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Cherry tomato production and seed vigor under irrigation with saline effluent from fish farming[1]

Produção e vigor de sementes de tomate cereja sob irrigação com efluente salino da piscicultura

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HIGHLIGHTS:

Irrigation with saline effluent from fish farming does not reduce cherry tomato fruit production.
The use of saline effluent from fish farming in irrigation reduces production and vigor of cherry tomato seeds.
Application of effluent in the appropriate stages promotes production of fruits and seeds of cherry tomato equal to those of the control.

ABSTRACT: This study aimed to evaluate the effect of irrigation with saline effluent from fish farming in different phenological stages on fruit production and seed vigor of cherry tomato. The experiment was conducted in a greenhouse in Mossoró, RN, Brazil, using a completely randomized design with 10 treatments, which consisted of the use of fish farming effluent with electrical conductivity (EC) of 4.54 dS m^{-1} and public-supply water with EC of 0.54 dS m^{-1}, alternated during four phenological stages (growth from 1 to 19 days after transplantation (DAT), flowering from 20 to 31 DAT, fruit filling from 32 to 60 DAT and maturation from 61 to 77 DAT). Application of saline effluent from fish farming throughout a phenological stage of cherry tomato does not reduce fruit production per bunch, but reduces seed production and the vigor of the seeds produced. The use of saline effluent from fish farming in the initial and maturation stages, and the use of effluent with two successive applications, alternated with irrigation with low salinity water, are favorable for the production of cherry tomato seeds with satisfactory vigor. Alternated application of saline effluent from fish farming, with two subsequent successive irrigations with low-salinity water, despite reducing seed production, favors the production of seeds with high vigor. The use of saline effluent from fish farming in the flowering and fruiting stages reduces seed production and the vigor of the seeds produced.

Key words: *Solanum lycopersicon*, reuse, semi-arid region, phenological stages

RESUMO: Objetivou-se com este estudo avaliar o efeito da irrigação com efluente salino da piscicultura aplicado em diferentes fases fenológicas sobre a produção de frutos e o vigor de sementes de tomateiro cereja. O experimento foi conduzido em casa de vegetação, em Mossoró, RN, utilizando-se delineamento inteiramente casualizado, com 10 tratamentos, que consistiram do uso do efluente da piscicultura de condutividade elétrica (CE) de 4,54 dS m^{-1} e água de abastecimento com CE de 0,54 dS m^{-1}, intercalados durante quatro fases fenológicas (crescimento de 1 a 19 dias após transplantio (DAT), florescimento de 20 a 31 DAT, enchimento do fruto de 32 a 60 DAT e amadurecimento de 61 a 89 DAT). A aplicação do efluente salino da piscicultura durante toda uma fase fenológica do tomateiro cereja não reduz a produção de frutos por cacho, mas reduz a produção de sementes e o vigor das sementes produzidas. O uso do efluente salino da piscicultura nas fases inicial e de maturação, e o uso do efluente com duas aplicações sucessivas, intercaladas com uma irrigação com água de baixa salinidade, são favoráveis para a produção de sementes de tomateiro cereja com vigor satisfatório. A aplicação intercalada do efluente salino da piscicultura, com duas posteriores irrigações sucessivas com água de baixa salinidade, apesar de reduzir a produção de sementes, favorece a produção de sementes de alto vigor. O uso do efluente salino da piscicultura nas fases de floração e frutificação reduz a produção de sementes e o vigor das sementes produzidas.

Palavras-chave: *Solanum lycopersicon*, reuso de água, semiárido, fases fenológicas

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Introduction

Tomato (*Solanum lycopersicon* L.) is one of the most relevant horticultural species worldwide, used for fresh consumption or processed. The fruit stands out for its high nutritional value, high soluble solids content and good market acceptance, which guarantees rapid economic return to rural producers (Silva et al., 2011; Maia et al., 2019). The maintenance and growth of production are dependent on the water resources available in a region; in the semi-arid region, the rainfall regime is marked by extreme irregularity and high evaporation rates, so the use of irrigation becomes necessary (Costa et al., 2009). Considering the limitation of water available for irrigation, alternative sources of water have been incorporated into the production system, such as the use of saline effluent from fish farming, which in addition to meeting water demand serves as an extra source of nutrients (Nascimento et al., 2016; Almeida et al., 2017).

The effect of salinity differs among species, and tomato is considered moderately sensitive, with salinity threshold of 2.5 dS m^{-1} (Rhoades et al., 1992), showing yield losses as a function of the increase in electrical conductivity (Viol et al., 2017). The effects of salinity can go beyond the reduction in fruit and seed production, since the number of pollen grains, germination percentage, and pollen tube growth rate are negatively influenced by increased salinity (Heslop-Harrison, 1987). Changes caused by salinity during the crop cycle may affect the second generation of plants. According to Pedroso et al. (2009), it has been detected that stress causes a great variability in seed viability and vigor. The objective of this study was to evaluate the effect of irrigation with saline effluent from fish farming applied in different phenological stages on fruit production and seed vigor of cherry tomato.

