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Saline irrigation water indices affect morphophysiological characteristics of collard

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ABSTRACT

Collard is a vegetable widely consumed in Brazil. However, the quality and production of this vegetable depend on the supply and quality of water. Water stress and saline stress can make it impossible to grow. The objective of this study was to evaluate the performance of morphophysiological characteristics of collard cv. Georgia under irrigation levels and saline indices after the first defoliation.The experiment was conducted in a greenhouse, under random blocks design, and the treatments consisted of combinations of five water electrical conductivities (CEi in dS m^{-1}: C_1 =0.80; C_2 =1.30; C_3 = 1.80; C_4 = 2.30; C_5 = 2.80) and four irrigation levels based on the vase capacity (P_wC: L_1 = 55%; L_2 = 70%; L_3 = 85%; L_4 = 100%), with four replications. Plant height, stem diameter and number of leaves were directly affected by combinations of high salinity levels in irrigation water. On the other hand, the green color index had a higher negative effect caused by the treatments in the first evaluation. For fresh and dry matter weight, and leaf area, T16 treatment (Conductivity 2,30 dSm^{-1} + irrigation level 100% vase water capacity) presented the best result (206.67 g; 25.46 g; 3044 cm^2, respectively), while for water use efficiency, T_3 treatment (Conductivity 0,80 dSm^{-1} + irrigation level 85% vase water capacity) (22.95 g L^{-1}) gave better results. The water electrical conductivities linked to irrigation levels had a direct effect on the morphophysiological characteristics of collard.

Keywords: *Brassica oleracea* var. acephala, leafy vegetable, brackish water, irrigation management.

RESUMO

Índices salinos da água de irrigação afetam as características morfofisiológicas da couve

A couve é uma hortaliça muito consumida no Brasil. No entanto, a qualidade e a produção desta hortaliça dependem da oferta e da qualidade da água, e o estresse hídrico, o salino, ou ambos podem inviabilizar seu cultivo. Objetivou-se avaliar o desempenho das características morfofisiológicas da couve cv. Geórgia sob níveis de irrigação e índices salinos após a primeira desfolha. O experimento foi conduzido em delineamento de blocos ao acaso, com tratamentos constituídos de combinações de valores de cinco níveis de condutividade elétrica da água (CEi, em dS m^{-1}: C_1 =0,80; C_2 =1,30; C_3 = 1,80; C_4 = 2,30; C_5 = 2,80) e quatro níveis de irrigação, baseado na capacidade do vaso (P_wC: L_1 = 55%; L_2 = 70%; L_3 = 85%; L_4 = 100%), com quatro repetições. A altura de plantas, o diâmetro do caule e o número de folhas foram diretamente afetados pelas combinações de altas salinidades na água de irrigação. Já o índice de cor verde teve maior efeito negativo ocasionado pelos tratamentos na primeira avaliação. Para peso de matéria fresca e seca, e área foliar, o tratamento T16 (Condutividade 2,30 dSm^{-1} + nível de irrigação 100% da capacidade de água do vaso) apresentou o melhor resultado (206,67 g; 25,46 g; 3044 cm^2, respectivamente). Já para eficiência do uso da água o tratamento T3 (Condutividade 0,80 dSm^{-1} + nível de irrigação 85% da capacidade de água do vaso) (22,95 g L^{-1}) obteve melhor resultado. Os níveis de condutividade elétrica da água atrelados aos níveis de irrigação tiveram efeito direto sobre as características morfofisiológicas da couve.

Palavras-chave: *Brassica oleracea* var. acephala, hortaliça folhosa, água salobra, manejo da irrigação.

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Collard (*Brassica oleracea* var. acephala) has its origin in the Eastern Mediterranean and is one of the oldest vegetables of the brassicaceae family, having great importance (Balkaya & Yanmaz, 2007).

