Original Research Article

Influence of Irrigation Depths on the Growth of Chrysanthemum, Cultivated in Pots, in a Greenhouse in the Northwest Region of Espírito Santo

ABSTRACT

Chrysanthemum is one of the most important plants in the national and international market of ornamental plants since it has relevant commercial value and presents short cycle and extensive diversity of inflorescences and colors. The present work aimed to evaluate the productive performance of the Puritan cultivar grown in pots under different irrigation depths, in greenhouse conditions in the northwest region of Espírito Santo. The experiment was set up in a completely randomized design with 6 treatments defined by crop evapotranspiration daily replacements (ETc) of 50% 75%, 100%; 125%, 150% and 175%, with 20 repetitions (pots) each treatment. An auto compensating trickle irrigation system was used, a dripper per pot, discharging 1.3 liters per hour. The evaluations were made at 90 days after planting, when measurements of fresh and dry mass of roots, fresh and dry mass of shoot system, plant height, stem diameter, dry mass of the flowers and flowers diameter were performed. The analysis of variance at 5% probability, showed significant quadratic effect for the dry matter characteristics of the aerial part and height of the plant and significant linear positive effect for the other evaluated characteristics. Under the conditions of the study, daily replacements of 175% of the crop evapotranspiration, which corresponded to daily average depths of 12.25 mm, conferred the best results in all evaluated parameters.

Keywords: Crop evapotranspiration, irrigation management, Dendranthema grandiflora, analysis of growing, Floriculture.

1. INTRODUCTION

The worldwide commercialization of flowers is in constant growth and development, making that the floriculture stops characterizing itself like secondary activity in the national market. The flower trade has been growing in recent years.

In Espírito Santo, the production of ornamental plants occupies the area of 163 hectares and is highlighted in seventeen cities. The sector promotes the creating of approximately 8,000 jobs throughout the production chain and mobilizes more than 10 million reais per year. Santa Teresa and Guaçuí are the most notorious cities in this activity [1].

Floriculture is a widely competitive sector, ranging from flower cultivation, cutting, potting or gardening, to the production of seedlings of large ornamental trees, seeds and bulbs [2]. The production cycle of some ornamental plants is short, guaranteeing the rapid turn of capital.

33 The cultivation of flowers requires the use of technological innovations, technical
34 understanding, and a competent system of trade and distribution [3].
35
36 Chrysanthemum (*Dendranthema grandiflora*, Tzevelev) is among the most relevant in the
37 international and Brazilian market of ornamental plants. It is a short-cycle flower that
38 manifests an extensive diversity of colors and types of inflorescences, allowing versatility of
39 use [4].
40
41 The cultivation of chrysanthemums is an excellent possibility of revenues that mainly
42 involves family farming, which normally has small properties, insufficient for the production of
43 other crops, but suitable for the use of protected environment [5]. In addition, it is a flower of
44 relevant commercial value that requires photoperiodism and extensive technology for its
45 production. For this reason, their cultivation is usually conducted in protected environments
46 for guaranteeing flowers throughout the year [6].
47
48 Despite its agronomic relevance, the technical-scientific knowledge about the management
49 of irrigation for the chrysanthemum growth is still incipient and requires dedication and study
50 to understand its water needs.
51
52 In irrigated agriculture, growth and definition of water use efficiency levels are copiously
53 complex and demand interdisciplinary understanding and thinking [7]. On the other hand, the
54 lack of adequate management contributes to the failure of plant development, losses in
55 production and in the quality of the final product. Although it is cultivated in smaller areas,
56 when it is oversized, water consumption of chrysanthemum cultivation can contribute to the
57 reduction of scarce water sources, evidencing the need for accurate scaling [8].
58
59 Considering the questions above, this study aimed to evaluate the productive performance
60 of chrysanthemum Puritan cultivar grown in pots under different irrigation depths in
61 greenhouse conditions, in the northwestern region of Espirito Santo, in order to increase and
62 enhance the quality of the flowers produced in this location.
63
64
65 ## 2. MATERIAL AND METHODS
66
67 The experiment was conducted in the experimental field of the Federal Institute of Espírito
68 Santo - Campus Itapina, located in Colatina - ES (19°29' South; 40°45' West; 62 m). The
69 climate of the region is Tropical Aw, according to the climatic classification of Köppen[9],
70 characterized by the irregularity of rain and high temperatures.
71
72 The experiment was carried out from April 08 to July 06, 2018, in an agricultural greenhouse
73 with an area of 125 m² and 3 meters high, arranged in the east west direction, covered in an
74 arc with transparent plastic of 150 microns and black polypropylene fabric with 50% shading.
75 External weather conditions were by an ONSET[®] weather station installed next to the
76 experiment and internal conditions recorded by a WatchDog[®] Model 200 Data Logger.
77
78 Through the climatic variations registered by the weather station, the reference
79 evapotranspiration (ETo) was estimated using the Penman-Monteith method FAO-56
80 Standard [10], Equation 01.
81

