catchment tank placed at the final part of the gutter.

A randomized block experimental design with three replications was used. Each gutter was considered a block (corresponding to 18 plants).

The nutrient solution recommended by (Sonneveld; Straver, 1994) was employed with electrical conductivity of 1.7 dS m^{-1} and the following macronutrients composition (mmol/l): 15.0 NO_3^-; 1.7 $H_2PO_4^-$; 1.5 SO_4^{2-}; 1.2 NH_4^+; 7.0 K^+; 4.5 Ca^{2+}; and 1.2 Mg^{2+}; and micronutrients (mg/l): 1.40 Fe; 0.6 Mn; 0.30 Zn; 0.30 B; 0.05 Cu; and 0.05 Mo. The pH was maintained in the range from 5.5 to 6.5.

Stalk staking was carried out by plastic nets (0.15 x 0.15 m meshes) placed over the gutters, supported by bamboo and wood structures. At 21 days after setting, apical pruning (pinch) was performed. The primary stem apex of all plants was removed.

The date of occurrence and time length of phenological phases were recorded considering all the plants in the experiment. In this evaluation, 50% of plants that reached such stage was considered. Gypsophila development, based on characteristics of plant blossoming and accordingly the phenological scale Danziger (1995), was divided into phases with the following criterion: a) Vegetative phase (I): from setting to bloom induction; b) Bloom induction (II): from pinch pruning to stalk elongation: c) Elongation and initial bloom (III): period in which stalks start elongation up to the beginning of bloom; and d) Bloom (IV): period in which 50% of plants exhibits buds at harvest point.

Daily thermal sum (dTS, °C day-1) was calculated by Equation 1, proposed by Arnold (1960):

$$dTS = (Tmean - Tb) \times 1 \text{ day} \quad (1)$$

Where Tmean is the mean air temperature, calculated by the mean of daily minimum and maximum air temperatures and Tb is the base temperature of the species (10°C).

Accumulated thermal sum (aTS) of different phenological phases was calculated by the sum of dTS values.

In order to evaluate gypsophila water consumption in different growing media, each set composed of a gutter, a catchment tank (graduated from 0 to 100 centimeters) and the corresponding 18 plants formed a lysimeter, similarly the methodology proposed by (Peil; Strassburger; Fonseca; 2012) for water consumption determination in closed soilless systems. From a known initial volume of nutrient solution and taking account the amount of solution added to the system, the volume consumed by the plants in a certain period was determined. Nutrient solution replacement was carried out whenever the nutrient solution reached a reference volume.

Volumes of nutrient solutions added to the reservoir were summed from transplant to final harvest, which occurred 97 days after setting.

A bifactorial analysis was carried out to investigate water consumption in periods that corresponded to every phenological phase; growing media and phenological phase were considered the experimental factors (both with four levels).

Water use efficiency (WUE) was determined by the ratios between both fresh matter and dry matter production of aerial plant parts accumulated at the end of the crop-season and the total volume of water consumed per plant. Eight control plants per plot were selected to determine both fresh and dry matter production.

Data were submitted to the analysis of variance and means were compared by the Tukey's test at 5% significance.

5 RESULTS AND DISCUSSION

The plants followed the same growth pattern related to the thermal sum in all evaluated substrate. Therefore, the data presented (Table 2) are concerning the average obtained from the totality of the plants in the experiment. The crop cycle enclosed 97 days from setting to final harvest of flower stems and the total accumulated thermal sum was 981.3 ºC day.

Table 2. Length of the period, accumulated thermal sum (aTS), medium air temperature and global solar radiation mean daily observed in the phenological phases of Gypsophila paniculata cultivated in gutters on rice husk-based substrate with recirculating nutrient solution. Capão do Leão, Rio Grande do Sul, Brasil.

Phenological phase	**Period**	**Days**	**Medium temperature * (T ºC)**	**Thermal sum (ºC day)**	**Daily income solar radiation ** MJ m-² day -¹**
I	08/10/2015 28/10/2015	21	16.5	135.1	12.7
II	29/10/2015 03/12/2015	36	19.5	341.0	16.1
III	04/12/2015 30/12/2015	27	22.4	334.6	19.1
IV	31/12/2015 12/01/2016	13	23.1	170.6	17.3
Total cycle		97		981.3	1586.8

*Means temperature inside greenhouse. **Daily mean income global solar radiation outside greenhouse. Phenological phase: I – Vegetative; II – Bloom induction; III – Elongation and initial bloom; IV – Bloom.