The consumption of collard in Brazil is increasing, when compared to other leafy vegetables, because it presents high levels of proteins, carbohydrates, fibers, calcium, iron, and vitamins A and C (Novo *et al*., 2010), besides being rich in fibers that increase the feeling of satiety. It is poor in calories and so it is widely used in diets for weight reduction. According to CEAGESP (2017), it was the 49th most commercialized product with approximately 10,166 t.

Butter collard is considered a rustic crop, with high water demand. It is cultivated in autumn - winter seasons and produces all year round (Filgueira, 2002).

Irrigation is a key factor in crop yield, especially in summer or in dry seasons, and allows to obtain products with higher added value, being decisive in the expansion of agricultural frontiers. However, the use of poor quality water associated with inadequate management may contribute to increase the concentration of salts in the soil, reducing the productive potential (Ferreira *et al*., 2006). For Paulus *et al.* (2010, 2012), the insignificant use of this water by farmers is due to the lack of information on the feasibility of its use.

The excess of salts in soil may compromise crop yield because it reduces the water availability to plants, causes nutritional imbalance and toxicity of specific ions for crops (Ferreira Neto *et al*., 2007). However, despite irrigation has a potential effect on soil salinization, this does not imply in soil salinization till the point of making it unsuitable for agriculture (Cordão Terceira Neto *et al*., 2013). Furthermore, the use of this water will enable an increase in agricultural production for those producers who have an available supply of brackish water but a restricted supply of fresh water, reflecting in greater environmental control and the preservation of the fresh water for other purposes (Lira *et al*., 2015).

Salinity is one of the most important factors that limit the production of vegetables, so, the number of studies on the effect of irrigation water quality is growing, in order to help farmers in the efficient use of water (Cerqueira *et al*., 2017).

Crops may present different responses to salinity, ranging from sensitive to tolerant (Neves *et al*., 2002). According to Lorens & Maynard (1988), collard cultivars are vegetables considered moderately sensitive to salinity, but one needs further studies for this crop.

When brackish water with different salinity levels was used in the production of hydroponic collard, there was a reduction in relative and absolute growth rates for plant height and number of leaves (Ferreira *et al*., 2017). There were no symptoms of toxicity due to excess of sodium (Na^+) and chlorine (Cl^-), as well as no decrease in some essential nutrients, such as potassium and nitrogen. Otherwise, this excess of Na^+ and Cl^- affected the concentration of important nutrients such as calcium, magnesium and phosphorus (Viana *et al*., 2018).

Regarding the efficient use of water based on fresh weight of leaves, salinity increased this efficiency in some periods (15 and 45 days after transplantation), but in the last periods there was a negative effect (Cerqueira *et al*., 2017).

Considering the cited results, this study aimed to evaluate the performance of morphophysiological characteristics of collard under saline irrigation levels after the first defoliation.

MATERIAL AND METHODS

The experiment was conducted in a greenhouse from the Rural Engineering Department, at the Faculty of Agricultural and Veterinary Sciences, Jaboticabal Campus, (21°15”S, 48°19”W, 595 m altitude). The local climate is Aw, according to Köppen’s classification (tropical, warm summer and mild winter, annual rainfall of 1,340 mm concentrated in summer, and mean annual temperature of 21.7°C (CEPAGRI, 2016).

In an agricultural greenhouse, chapel type, 12 dm^3 vases were filled with a substrate composed by soil (eutrophic Red Latosol) (Embrapa, 2018) and filter cake (ratio 2:1). The soil chemical characterization resulted in organic matter contents of 24 g dm^{-3}; pH ($CaCl_2$) of 6.3; P_2O_5 of 52 mg dm^{-3}; K_2O of 2.3 mmolc dm^{-3}; Ca of 30 mmolc dm^{-3}; Mg of 9 mmolc dm^{-3}; S of 11 mg dm^{-3} and V of 71%.

For drainage purposes, gravels size #2 were placed at the bottom of the vases, covering it with a geotextile (Geotextil Bidim®), and finally, the soil was added.