Material and Methods

The study was conducted in a greenhouse on the West campus of the Universidade Federal Rural do Semiárido (UFERSA), Mossoró, RN, Brazil (5° 11’ S, 37° 20’ W and 18 m altitude). According to Köppen’s classification, the climate of the region is BSwh’ (hot and dry), with very irregular rainfall, annual average of 673.9 mm $year^{-1}$, temperature of 27 °C and relative humidity of 68.9% (Diniz & Pereira, 2015).

The experiment was conducted in a completely randomized design, evaluating 10 treatments, corresponding to different irrigation management strategies as a function of the phenological stage of the crop, with four replicates of three plants (Table 1).

The experiment was conducted using seeds of the cultivar Samambaia from the company TopSeeds, which has vigorous, compact plants with determinate growth habit, fruits with average size of 30 to 35 mm and weight between 10 and 15 g, intense red color, firm peel and good postharvest conservation.

Table 1. Details of treatments and alternated use of fish farming effluent

Treatments	Phenological stages			
	Growth 1-19 DAT	Flowering 20-31 DAT	Fruiting 32-60 DAT	Maturation 61-89 DAT
1 (Control)	W	W	W	W
2	W	E	E	E
3	W	W	E	E
4	W	W	W	E
5	E	W	E	E
6	E	W	W	E
7	E	E	W	E
8	E	E	E	E
9	E – W – W			
10	E – E – W			

W - Public-supply water; E - Effluent from fish farming; T9 - One irrigation with E and two irrigations with W, sequentially throughout the cycle; T10 - Two irrigations with E and one irrigation with W sequentially throughout the cycle; DAT - Days after transplanting

Sowing was performed in polyethylene trays and after the development of true leaves, at 12 days after planting (DAP), the seedlings were transplanted into flexible plastic bags with capacity for 4.0 dm^3. At the bottom, a 2-cm-thick layer of crushed stone was placed on a geotextile to prevent substrate loss. Subsequently, they were filled with coconut fiber and organic compost based on bovine and goat manure (Table 2), in a 2:1 ratio (v/v), respectively. One tomato seedling was transplanted to each bag, and the bags were spaced 1.0 m between rows and 0.5 m between plants.

The treatments began to be applied four days after transplantation (DAT), when the plants were already well established in the bags, with two true leaves. Two types of water were used in the experiment; the first is water from supply system of the UFERSA campus (Table 3) and the second is water from a well open in Jandaíra limestone and used for tilapia farming. This post-tilapia farming water was deposited in a stabilization pond, and the reject was collected and used in this experiment.

Plants were irrigated twice a day (early morning and late afternoon) in the seedling production stage with public-supply water and once a day after transplanting, according to the respective treatments. The volume of water required to replace the losses caused by evapotranspiration (ET) was applied. The depth applied in each irrigation was calculated

Table 2. Chemical characterization of the organic compost used in the experiment

N	Moisture	OC	pH	CEC	C/N	CEC/C
(%)				($mmol_c$ dm^{-3})		
18.0	50.0	21.0	6.0	371.0	15.8	17.6

N - Nitrogen; OC – Organic Carbon; pH – Hydrogen potential; CEC - Cation exchange capacity

Table 3. Physicochemical characterization of the waters used in the experiment

Water	Attributes									
	pH	EC	K^+	Na^+	Mg^{2+}	Ca^{2+}	Cl^-	CO_3^{2-}	HCO_3^-	SAR
	H_2O	(dS m^{-1})	($mmol_c$ L^{-1})							($mmol$ L^{-1})$^{0.5}$
W	7.57	0.54	0.31	3.79	1.20	0.83	2.40	0.60	3.20	3.76
E	7.40	4.54	1.02	25.66	17.30	12.40	30.20	0.00	3.90	6.66

W - Public-supply water; E - Effluent from fish farming; pH (H_2O) - Hydrogen potential in water; EC - Electrical conductivity; K^+ - Potassium; Na^+ - Sodium; Mg^{2+} - Magnesium; Ca^{2+} - Calcium; Cl^- - Chloride; CO_3^{2-} - Carbonate; HCO_3^- - Bicarbonate; SAR - Sodium adsorption ratio in additional plots through drainage lysimetry, using the difference between the depth applied via irrigation (I) and the water depth percolated (D) in bags/trays for this purpose, according to Eq. 1.