$$\text{ETo} = \frac{0.408\Delta(\text{Rn} - \text{G}) + \gamma\,\frac{900}{T+273}u_2(e_s - e_a)}{\Delta + \gamma(1 + 0.34\,u_2)} \qquad (1)$$

in which ETo is the daily reference evapotranspiration ($mm.d^{-1}$); Rn is the daily radiation
balance ($MJ.m^{-2}.d^{-1}$); G is the daily flow of heat in the soil ($MJ.m^{-2}.d^{-1}$); T is the daily average
air temperature (ºC); u_2 is the daily average wind speed at 2 m in height ($m.s^{-1}$); e_s is the
saturation pressure of the daily average water vapor (kPa); e_a is the daily average water
vapor pressure (kPa); Δ is the slope of the vapor pressure curve at the point of T ($kPa.ºC^{-1}$)
and γ is the psychrometric coefficient ($kPa.ºC^{-1}$).

The cultivar of chrysanthemum used was Puritan, one of the cultivars that presents greater
acceptance by the market and greater predominance of planting when in cultures of
chrysanthemum in pots, has large inflorescence and white coloration with compound petals.
The cuttings were planted, four per pot, equally spaced, into number 13 pots (0.8 dm³)
previously filled with the mixture of 70% substrate Tropstrato HTHortaliças®and 30% of
subsoil inert soil.

For the rooting, the pots were arranged side by side, irrigated and covered with transparent
polyethylene plastic for 7 days, to maintain the moisture of the pots during the rooting period.
On the 14th day after planting, when the plants presented around 5 to 6 developed leaves,
the pinch (apex removal) was performed to stimulate the development of the lateral
branches.

From planting to the 21st day, for better vegetative growth, the cuttings received 4 hours of
artificial lighting a day from 8:00 pm to 0:00 am. For this, 25 W fluorescent lamps were
spaced 1.5 x 1.5 m at a height of 2 m.

The treatments started on the 22nd day after planting, when the pots were kept on ceramic
bricks, spaced 0.3 m x 0.3 m, to avoid fixation and root contact with the soil and
contamination by diseases.

The treatments corresponded to daily replacements of 50% (T1), 75% (T2), 100% (T3),
125% (T4), 150% (T5) and 175% (T6) of the crop evapotranspiration (ETc) assembled in a
completely randomized design with 20 repetitions (pots) each treatment.

The crop evapotranspiration (ETc) was determined daily through six selected pots by the
drainage lysimeter method (Fig 1). At the end of the day, the daily water volume (the proper
daily irrigation depth was chosen observing the ETc results of the previous day plus 10% to
enable a small leaching) was added in each pot and after the drainage was complete, the
stored volume, which corresponds to the crop evapotranspiration (ETc), was determined by
Equation 2, according to methodology proposed by Medeiros *et al.*[11]; Medeiros *et al.* [12];
Oliveira *el al.* [13]; Silva *et al.* [14].

$$ETc = \frac{Av - Dv}{A} \qquad (2)$$

where
ETc: cropevapotranspiration (100% (T3), $mm\ d^{-1}$);
Av: applied volume (L);
Dv: drained volume (L);
A: Pot area (0.01326 m²).

A   **B**

Fig 1. Drainage lysimeter (A) and overview of the six drainage lysimeters (B)

The average ETc, determined at the end of the day, was applied the next day through an auto compensating trickle irrigation system flowing 1.3 liters per hour, with an application efficiency (AE) of 95%, with a dripper per pot. The irrigations were automated and performed with a single daily pulse, in which each sector represented a corresponding treatment. In order to calculate the irrigation timefrom each irrigation depth, the net volume (V; liters per pot) was considered in relation the pot surface area ($0.01326\ m^2$), the treatment level (0.5; 0.75; 1.00; 1.25; 1.50 and 1.75) and the crop evapotranspiration (ETc), according Equation 3:

$$V\ (L)\ =\ \frac{ETc\ x\ A\ x\ (Treatments\ Level)}{AE}(3)$$

Fertilization and other cultural treatments were done according to the recommendations for this crop [4] and growth regulators were not used.