Based on the results of the soil chemical analysis, transplant fertilization was performed, according to the recommendations for the cultivation of collard in the Bulletin 100 - IAC (Van Raij *et al*., 1997). We applied 0.24 g $vase^{-1}$ of N (urea), 0.96 g $vase^{-1}$ of K_2O (potassium chloride) and 106.67 g $vase^{-1}$ of P_2O_5 (single superphosphate).

The experimental design was random blocks, with four replications. The treatments were combinations of five levels of water electrical conductivity (CEi, in dS m^{-1}: C_1 =0.80; C_2 =1.30; C_3 = 1.80; C_4 = 2.30; C_5 = 2.80) and four levels of irrigation water, based on the vase water capacity (P_wC: L_1 = 55%; L_2 = 70%; L_3 = 85%; L_4 = 100%), resulting in 20 treatments. So, the evaluated treatments were defined as T1 (C_1 and L_1); T2 (C_1 and L_2), T3……T16 (C_5 and L_4).

The irrigation level of 100% (L_4) was obtained through vessel saturation and subsequent drainage. Defining, the “vessel capacity” occurred at 14 days after soil saturation in the pot, which corresponds to the maximum amount of water that can be retained in the soil volume (Casaroli & Jong Van Lier, 2008). The irrigations were carried out through the adoption of a one-day irrigation shift, during the morning between 7:30 am and 8:30 am. The daily depth applied was determined from the evapotranspiration of the crop, weighing five vessels per treatment.

The mean daily water intake by butter collard after the first defoliation for the irrigation levels 100%, 85%, 70% and 55% of the vase capacity (P_wC) were 5.85 mm, 4.98 mm; 4.29 mm and 3.59 mm respectively.

For imposing the levels of electrical conductivity of irrigation water (CEi), we prepared solutions of water and sodium chloride (NaCl) in plastic containers of 20 L in volume, subsequently sealed with black plastic film to prevent water evaporation. The CEi was monitored with a portable CE meter, with 2% accuracy.

Waters with different CEi levels were used to supply evapotranspiration losses, according to the pre-established irrigation levels.

Initially the vases had already been irrigated with different irrigation levels and different salinities.This experiment was carried out after the first defoliation of the butter collard, performed 50 days after transplanting the seedlings.

To evaluate the morphophysiological performance of the butter collard cv. Georgia, the following characteristics were evaluated: 1) plant height [(using a graduated ruler, from the plant neck to the insertion of the first leaf in the stem (cm)]; 2) stem diameter [using a digital caliper (Starrett Digital caliper) just below the first leaf near the soil (mm)]; 3) number of leaves per plant (only the fully expanded leaves); 4) green color index [using a chlorophyllmeter, ChlorophyLOG, model CFL 1030 in the first fully expanded leaf of each plant (more exposed to solar radiation)]; 5) fresh (FW) and dry (DW) matter weight of leaves, considering all marketable leaves. The leaves were collected and sent to the laboratory for weighing (MF) and then dried in a forced air-circulation greenhouse, at 65ºC for 72 hours, and then weighed, on an analytical weight meter with accuracy of 0.0001 g, in order to obtain the dry matter (MS) and water use efficiency (WUE) by equation 1:

$$WUE = FW/Vapl \qquad (1)$$

in which, WUE: water use efficiency (g L^{-1}); FW: fresh weight of marketable leaves (g) and V_{apl}: total volume of water applied (L). 6) leaf area index (LAI) (measured in all leaves collected from each plant by reading in bench top leaf area meter model LI-3000C).

The collected data were submitted to analysis of variance by the F-test, and the means compared by the Tukey test (p = 0,05) using the Software Agroestat version 1.0.