$$ET = I - D \quad (1)$$

During the experiment, complementary fertilization was performed in all treatments in the fruiting stage, applying 30% of the recommendation of fertilization for pots proposed by Novais et al. (1991), which corresponded to 300 mg of $P_2O_5^-$, 150 mg of K_2O, and 100 mg of N, per dm^3 of soil. Top-dressing fertilization was performed using mono ammonium phosphate (MAP) at 49 and 54 DAT, ammonium nitrate at 50 and 54 DAT and potassium phosphate monobasic at 49, 54 and 70 DAT, thus providing the doses of 90 mg of $P_2O_5^-$, 45 mg of K_2O, and 30 mg of N, per dm^3 of soil. At 41, 49, 64 and 70 days after transplantation (DAT), foliar fertilization was applied to supply calcium and micronutrients, using the foliar fertilizer Liqui-Plex Fruit®, at dose of 3 mL L^{-1}, following the manufacturer's recommendation for tomato (Table 4).

At 89 DAT, the fruits were harvested at the point of commercial maturity. Initially, the number of bunches per plant (NBP) and number of fruits per bunch (NFB) were determined by counting. Next, the fruits were placed in plastic bags and taken to the Laboratório de Análise de Sementes of UFERSA. Average fruit weight per bunch (FWB), in grams, was determined using a scale with precision of 0.01 g. Subsequently, seeds were extracted and dried naturally (Brasil, 2009). After drying, the number of seeds per fruit (NSF) and the number of seeds per plant (NSP) were determined by counting, and average seed weight per plant (SWP), in grams, was determined on a scale with precision of 1 mg.

The seeds were then subjected to an emergence test, using four replicates of 50 seeds for each treatment. The seeds were sown in polyethylene trays of 200 cells, filled with inert substrate based on coconut fiber. Irrigation was carried out with a floating-type system for seedlings, using water from the local supply (0.54 dS m^{-1}). This device was installed on a 0.25-m-high wooden box (1.5 x 1.0 m). Each part was covered with plastic tarpaulin, forming a micro-pool with capacity to hold two trays.

During the experiment, the emergence of tomato seeds was monitored by daily counts of the number of germinated seedlings, that is, with emergence of hypocotyl above the substrate, without discarding them, so as to obtain a cumulative value. Thus, the number of seedlings emerged referring to each count was obtained by subtracting the reading of the previous day from the value read. With the number of germinated seeds referring to each reading, the emergence speed index (ESI) was calculated using the equation of Maguire (1962).

Table 4. Chemical characterization of the foliar fertilizer Liqui-Plex Fruit®

Attributes								OC
N	Ca	S	B	Cu	Mn	Mo	Zn-	(%)
(g L^{-1})								
73.50	14.70	78.63	14.17	0.74	73.50	1.47	73.50	2.45

N - Nitrogen; Ca - Calcium; S - Sulfur; B - Boron; Cu - Copper; Mn - Manganese; Mo - Molybdenum; Zn - Zinc; OC - Organic carbon

At 14 days after sowing, the emergence percentage (EP) was obtained by the relationship between the number of normal seedlings emerged and the number of seeds planted (Brasil, 2009).

At the end of the emergence test, the primary root and shoots of all normal seedlings were measured with a ruler graduated in millimeters, with the results expressed in cm per seedling, and stem diameter was measured with a digital caliper, with data expressed in mm per seedling. To determine the total dry mass, seedlings were collected, placed in Kraft paper bags, kept in a forced air circulation oven at 65 °C until reaching constant weight, and weighed on an analytical scale (1 mg), and the results were expressed in mg per seedling.

The data obtained were subjected to analysis of variance and Dunnett's test using the statistical program Sisvar, version 5.6 (Ferreira, 2014).

Results and Discussion

Continuous or alternated application of saline effluent from fish farming in the different phenological stages of cherry tomato caused a significant difference in the number of fruits per bunch (NFB, $p \leq 0.001$), number of seeds per fruit (NSF, $p \leq 0.001$), number of seeds per plant (NSP, $p \leq 0.05$) and average seed weight per plant (SWP, $p \leq 0.001$) of cherry tomatoes cv. Samambaia in response to the cultivation conducted with effluent (Table 5). On the other hand, there was no significant effect of the treatments on number of bunches per plant (NBP) and average fruit weight per bunch (FWB) (Table 5).

NFB values in treatments T3, T4, T6, T8, T9 and T10 were similar to those of the control treatment (T1). Treatments T2, T5 and T7 led to lower NFB than the control, with reductions of 30, 36 and 39%, respectively (Table 5). Despite the difference in NFB, there was no difference in FWB, so there was a compensation by the size and individual weight of the fruits in the bunch (Santos et al., 2016). However, these small changes in the production of tomato fruits cv. Samambaia under different irrigation strategies with saline effluent also altered seed production (Table 5).