The evaluations were done 90 days after planting (DAP), when the plants had all the inflorescences open. Fresh mass of the root system (FMRS), dry mass of the root system (DMRS), fresh mass of shoot system (FMSS) and dry mass of shoot system (DMSS), plant height (PH), stem diameter (SD), dry mass of the flowers (DMF) and flower diameter (FD) were measured.

The data obtained were submitted to analysis of variance at 5% probability using the R software[15]. When significant, by the F test, regression models were adjusted to demonstrate the influence of the depths applied in each treatment on the development of the chrysanthemum.

3. RESULTS AND DISCUSSION

During the whole crop cycle, the average evapotranspiration in the external environment of the agricultural greenhouse, estimated by the FAO 56 Penman-Monteith model, was 2.70 mm d^{-1}, while the maximum and minimum temperatures recorded were 34.20°C and 13.11°C, respectively, with an average range of 22.9°C (Fig.2).
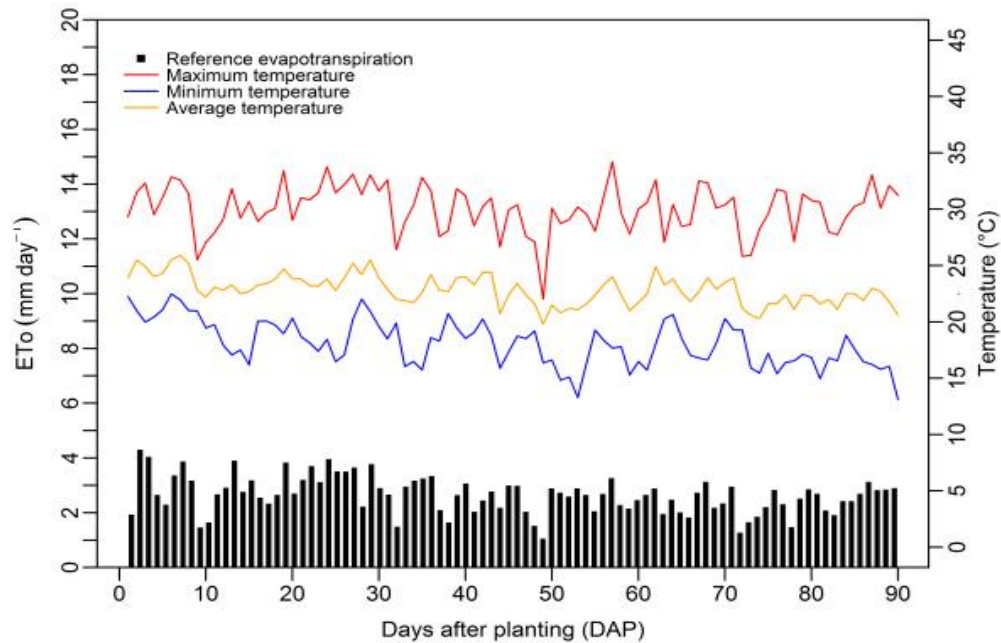
Fig. 2. Daily values of reference evapotranspiration (ETo), maximum, average and minimum temperatures (°C) occurred outside the greenhouse during the period of production of the Chrysanthemums

The air temperature inside the greenhouse reached a maximum value of 46.4°C, minimum of 14.1°C, with an average value for the growing period of 30,25°C (Fig.3A). The maximum relative humidity was 91.5% and the minimum was 20.7%, with anaverage range of 57.5% throughout the period (Fig.3B).