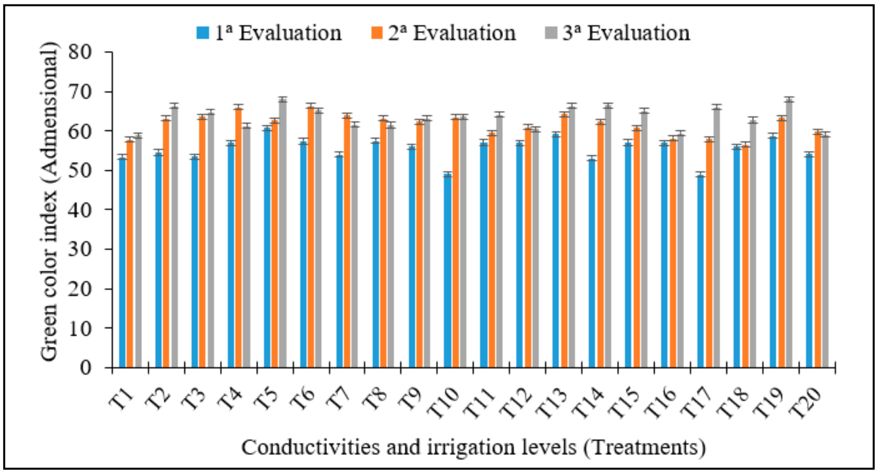

Figure 1. Green color index of butter collard cv. Georgia submitted to electrical conductivities and irrigation levels after first defoliation. T1= C_1L_1; T2= C_1L_2; T19= C_5L_3; T20= C_5L_4. UNESP, Jaboticabal, 2018.

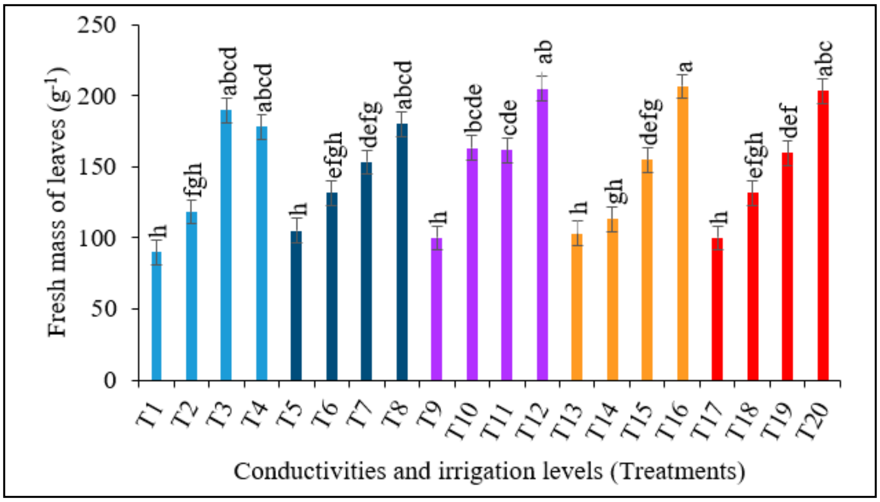

Figure 2. Fresh matter (g) of butter collard leaves cv. Georgia as a function of electrical conductivities and irrigation levels after first defoliation. Equal lowercase letters between bars do not differ from each other (p<0.05). Blue bars, CEi= 0.80 ds m^{-1}; navy blue bars, CEi= 1.30 dS m^{-1}; violet bars, CEi= 1.80 dS m^{-1}; orange bars, CEi= 2.30 dS m^{-1} and red bars, CEi= 2.80 dS m^{-1}. T1= C_1L_1; T2= C_1L_2; T19= C_5L_3; T20= C_5L_4. UNESP, Jaboticabal, 2018.

RESULTS AND DISCUSSION

The effects of salinity and irrigation levels had a direct effect on the stem diameter and number of leaves of collard cv. Georgia (Table 1). There were significant differences for plant height, stem diameter and number of leaves (p<0.05) (Table 1).