Regardless the media, accumulated and daily water consumption varied significantly among all phases (Table 3). A general approach indicates that the accumulated amount of water consumed increased from vegetative phase (I) till stem elongation and initial bloom phase (III) and decreased during the bloom phase (IV) in all substrates. On the other hand, the daily average water consumption increased from phase I until phase IV. On average, the accumulated water consumption comprised 4.2, 19.3, 49.6 and 26.9 % of the total crop consumption and plants consumed 0.014, 0.038, 0.131 and 0.147 liters plant^{-1} day^{-1} in the phenological phases I, II, III and IV, respectively.

Table 3. Accumulated and daily water consumption according to the phenological phases of *Gypsophila paniculata* (vegetative growth - I), bloom induction - II), stem elongation and initial bloom - III) and bloom - IV) grown on different rice husk-based media in a recirculating nutrient solution system. Capão do Leão, Rio Grande do Sul, Brasil.

Media	**Accumulated water consumption (liter plant^{-1})***				
	Phenological Phases				
	I	**II**	**III**	**IV**	**Total**
CRH	0.28 aD**	1.38 aC	3.83 aA	1.99 aB	7.48a
RRH	0.31 aD	1.19 bC	3.33 bA	1.69 bB	6.52c
CRH + S10***	0.32 aD	1.51 aC	3.63 aA	2.06 aB	7.52a
RRH + S10	0.29 aD	1.42 aC	3.38 bA	1.95 aB	7.04b
Mean	0.30 D	1.38 C	3.54 A	1.92 B	7.14
	Daily Water Consumption (liter plant^{-1} day^{-1})				
	Phenological Phases				
Media	I	II	III	IV	Mean
CRH	0.013 aD	0.038 aC	0.142 aA	0.153 aB	0.087a
RRH	0.015 aD	0.033 bC	0.123 bA	0.130 bB	0.075c
CRH + S10	0.015 aD	0.042 aC	0.134 aA	0.158 aB	0.087a
RRH + S10	0.014 aD	0.039 aC	0.125 bA	0.150 aB	0.082b
Mean	0.014D	0.038C	0.131B	0.147A	0.083

Means followed by the same small letters in vertical columns and capital letters in horizontal lines do not differ by the Tukey's test at 5% probability. CRH (Carbonized rice husk); RRH (Raw rice husk); CRH + S10 (Carbonized rice husk + S10*); RRH + S10 (Raw rice husk + S10). *** Commercial organic medium S10® (Beifort®) used in the ratio of 15%.

The vegetative phase (I), which ranged from transplant to bloom induction, presented the lowest thermal sum (135.1 ºC day were accumulated from October, 08th to 28th) (Table 2) as well as the lowest water consumption (Table 3). Once the plants were at the beginning of their development and presented small leaf area, a low water consumption is expected. This it corresponded to the lowest medium temperature and daily income global solar radiation period (Table 2), which also determined a low atmosphere water demand.

During the phase of bloom induction (II), which covered the period from pinch to stem elongation (from October, 29th to December, 03th), the thermal sum was 341.0 ºC day (Table 2). It was the longest and coincided with an increase in income solar radiation and, consequently, in the daily medium temperature that guarantee the highest thermal sum and an increase in plant growth and water consumption (Table 3).