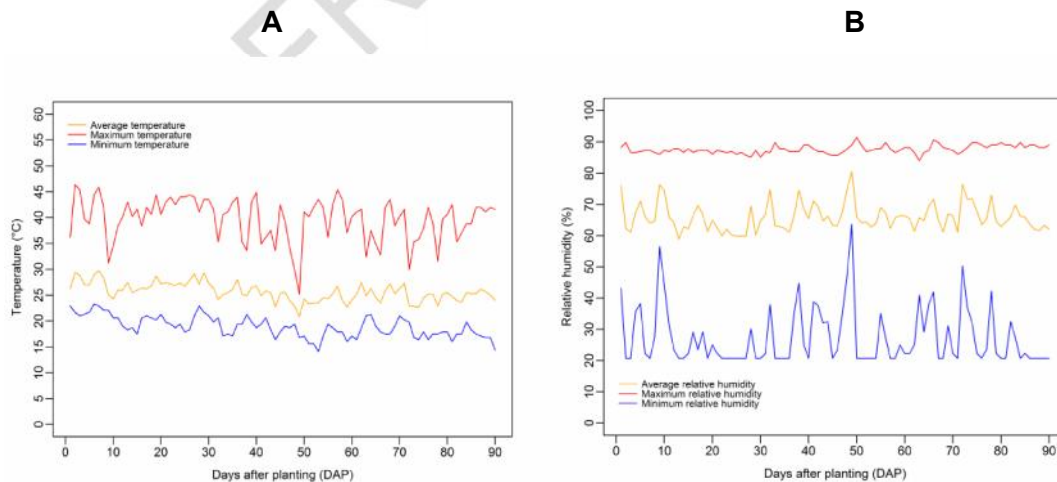**A**   **B**

Fig. 3. Daily values of maximum, average and minimum temperature (°C) (A) and maximum, average and minimum humidity (%) (B) occurred inside the greenhouse during the production period

176
177 According to Petry [16], the ideal temperature range for chrysanthemum cultivation is from
178 18°C to 25°C. High temperatures, between 27°C and 32°C, according to Whealy*et al.*[17],
179 may influence the growth of some cultivars, as well as promote delay in induction,
180 unevenness and floral anomalies, depending on the time of exposure to these temperatures
181 and the tolerance presented by the cultivars submitted to them. Even with the average
182 temperature recorded during the crop cycle being elevated and averaging 8.75°C above the
183 ideal, the plants remained apparently unaffected.
184
185 The average daily evapotranspiration (ETc) recorded by lysimeters (100% ETc) during this
186 period was 7.00 mm, as can be observed in Table 1.
187
188 **Table 1. Daily average depth, daily average volume and total depth applied during the**
189 **production period**

Treatments (% ETc)	Daily average depth applied (mm d^{-1})	Daily average volume applied (ml d^{-1})	Total depth applied during the cycle (mm)
50	3.50	46.55	196
75	5.25	69.83	294
100	7.00	93.11	392
125	8.75	116.38	490
150	10.5	139.66	588
175	12.25	162.95	686

190
191 However, an observation is made about the unique frequency of irrigation adopted in this
192 study, for the replacement of the depths that composed the treatments that, according to
193 Pereira *et al.*[18], studying the consumption of water by the chrysanthemum cultivated in a
194 protected environment, verified that irrigation applied once a day demands the application of
195 larger volumes of water, which causes more percolation when compared to the frequency of
196 divided irrigation behavior attributed in part to the nature of the substrate. This fact,
197 according to the same authors, generated a non-supply of water needs of plants, even with
198 the integral water replacement.
199
200 Farias *et al.*[19], in order to analyze the growth of potted chrysanthemum, Puritan cultivar,
201 irrigated at different water stresses in protected environment, applied daily average depths
202 superior to those found in this work, so that the substrate reached its maximum water
203 retention condition, reaching a maximum total depth during the cultivation cycle of 1,428 mm
204 for the tension of -4 KPa. This shows the low retention capacity of the substrate, thus
205 requiring high water replacement through irrigation so that plants are not subjected to water
206 stress.
207
208 Pereira *et al.*[18], point out the existence of differences in sensitivity to water application
209 among chrysanthemum cultivars. The use of an average amount of crop consumption during
210 irrigation throughout the crop cycle tends to generate water waste in the vegetative phase
211 and, consequently, a possible increase in the occurrence of pests and diseases and
212 unnecessary waste of energy and replacement of leached nutrients and water deficit in the
213 flowering stage, tending to reduce the final quality of the product.
214
215 Through the analysis of variance (Table 2), a significant positive linear effect was observed
216 for all the evaluated characteristics and a quadratic effect for dry matter of the aerial part and
217 plant height ($P<0.05$), in response to the application of the water depths.
218