At 27 days after the first harvest of leaves, the collard plants had heights ranging from 5.80 cm to 8.17 cm. The highest height was observed in T15(C_4L_3), and the lowest, in T9 (C_3L_1). Such behavior in T15 was due to the dilution effect of irrigation (L_3 = 85% P_wC), that was able to dilute the salts and avoid a chemical imbalance in plant cells. This is also explained by the fact that salinity has a cumulate effect; after the first leaf harvest, it began a new process of salt accumulation on the new leaves.

The crop stem diameter ranged from 19.10 to 23.36 mm, and was inversely proportional to the plant height (Table 1). The treatments with the smallest diameter were T1 (C_1L_1, 19.10 mm), T5 (C_2L_1, 19.17 mm) and T10 (C_3L_2, 19.25 mm). Collard is a leafy vegetable, composed by 90% water, approximately (Feiber & Caetano, 2012). Thus, it needs high water levels in its production process. Smaller stem diameter tends to present lower support for the plant, favoring its bending, as well as reducing the accumulation of solutes produced in photosynthesis. This fact can be explained by treatments with smaller plant stem diameters.

The crop behavior for the number of leaves indicates that the increase was gradual due to the treatments imposed. The number of leaves ranged from 8.25 to 12. The highest values found were for treatments T10 (C_3L_2, 12 leaves), T12 (C_3L_4, 12 leaves) and T16 (C_4L_4, 12 leaves). This discrepancy for the number of leaves (Table 1) is probably due to the irrigation water level during the cycle, that met the crop water requirement (L_4 in T12 and T16). In T9 treatment, even with the smallest irrigation level (L_1),

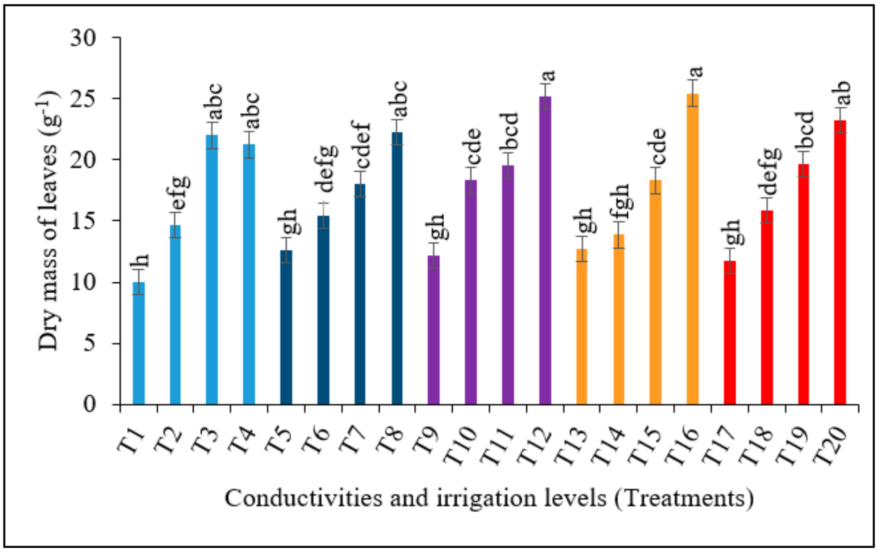

Figure 3. Dry matter (g) of leaves of butter collard cv. Georgia as a function of electrical conductivities and irrigation levels after first defoliation. Equal lowercase letters between bars do not differ from each other (p<0.05). Blue bars, CEi= 0.80 ds m^{-1}; navy blue bars, CEi= 1.30 dS m-1; violet bars, CEi= 1.80 dS m-1; orange bars, CEi= 2.30 dS m^{-1} and red bars, CEi= 2.80 dS m-1. T1= C_1L_1; T2= C_1L_2; T19= C_5L_3; T20= C_5L_4. UNESP, Jaboticabal, 2018.

Table 1. Average values, 27 days after first harvest, of plant height, stem diameter and number of leaves of leafy vegetable butter collard cv. Georgia submitted to electrical conductivities and irrigation levels after first defoliation. UNESP, Jaboticabal, 2018.