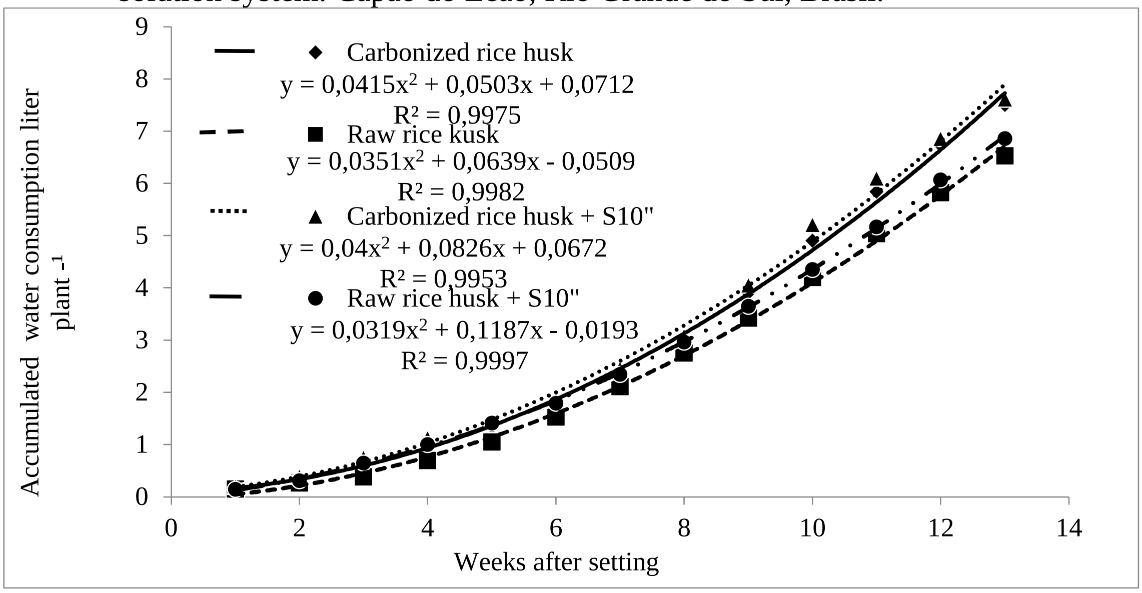
In the phase of elongation and initial bloom (III; from December, 4th to 30th) the thermal sum was 334.6 ºC day (Table 2), similar to that observed in phase II. The maximum accumulated water consumption amount was reached. On average, 3.54 liters plant^{-1} (Table 3) was consumed in phase III, which means an increase of 156 % related to the amount of 1.38 liter plant^{-1} consumed in phase II. Furthermore, in phase III, the second largest daily water consumption was observed (average of 0.131 liter plant^{-1} day^{-}

[1]). The large water consumption may be attributed to the highest daily income global solar radiation and to the second highest medium temperature, which determined a great demand of water vapor by atmosphere, as well as to a great plant growth. Increase plant growth and leaf area ensures photosynthesis and transpiration rates increase, and consequently, the demand for water enhanced during the stem elongation and initial bloom, as previously reported for many cut flowers crops, such as carnation (Schwab *et al*., 2013), sunflower (Santos Júnior *et al*., 2014) and gypsophila (Girardi *et al*., 2012).

During the last and shortest phenological phase, the bloom phase (IV), which ranged from the initial flowering until the final harvest (from December, 31st to January, 12th), the thermal accumulation was only 170.6 ºC. The decrease in the total amount of water consumption (Table 3) corresponded to the gypsophila typical fast flowering stage and it is a predicable result since it comprised only 13 days. However, during this short period, the highest daily water consumption was recorded (average of 0.147 liter plant^{-1} day^{-1}), which was due to the high leaf area associated to the highest daily medium temperature and the great income global solar radiation of summer time (Table 2).

Fitting various low-degree polynomials showed that the time course of accumulated water consumption as a function of week after setting (Figure 1) revealed a similar polynomial of the second degree pattern for all media.

Figure 1. Accumulated water consumption as a function of week after setting of *Gypsophila paniculata* grown on different rice husk-based media in a recirculating nutrient solution system. Capão do Leão, Rio Grande do Sul, Brasil.



Source: Höhn (2018).

At the beginning of the growing period, up to about 6 weeks after setting −which comprised all vegetative phase and about 60 % of the bloom induction period, the increase in water consumption of the plants was slow (Figure 1). Thereafter, water consumption increased significantly and assumed a linear exponential until the end of the crop cycle. This increase may be attributed largely to the increase in leaf area and plant ramifications occurred during the phase of stem elongation and initial bloom closely accompanied by an increase in daily income global solar radiation and air temperature (Table 2).

Significant statistical interaction between growing media and phenological phases for both accumulated and daily water consumption was detected (Table 3).

In phenological phase I, regardless growing media, no differences among plants water consumption were observed, which can be attributed to the low water demand by the plants at their initial growth as well as to the low temperature and incident solar radiation conditions of the period that standardized crop responses.