219 **Table 2. Regression analysis for growth variables of chrysanthemum 'Puritan' in pots,**
220 **conducted in an agricultural greenhouse. Colatina - ES, 2018**

	FMSS	DMSS	FMRS	DMRS	FD	DMF	SD	PH
Linear effect	0*	0*	0*	0*	0*	0*	0*	0*
Quadratic effect	0.082^{NS}	0.019*	0.549^{NS}	0.534^{NS}	0.690^{NS}	0.323^{NS}	0.645^{NS}	0.04*
Cubic effect	0.083^{NS}	0.153^{NS}	0.451^{NS}	0.850^{NS}	0.831^{NS}	0.602^{NS}	0.270^{NS}	0.268^{NS}
Regression Deviations	0.028*	0.167^{NS}	0.154^{NS}	0.199^{NS}	0.410^{NS}	0.736^{NS}	0.636^{NS}	0.299^{NS}
CV (%)	15.28	14.86	16.85	17.8	9	21.03	21.33	11.25

221 FMSS: fresh mass of shoot system, DMSS: dry mass of shoot system, FMRS: Fresh mass of the root
222 system, DMRS: dry mass of the root system, FD: flower diameter, DMF: dry mass of the flowers, SD:
223 stem diameter, PH: plant height. *: Significant at 5% probability. ^{NS}: Not significant.
224

225 For the adjusted quadratic regression model, with coefficient of determination (R^2) of 0.96,
226 the highest estimated response in relation to the height of the chrysanthemum plants would
227 occur in the 191% depth, 22.92 cm high (Fig.4). This value corresponds to the minimum
228 height of 18cm and maximum of 30cm of the chrysanthemum plants, presented by
229 Holambra[20], for plants grown in number 13 pots. For the plant height, only the applied
230 depth corresponding to 50% of ETc presented a response lower than the minimum value (18
231 cm) established by Holambra[20].

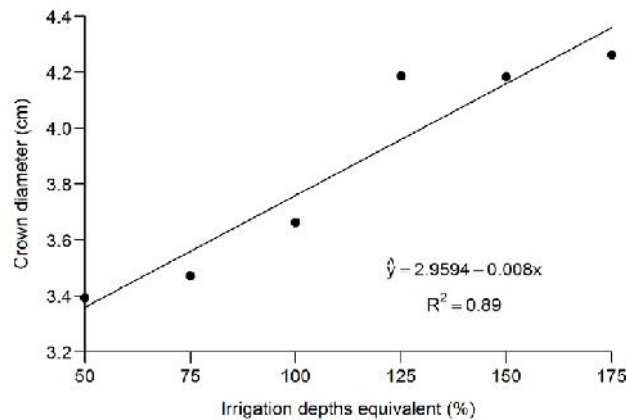$$\hat{y} = 11.9829 + 0.1146x - 3e\text{-}04x^2$$
$$R^2 = 0.96$$
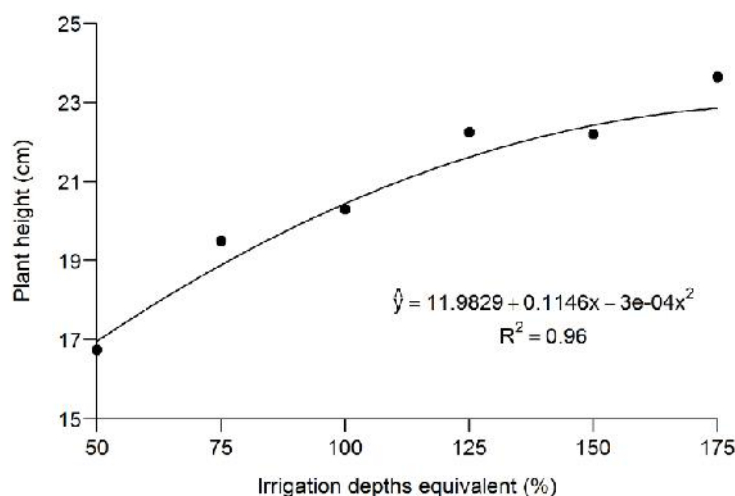
232 **Fig. 4. Plant height variation (PH) in response to different irrigation depths in the**
233 **production of chrysanthemum 'Puritan' in pots, conducted in greenhouse, Colatina /**
234 **ES, 2018**
235