Treatments	Plant height (cm)	Stem diameter (mm)	Number of leaves
T1	6.67 ab	19.10 e	8.25 de
T2	7.22 ab	21.03 bcde	10.00abcde
T3	6.42 ab	21.76 abcde	11.00 ab
T4	6.90 ab	24.17 ab	10.75 abc
T5	6.27 ab	19.17 e	9.75 bcde
T6	7.67 ab	21.56 abcde	9.75 bcde
T7	7.62 ab	23.09 abcde	10.75 abc
T8	6.17 ab	23.01 abcde	10.75 abc
T9	5.80 ab	20.67 cde	9.00bcde
T10	6.17 ab	19.25 e	12.00 a
T11	6.67 ab	22.36 abcde	10.00 abcde
T12	6.80 ab	24.64 a	12.00a
T13	6.82 ab	20.43 cde	8.75 cde
T14	6.82 ab	20.99 bcde	8.75 cde
T15	8.17 a	20.83 bcde	10.25 abcde
T16	7.17 ab	23.79 abc	12.00 a
T17	6.82 ab	20.11 de	8.00 e
T18	6.30 ab	20.60 cde	9.25 bcde
T19	6.00 b	22.38 abcde	10.75 abc
T20	6.52 b	21.93 abcde	11.00 ab
F	*	**	**
CV (%)	12.92	6.11	8.18

Lowercase letters in the column do not differ from each other on Tukey test, 5% probability level. *,**Significant at 1% and 5% respectively. T1= C_1L_1; T2= C_1L_2; T19= C_5L_3; T20= C_5L_4.

the CE_i level (C_3, 1.80 $dS.m^{-1}$) was the recommended in the literature, as a level tolerated by the crop. The highest irrigation level coupled with the highest electrical conductivity level increased the number of leaves, due to the lower concentration of salts in the rhizosphere, allowing a better absorption of nutrients and water by the roots, and favouring a better crop performance.

Figure 1 shows that the green color index throughout the evaluations was quite differentiated at each treatment. The lowest values of green color index were observed for the first day of evaluation in T10 (C_3L_2, 49.1) and T17 (C_5L_1, 49). The green color index is directly related to the plant chlorophyll content. It is a way to measure the photosynthetic activity.

Chlorophyll is directly related to biomass yield and accumulation of photoassimilates produced in photosynthesis. Cruz *et al.* (2017) made an experiment with collard plants and observed that the salinity increase of irrigation water resulted in greater plant water stress. This helps to justify the lower green color index values found in the present study. The excess of salts affected all the crop physiological processes, viewed in some crop morphological variables in the present study.

In the butter collard cv. Georgia, the salinity effect linked to irrigation levels was observed in the leaves closest to the soil, which greatly influenced the reduction in the number of commercial leaves, and reducing the fresh weight of leaves (Figure 2).

Higher fresh matter weights of leaves were observed in treatments T3 (C_1L_3) (190 g), T4 (C_1L_4) (178.33 g), T8 (C_2L_4) (180 g), T12 (C_3L_4) (205 g), T16(C_4L_4) (206.67 g) and T20 (C_5L_4) (203.33 g), corresponding to intermediate and optimal irrigation levels, regardless of the CEi. Higher irrigation levels result in better environment for collard crop, increases the water absorption rate and favors the fresh matter accumulation (Figure 2).

Studies carried out by Ferreira *et al*. (2001), Farias *et al.* (2009) and Cavalcante *et al.* (2010), demonstrated that excessive levels of salts in the irrigation water affects the absorption and the transport of nutrients, and causes a reduction in plant development due to nutritional imbalances. These effects were also found in the present study. Salinity also considerably inhibits plant growth, due to the osmotic and toxic effects of ions (Munns, 2005). The presence of salt in soil solution leads to a decrease in external water potential (Epstein & Bloom, 2006), thus the plant stops absorbing nutrients that would be favorable to the gain of fresh matter.