From phase II to phase IV, when plant growth increased highly, which coincided with a significant rising in incident solar radiation and temperature the demand for water also increased greatly and so differences among media were detected. The cultivation in raw rice husk alone reduced the accumulated water consumption and consequently daily consumption in phases II, III and IV as well as the total water expended in the crop cycle. The total amount of water consumed by plants cultivated on pure raw rice husk represented about one liter per plant less than the average consumed on carbonized rice husk media). These results may be associated with the low water holding capacity (WHC; Table 1) of raw rice husk, since particles that compose this material are large and uniform, a fact that hinders water availability (Ludwig *et al.*, 2010), which is evidenced by its reduced easily available water.

The addition of commercial medium S10 increased the WHC from 0.14 to 0.35 and the EAW from 0.04 to 0.12 (Table 1) of the mixture in relation to the raw rice husk used alone, which promoted water consumption of the plants to similar amount recorded in carbonized rice husk media during phenological phases II and IV However, in phase III, when the highest daily solar radiation occurred, even with S10 addition to raw rice husk, on average, the crop water consumption in raw rice husk media was about 10 % lower than that observed in carbonized rice husk media. As a consequence the total amount of water consumed by plants during the whole period of cultivation decreased slightly in RRH+S10 compared to both carbonized rice husk media.

On the other hand, S10 addition to carbonized rice husk had no effect on water consumption during all phenological phases and consequently on total amount of water used compared to that observed in pure carbonized rice husk (Table 3). This is in contrast with the results of (Souza *et al.*, 2010), who observed reduced water consumption in Kalanchoe grown in carbonized rice husk with organic compost addition. Since the WHC and EAW (Table 1) slightly changed when S10 was added to carbonized rice husk, less pronounced effects of S10 on water consumption are to be expected when plants growing on carbonized rice husk alone and the mixture CRH+S10 are compared.

On average, the amount of water consumed by plants cultivated in both carbonized and raw rice husk used alone in phase III represented about 51 % of the total consumption in the whole crop cycle, whereas, in the cases of the media with addition of S10, these figures were 48 %. The media did not affect the water use efficiency (WUE; the ratio of plant weight to total amount of water) regarding dry matter production (Table 4).

Table 4. Water use efficiency given by the ratio of plant dry and fresh weight to total amount of water used to grow *Gypsophila paniculata* on different rice husk-based media in a recirculating nutrient solution system. Capão do Leão, Rio Grande do Sul, Brasil.

Media	**Dry weight (g liter^{-1})**	**Fresh weight* (g liter^{-1})**
CRH	8.58 a	59.7 bc**
RRH	8.15 a	51.3 c
CRH + S10***	10.89 a	73.5 a
RRH + S10	9.85 a	64.1 ab
Cv %	19.01	11.6

Means followed by the same letter at the columns do not differ by the Tukey's test at 5% probability. CRH (Carbonized rice husk); RRH (Raw rice husk); CRH + S10 (Carbonized rice husk + S10*); RRH + S10 (Raw rice husk + S10). ***Commercial organic medium S10® (Beifort®) used in the ratio of 15%.

The results suggest that, regardless of the growing medium and the volume of water consumed by plants (Table 3), the high frequency of nutrient solution supply adopted in the cultivation cycle probably allowed a proper water provision and a similar assimilates production by photosynthesis in all four evaluated media. In accordance with our results with gypsophila, (Lopes *et al*., 2011) found an increase in WUE in melon crop due to a high frequency of irrigation, irrespective of the irrigation volume applied. Thus, values of WUE referred to dry matter production found by this study had little variation and suggested that water use by plants in their photosynthesis metabolism and evaporation through the substrate surface were little affected by the medium constituents.

Fresh matter production, which is related to marketable yield, apparently was more stimulated by the addition of S10, to both carbonized and raw rice husk media, than dry matter production. It should be noted that since the WUE related to fresh matter production were increased by S10 addition. This effect should be ascribed to the highest WHC (Table 1) given by the addition of this commercial organic medium, which probably ensured better water supply to the plants even during the phases of high incident solar radiation and temperature. Furthermore, the increase in WHC may be the result from rearrangement and accommodation of growing media particles throughout the crop cycle, a fact that may have been improved by composted material of S10. Consequently, when plants were cultivated in CRH+S10 and RRH+S10, the total accumulated water consumption was increased and it allowed a higher production of fresh matter, which resulted in a greater WUE (Table 4).