236 The value of the highest height, estimated by the regression, represents a 12.13% increase
237 in plant growth if compared to the 100% ETc replacement and 35.14% replacement of the
238 half of this one (50% ETc), evidencing a stimulus in the growth of the plants with the
239 increase of the irrigation depths. Rêgo*et al.*[3], also found a quadratic model as the height
240 response of cut chrysanthemum plants, in which the best was obtained in the treatment
241 corresponding to the depth of 100% evaporation in Class "A" tank.
242

243 The linear model for stem diameter presented the best fit and significance at 5% probability
244 according to the response of the different depths applied, with R^2 value of 0.89 (Fig.5).
245

246 **Fig. 5. Variation of stem diameter (SD) in response to different irrigation depths in the**
247 **production of chrysanthemum 'Puritan' in pots, conducted in greenhouse, Colatina /**
248 **ES, 2018**
249

250 The quality standard stipulated by Holambra[20], emphasizes the firmness and good support
251 of the branches of the chrysanthemum plants in pots, being able to infer the importance of
252 the plants to present stems with larger diameters, since, consequently, they present better
253 sustentation. It is noted that the volume of the largest depth applied in the experiment was
254 not enough to cause negative responses when the water excess is applied, according to
255 Rêgo et al.[3], as lower efficiency of photo assimilated transformation in the diameter of the
256 stem, although such answers evidenced in the lower growth of the plants.
257

258 In addition to height and diameter, the increase of the irrigation depths provided a
259 considerable increase in fresh and dry matter of the aerial part of the plants. The fresh
260 matter of the aerial part(Fig.6A) presented regression with linear behavior and coefficient of
261 determination (R^2) of 0.78, while dry matter of the aerial part (Fig.6B) showed as best fit a
262 quadratic polynomial with R^2 of 0.86, both significant at 5% probability.
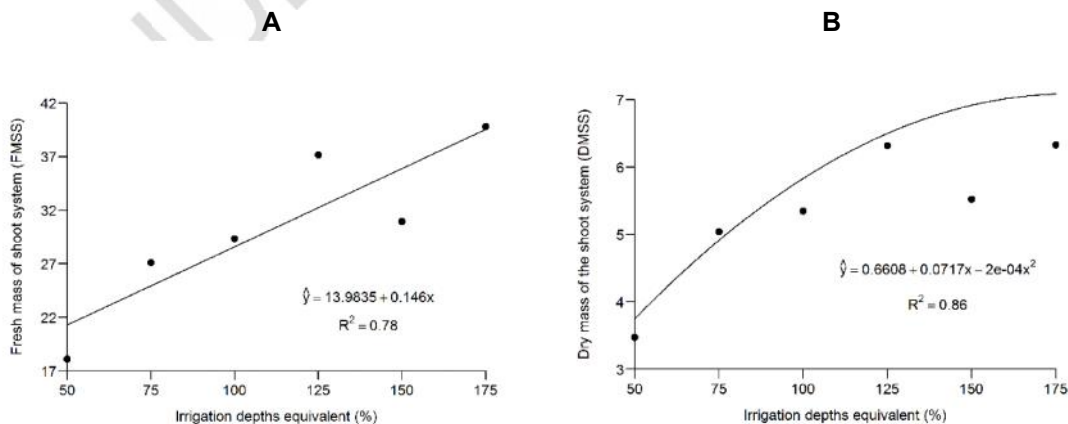263

A   **B**

Fig. 6. Variation of the fresh mass of shoot system (FMSS) (A) and dry mass of the shoot system (DMSS) (B) of chrysanthemum 'Puritan' cultivated in pots, conducted in greenhouse, in response to different irrigation depths, Colatina, 2018

Both FMSS and DMSS presented a positive tendency to development with the increase of the depths applied by the treatments in question. However, it is observed that in the dry mass of the shoot system, this increase tends to a stabilization, reaching its maximum response in the 179.25mm depth with 7.1g. Such quadratic behavior of the dry mass in contrast to the linear behavior of the fresh mass plus the behavior of the height and diameter characteristics may be due to a greater contribution of the mass of leaves, more tender and with more water than the branches, in the fresh mass of the shoot system in the upper depths, which would fit the plants grown on these depths as well formed and with good foliar mass.

About the root system in relation to the applied depths, both fresh and dry mass of the root system showed adjusted linear regression models, with determination coefficients (R^2) of 0.93 and 0.86, respectively (Fig.7A; Fig. 7B).