Figure 3 shows the results found for dry matter weight of leaves of collard butter cv. Georgia. Lower dry matter weights were found for treatments T1 (9.99 g pl^{-1}), T5 (12.62 g pl^{-1}), T9 (12.14 g pl^{-1}), T13 (12.75 g pl^{-1}), T14 (13.86 g pl^{-1}), T17 (11.71 g pl^{-1}) and higher for T2 (14.63 g pl^{-1}), T3 (21.99 g pl^{-1}), T7 (18.02 g pl^{-1}), T11 (19.54 g pl^{-1}), T15 (18.32 g pl^{-1}), T16 (25.46 g pl^{-1}), T19 (19.69 g pl^{-1}) and T20 (23.21 g pl^{-1}).

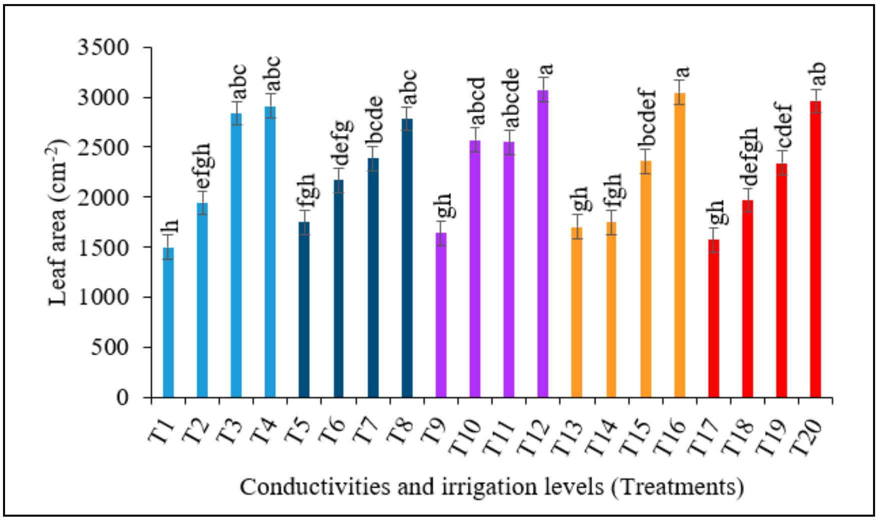

Figure 4. Leaf area of butter collard cv. Georgia as a function of electrical conductivities and irrigation levels after first defoliation. Equal lowercase letters between bars do not differ from each other ($p<0.05$). Blue bars, CEi= 0.80 ds m^{-1}; navy blue bars, CEi= 1.30 dS m^{-1}; violet bars, CEi= 1.80 dS m^{-1}; orange bars, CEi= 2.30 dS m^{-1} and red bars, CEi= 2.80 dS m^{-1}. T1= C_1L_1; T2= C_1L_2; T19= C_5L_3; T20= C_5L_4. UNESP, Jaboticabal, 2018.