Like the total amount of water used to grow gypsophila, the WUE related to fresh matter production decreased when plants were cultivated on medium of raw rice husk alone. Nevertheless, even though the WHC of pure carbonized rice husk, as well as the water consumption by plants in this medium (Table 3) were superior to those verified in the cultivation on pure raw rice husk, the WUE) was similar in both growing media. This indicates that water absorption by roots may have been limited in pure carbonized rice husk medium due to its low WHC (Table1). The carbonization process makes part of the husk breaks, which causes high variation in the distribution of particle size of the medium; a certain small percentage is the size of particles of S10. However, it was not enough to reach a higher WHC and guarantee a WUE like in CRH+S10 medium.

6 CONCLUSIONS

The rice husk-based growing media had no effect on the thermal sum of the different phenological phases of gypsophila. The total accumulated thermal sum of the crop cycle was 981.3 °C and the phases II (bloom induction) and III (elongation and initial bloom) comprised, respectively, 34.2 and 34.1 % of the total sum. The accumulated amount of water consumed increased from vegetative phase (I) till stem elongation and initial bloom phase (III) and decreased during the bloom phase (IV) in all evaluated media. The daily average water consumption increased from phase I until phase IV. Growing medium had a slightly effect on plant water consumption. The amount of water consumed by plants cultivated in both carbonized and raw rice husk pure material in phase III represented about 51 % of the total consumption in the whole crop cycle and in the substrates with addition of commercial organic medium, these figures were 48 %. In raw rice husk media, the crop water consumption was about 10 % lower than that observed in carbonized rice husk media. The addition of organic medium to raw rice husk increased water consumption of the plants in relation to the material alone. Although, the addition of S10 improved physical characteristics of both carbonized and raw rice husk throughout the cycle. The addition organic medium improved water holding capacity of both carbonized and raw rice husk, enableded better water use efficiency about to fresh matter production.

7 REFERENCES

ARNOLD, C.Y. Maximum-minimum temperatures as a basis for computing heat units. **American Society for Horticultural Sciences**, Boston, v. 76, p. 682-692, 1960.

ANDRADE JUNIOR, A. S.; BASTOS, E. A.; MONTEIRO, M. M. S.; SILVA JUNIOR, J. S. Evapotranspiração e coeficiente de cultura do feijão-caupi sob sistema de cultivo convencional e plantio direto. **Agrometeoros**, Serra Talhada, v. 26, n. 1, p. 191-199, 2018. DOI: 10.31062/agrom.v26i1.26370. Available at: file:///C:/Users/danie/Downloads/26370-126131-1-PB-1.pdf. Accessed on: 3 Jan. 2024.

CARINI, F.; PEIL, R. M. N.; MARQUES, G. N.; GROLLI, P. R.; SOUZA, R. S. Organic compost addition to raw rice husk substrate for tomato (*Solanum lycopersicum*) hybrid variety cultivation in a leach recirculating system. **Revista Colombiana de Ciencias Hortícolas**, Bogotá, v. 12, n. 1, p. 94-103, 2018. DOI: 10.17584/rcch.2018v12i1.6660. Available at: https://revistas.uptc.edu.co/index.php/ciencias_horticolas/article/view/6660. Accessed on: 3 Dec. 2019.

CARVALHO, P. H. S.; COSTA, W. R. S.; SILVA, J. S.; QUEIROZ, S. O. P.; SOUZA, J. C. Desempenho agronômico de gérbera sob reuso de água. **Revista Brasileira de Agricultura Irrigada**, Fortaleza, v. 12, n. 6, p. 3040-3047, 2018. DOI: 10.7127/rbai.v12n600922. Available at: http://www.inovagri.org.br/revista/index.php/rbai/article/view/922. Accessed on: 3 Jan. 2024.

DANZIGER, D. **Flower Farm Gypsophila**: cultivavion practices in Israel. Beit Dagan: Danziger “Dan” Flower Farm., 1995.