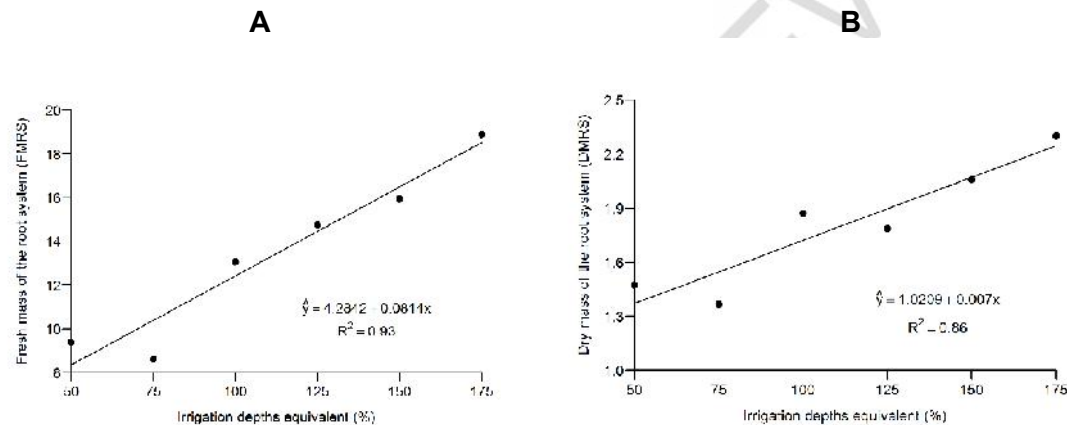**A**   **B**

Fig. 7. Variation of fresh mass of the root system (FMRS) (A) and dry mass of the root system (DMRS) (B) of chrysanthemum 'Puritan' grown in pots, conducted in greenhouses, in response to different irrigation depths, Colatina / ES, 2018

Based on the models, it was observed that the highest estimated dry mass of the root system gain was found when 175% of the daily ETc was restored, presenting a 2.25g weight in the root system. This represents a 30.50% increase when 100% of the total daily ETcis replaced and 62.76% when half of the evapotranspirateddepth is replaced by the crop (50% ETc).

The increasing linear behavior in both the fresh and dry masses of the root system shows that these factors are influenced positively by the increase of irrigation, as well as, it also shows that there was no restriction of the root development due to the cultivation in pots, by the restricted volume of substrate contained in them, which could lead to less development of both root and the shoot system, as Pinto et al.[21], pointed out.

Possibly, the inferior irrigation depths did not meet the physiological needs of the plants, causing water stress, which justifies the low growth and development. Spadeto[22], studying the development and production of chrysanthemum submitted it to different levels of water deficit in the soil, observed that there was a considerable decrease in height and dry mass of plants with increased water deficit, reaching the highest absolute growth rate when there