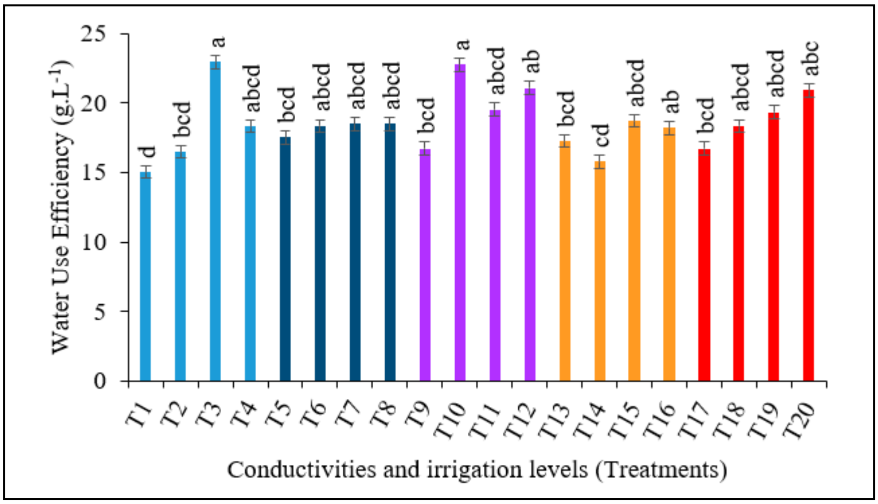

Figure 5. Efficiency of water use of butter collard cv. Georgia as a function of electrical conductivities and irrigation levels after first defoliation. Equal lowercase letters between bars do not differ from each other ($p<0.05$). Blue bars, CEi= 0.80 ds m^{-1}; navy blue bars, CEi= 1.30 dS m^{-1}; violet bars, CEi= 1.80 dS m^{-1}; orange bars, CEi= 2.30 dS m^{-1} and red bars, CEi= 2.80 dS m^{-1}. T1= C_1L_1; T2= C_1L_2; T19= C_5L_3; T20= C_5L_4. UNESP, Jaboticabal, 2018.

The higher the water electrical conductivity and the lower the irrigation level, the smaller the emission of new leaves, as well as the higher the death and fall of leaves. In addition, these conditions lead to reducing the leaf-blade expansion (Tester & Davenport, 2003). Under saline stress conditions, morphological and anatomical changes occur in plants, reflecting in reduction of transpiration, a way to maintain low absorption of saline water. One of these adaptations is the reduction in the number of leaves, which directly influences the reduction of the final dry matter weight.

In a study conducted by Medeiros *et al*. (2007), the highest salinity levels of irrigation water directly affected the dry matter weight of plants. In addition to water salinity, other factors may interfere with plant development, such as the combined effects of cations and anions present in the water. Irrigated agriculture promotes soil salinization if the amount of water applied is insufficient to leach salt below the root zone (Taiz *et al*., 2017).

Higher leaf area index in the crop of collard cv. Georgia directly reflects in higher photosynthetic activity, and higher production of photoassimilates, ensuring leaves of better quality for the consumer.

In the present study, the leaf area of collard showed significant differences according to the treatments imposed (Figure 4).

The higher leaf area values were found in T12 (C_3L_4, 3,075 cm^{-2}) and T16 (C_4L_4, 3,044 cm^2), both with the highest irrigation level applied (100%P_WC). This is justified by the higher number of leaves per plant, and by the increase of leaf area. Larger leaf area reflects in greater capture of sunlight energy and its conversion into chemical energy, essential for the plant development (Taiz & Zeiger, 2009). The CEi of 1.80 dS m^{-1} highlighted both, the number of leaves and the leaf area index, as this CEi level was well tolerated by collard crop.

For water use efficiency (WUE), the treatments resulted in significant effects (Figure 5). Higher WUE values were obtained on the treatments T3 (C_1L_3, 22.95 g L^{-1}) and T10 (C_3L_2, 22.76 g L^{-1}). Under these levels of CEi and irrigation, the plants were able to perform the highest water use, producing satisfactorily.

The results of WUE found in collard are similar to the work carried out by Cerqueira *et al*. (2017), who studied the WUE in hydroponic collard cultivated with brackish waters, and concluded that the increased water salinity did not cause a significant difference in water use efficiency.

Salinity and irrigation levels had a direct influence on the variable plant height, stem diameter, number of leaves, green color index, fresh and dry matter, water use efficiency and leaf area of collard cv. Georgia, because even exceeding the limit of salinity acceptable for the crop (1.80 dS m^{-1}) (Lorens & Maynard 1988), the plant showed good growth performance.

We conclude that irrigation levels had a direct effect on the water electrical conductivity, leading to salt dilution and reflecting on better performance for collard. However, further long-term studies are required for the crop in a protected environment, in order to better obtain information about the use of saline water in the cultivation of this vegetable.

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