GASPARI, L. C.; KHATOUNIAN, C. A. Características das Famílias, Estruturação da Produção e Estratégias de Comercialização em um Assentamento de Reforma Agrária. **Revista de Economia e**

Sociedade Rural, Brasília, DF, v. 54, n. 2, p. 243-260, 2016. DOI: https://doi.org/10.1590/1234.56781806-947900540203. Available at: https://www.scielo.br/j/resr/a/hCmGyZPdTfdX7C977H5pHhH/?lang=pt. Accessed on: 3 Jan. 2024.

GIMÉNEZ, G.; ANDRIOLO, J.; GODOI, R. Cultivo sem solo do morangueiro. **Ciência Rural**, Santa Maria, v. 38, n. 1, p. 273-279, 2008. DOI: https://doi.org/10.1590/S0103-84782008000100048. Available at: https://www.scielo.br/j/cr/a/MztLr3hy6QRjpnYskh5LVqf/?lang=pt. Accessed on: 4 Jan. 2024.

GIRARDI, L. B.; PEITER, M. X.; BELLÉ, R. A.; BACKES, F. A.; SOARES, F. C.; VALMORBIDA, I. Disponibilidade hídrica e seus efeitos sobre o desenvolvimento radicular e a produção de gipsofila envasada em ambiente protegido. **Irriga**, Botucatu, v. 17, n. 4, p. 501-509, 2012. DOI: 10.15809/irriga.2012v17n4p501 Available at: https://revistas.fca.unesp.br/index.php/irriga/article/view/511. Accessed on: 4 Jan. 2024.

KRATZ, D.; WENDLLING, I.; NOGUEIRA, A. C.; ZOUZA, P. V. Propriedades físicas e químicas de substratos renováveis. **Revista Árvore**, Viçosa, v. 37, n. 6, p. 1103-1113, 2013. DOI: https://doi.org/10.1590/S0100-67622013000600012. Available at: https://www.scielo.br/j/rarv/a/PXvdVBSqTbBfF5ChjpJq5SB/?lang=pt. Accessed on: 3 Jan. 2024.

LOPES, O. D.; KOBAYASHI, M. K.; OLIVEIRA, F. G.; ALVARENGA, I. C. A.; MARTINS, E. R.; CORSATO, E. Determinação do coeficiente de cultura (Kc) e eficiência do uso de água do alecrim-pimenta irrigado. **Revista Brasileira de Engenharia Agrícola e Ambiental**, Campina Grande, v. 15, n. 6, p. 548-553, 2011. DOI: https://doi.org/10.1590/S1415-43662011000600002. Available at: https://www.scielo.br/j/rbeaa/a/Z4D4yvWC3FM4cMkDZbRwkhy/?lang=pt. Accessed on: 3 Jan. 2024.

LUDWIG, F.; GUERRERO, A. C.; FERNANDES, D. M.; BOAS, R. L. V. Análise de crescimento de gérbera de vaso conduzida em diferentes substratos. **Horticultura Brasileira**, Recife, v. 28, n. 1, p. 70-74, 2010. DOI: https://doi.org/10.1590/S0102-05362010000100013. Available at: https://www.scielo.br/j/hb/a/HBCQfLBnccM6FpN7YSpbDdD/. Accessed on: 4 Jan. 2024.

MARQUES, G. N.; PEIL, R. M. N.; LAGO, L.; PERIN, L. Fenologia, consumo hídrico, rendimento e qualidade de minimelancia em hidroponia. **Revista de la Facultad de Agronomía**, Buenos Aires, v. 113, n. 1, p. 57-65, 2014. Available at: http://sedici.unlp.edu.ar/handle/10915/42052. Accessed on: 4 Jan. 2024.

NEUTZLING, C.; PEIL, R. M. N.; SIGNORINI, C.; PERIN, L. Reutilización del sustrato cascarilla de arroz in natura tras el cultivo de tomate para la producción de híbridos de pepino de conserva (Cucumis sativus L.) en sistema de recirculación de lixiviado. **Revista Colombiana de Ciencias Hortícolas**, Bogotá, v. 12, n. 3, p. 602-610, 2018. DOI: https://doi.org/10.17584/rcch.2018v12i3.7684. Available at: https://revistas.uptc.edu.co/index.php/ciencias_horticolas/article/view/7684. Accessed on: 3 Jan. 2024.