303 was no water deficit.According to Taiz *etal.*[23], when plants are submitted to water deficit,
304 cell dehydration occurs and that directly affects several basic physiological processes,
305 causing reduction of cell and leaf expansion, photosynthetic inhibition, abscission and leaf
306 death. These factors are undesirable in the commercial production of flowers, as they
307 directly affect the plants of chrysanthemums, reducing the quality demanded by the market.
308
309 The flowers also presented positive responses with the increase of the applied depths. An
310 increasing linear behavior for the diameter, fresh and dry matter of the flowers was
311 observed, presenting R^2 of 0.94, 0.95 and 0.92, respectively (Fig.8).
312
313 The flowers showed better development in the larger depths, with the highest result, among
314 those studied, in the replacement of 175% of the daily ETc, reaching 55.3 g of fresh mass
315 (Fig. 8A), 5.76 g of dry mass(Fig. 8B) and 6.9 cm in diameter of flowers (Fig. 8C). That is,
316 the flowers grew 34.9% in dry weight and 16.95% in diameter in relation to the 100%
317 replacement of ETc. In addition, the flowers showed greater uniformity of opening, which is
318 favorable and increases the quality gain of the plants to be commercialized.
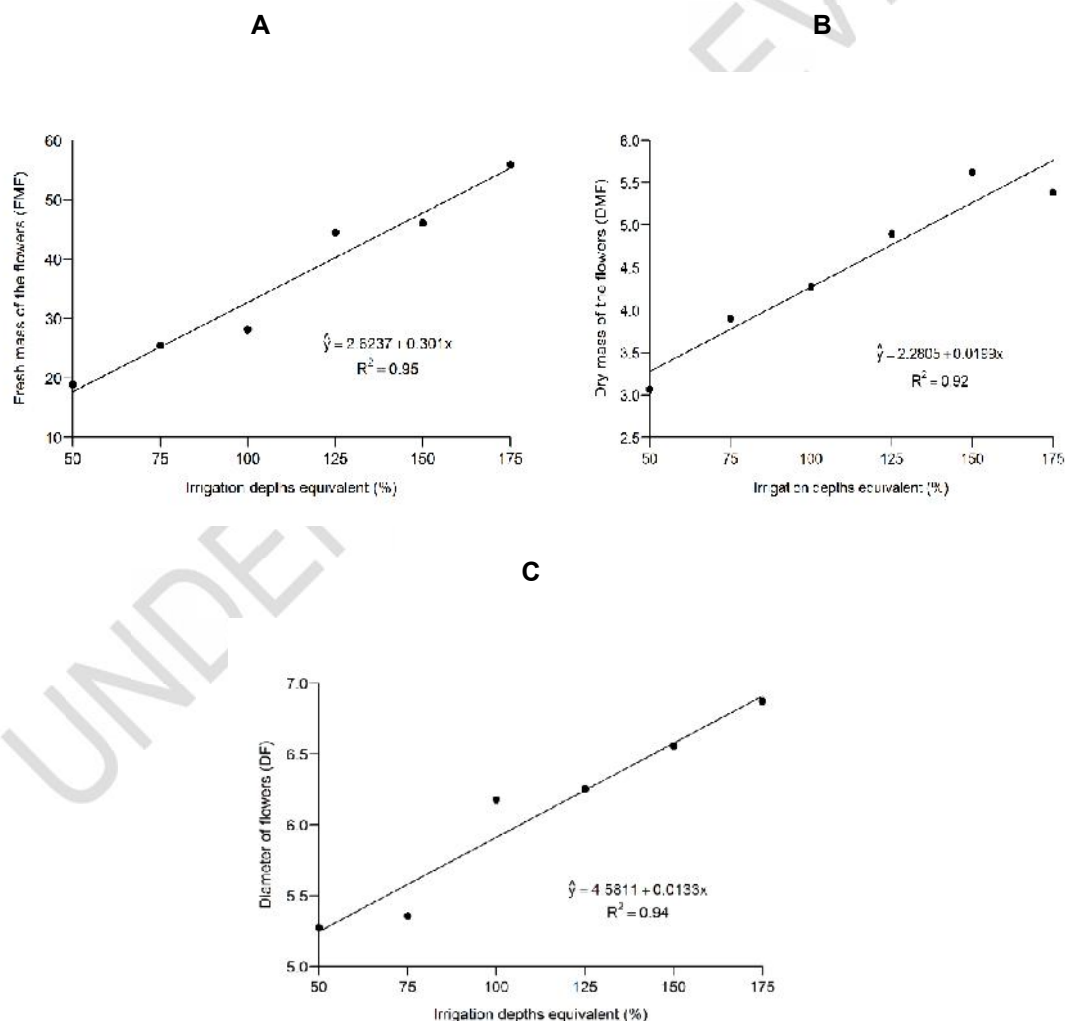319
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Fig. 8. Variation of fresh mass of the flowers (FMF) (A), dry mass of the flowers (DMF) (B) and diameter of flowers (DF) (C) of chrysanthemum 'Puritan' grown in pots, conducted in greenhouses, in response to different irrigation depths, Colatina / ES, 2018

Analyzing the fresh and dry mass responses of the flower buds, it is worth to highlight the increasing development in their fresh mass, cause of the water mass present in them, with the increase of the applied depths, which corroborates with the higher water demand noticed by Pereira *et al.*[18], in flowering.

Considering the results obtained, being the city of Colatina-ES a region that presents high temperatures, it is suggested that new studies be done in different climatic conditions and with daily water supplies in a parceled way.

4. CONCLUSION

Irrigation management with daily replacements of 175% of the crop evapotranspiration, corresponding to a daily average irrigation depth of 12.25 mm, showed the best results for all evaluated morphological parameters under the conditions of this study, that is primordial for the increase of the chrysanthemumsquality.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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