PETRY, C.; BELLÉ, S.; CALVETE, E. O. Produção de gypsophila. *In*: PETRY, C. (org). **Aspectos para a produção**. Passo Fundo: Universidade de Passo Fundo, 2008. p. 172-178.

PEIL, R. M. N.; STRASSBURGER, A. S.; FONSECA, L. A. Growth, water consumption and use efficiency of summer squash crop in closed rice husk medium growing system. **Acta Horticulturae**, Athens, v. 952, p. 645-650, 2012. DOI: 10.17660/ActaHortic.2012.952.81. Available at: https://www.actahort.org/books/952/952_81.htm. Accessed on: 3 Jan. 2024.

PEIL, R. M. N.; ALBUQUERQUE NETO, A. A. R. Densidade de plantio e genótipos de tomateiro cereja cultivados em casca de arroz com solução recirculante. **Horticultura Brasileira**, Recife, v. 32, n.2, p. 234-240, 2014. DOI: 10.1590/hb.v32i2.53. Available at: https://editor.horticulturabrasileira.com.br/index.php/HB/article/view/53/41. Accessed on: 3 jan. 2024.

SANTOS JÚNIOR, J. A.; GHEYI, H. R.; DIAS, N. S.; MEDEIROS, S. S.; FILHO, D. H. G. Substratos e tempo de renovação da água residuária no crescimento do girassol ornamental em sistema semi-hidroponia. **Revista Brasileira de Engenharia Agrícola e Ambiental**, Campina Grande, v. 18, n. 8, p. 790-797, 2014. DOI: https://doi.org/10.1590/1807-1929/agriambi.v18n08p790-797. Available at: https://www.scielo.br/j/rbeaa/a/RLNGYP3HsnfLWJnZQsbNyPv/?lang=pt. Accessed on: 3 Jan. 2024.

SCHWAB, N. T.; PEITER, M. X.; BELLÉ, A. R.; BACKES, F. A. A. L.; ROBAINA, A. D.; FERRAZ, R. C. Consumo hídrico de cravina submetida a diferentes estratégias de irrigação e tamanhos de vaso. **Irriga**, Botucatu, v. 18, n. 2, p. 328-336, 2013. DOI: https://doi.org/10.15809/irriga.2013v18n2p328. Available at: https://revistas.fca.unesp.br/index.php/irriga/article/view/178. Accessed on: 3 jan. 2024.

SEBRAE. **Flores e plantas ornamentais do brasil**. Série estudos mercadológicos. Brasília, DF: Sebrae, 2015. Available at: https://bibliotecas.sebrae.com.br/chronus/ARQUIVOS_CHRONUS/bds/bds.nsf/7ed114f4eace9ea970dadf63bc8baa29/$File/5518.pdf. Accessed on: 3 Jan. 2024.

SONNEVELD, C.; STRAVER, N. **Nutrients Solutions for Vegetables and Flowers Grown in Water or Substrates**. 10. ed. Aalsmeer: PBG, 1994. (Voedingsoplossingen Glastuinbouw, n. 8). Available at: https://edepot.wur.nl/237302. Accessed on: 12 Jan. 2024.

SOUZA, A. R. C.; PEITER, M. X.; ROBAINA, A. D.; SOARES, F. C.; PARIZI, A. R. C.; FERRAZ, R. C. Consumo hídrico e desempenho de Kalanchoe cultivado em substratos alternativos. **Ciência Rural**, Santa Maria, v. 40, n. 3, p. 534-540, 2010. DOI: https://doi.org/10.1590/S0103-84782010000300006. Available at: https://www.redalyc.org/articulo.oa?id=33118930003. Accessed on: 3 Jan. 2024.

ZORZETO, T. Q.; DECHEN, S. C. F.; ABREU, M. F.; FERNANDES JÚNIOR, F. Caracterização física de substratos para plantas. **Bragantia**, Campinas, v. 73, n. 3, p. 300-311, 2014. DOI: http://dx.doi.org/10.1590/1678-4499.0086. Available at: https://www.scielo.br/j/brag/a/nsjpDSJTKc8nYnd8nY3JzXk/?format=pdf. Accessed on: 3 Jan. 2024.