The NSF, NSP and SWP of treatments T2, T3, T7, T8 and T9 were lower than those obtained in the control treatment (T1). Although T4 obtained NSF equal to that of the control (T1), and T5 obtained NSF higher than that of the control (T1), the NSP and SWP of these treatments were lower than those obtained in the control (T1) (Table 5). The T6 treatment obtained NSF, NSP and SWP similar to those of the control (T1) and T10 obtained NSP and SWP similar to those of the control (T1) (Table 5).

The use of saline effluent from fish farming reduced the seed production of tomato cv. Samambaia, with the exception of the irrigation strategies T6 and T10. SWP was one of the main variables affected by the use of saline effluent, and the greatest reductions occurred in the treatments that received saline effluent in the flowering stage (T2 and T7), respectively, with 59 and 56% reduction in comparison to the control (T1), and the reductions in SWP of these treatments (T2 and T7) corroborate the reductions in NFB and NSF.

Table 5. Probability of the F test and means of the number of bunches per plant (NBP), number of fruits per bunch (NFB), average fruit weight per bunch (FWB), number of seeds per fruit (NSF), number of seeds per plant (NSP) and average seed weight per plant (SWP) of seedlings of cherry tomatoes cv. Samambaia produced under different irrigation strategies with saline effluent from fish farming in the phenological stages

Sources of variation	DF	F test (p-value)					
		NBP	NFB	FWB	NSF	NSP	SWP
Treatments	9	0.1900	0.0000	0.1920	0.0000	0.0226	0.0000
Coefficient of variation (%)		20.32	14.42	23.25	6.35	12.72	13.66

Treatment and Phenological stage	Means					
	NBP (Unit)	NFB (Unit)	FWB (g bunch^{-1})	NSF (Unit)	NSP (Unit)	SWP (g plant^{-1})
T1 = W1/W2/W3/W4 (Control)	4.3	3.6	22.64	24	359	1.25
T2 = W1/E2/E3/E4	3.8^{ns}	2.5*	20.72^{ns}	16*	146*	0.51*
T3 = W1/W2/E3/E4	4.0^{ns}	3.3^{ns}	29.82^{ns}	21*	266*	0.93*
T4 = W1/W2/W3/E4	3.0^{ns}	2.7^{ns}	27.29^{ns}	24^{ns}	188*	0.65*
T5 = E1/W2/E3/E4;	3.5^{ns}	2.3*	20.77^{ns}	28*	199*	0.69*
T6 = E1/W2/W3/E4	4.4^{ns}	3.2^{ns}	18.15^{ns}	25^{ns}	346^{ns}	1.21^{ns}
T7 = E1/E2/W3/E4	4.3^{ns}	2.2*	23.36^{ns}	17*	159*	0.55*
T8 = E1/E2/E3/E4	4.3^{ns}	4.0^{ns}	31.92^{ns}	13*	210*	0.74*
T9 = E/W/W	4.0^{ns}	2.9^{ns}	19.52^{ns}	20*	224*	0.78*
T10 = E/E/W	4.8^{ns}	4.3^{ns}	18.37^{ns}	17*	329^{ns}	1.15^{ns}
LSD	1.62	1.00	10.73	2.23	55.45	0.20

DF - Degrees of freedom; LSD - Least significant difference; * and ns - significant and non-significant difference compared to the control treatment by Dunnett's test (p ≤ 0.05), respectively; E - Effluent from fish farming; W - Public-supply water; Phenological stages: growth (1), flowering (2), fruit filling (3) and maturation (4); T9 - One irrigation with E and two irrigations with W, sequentially throughout the cycle; T10 - Two irrigations with E and one irrigation with W sequentially throughout the cycle

Under conditions of severe salt stress, disorders such as reduction in photosynthetic activity and in the processes of absorption, transport, assimilation and distribution of nutrients and increase in the accumulation of reactive oxygen species (ROS) are attributed to the osmotic and ionic effects caused by high salinity, reducing the yield of crops (Ashraf, 2009; Calvet et al., 2013; Turan & Tripathy, 2013; Huang, 2018). Salt stress in sensitive phenological stages, such as flowering, can lead to reduction in seed production because of the decrease in the number of fruits due to flower abortion (Santos et al., 2016), as well as non-fertilization of the eggs and/or their abortion after fertilization (Heslop-Harrison, 1987).

Continuous or alternated application of saline effluent from fish farming in the different phenological stages of cherry tomato led to significant differences in emergence percentage (EP, p ≤ 0.01), emergence speed index (ESI, p ≤ 0.01), shoot length (SL, p ≤ 0.001), root length (RL, p ≤ 0.01), stem diameter (SD, p ≤ 0.05) and total dry mass (TDM, p ≤ 0.01) in response to effluent application (Table 6).

For EP, treatments T8 and T9 differed from the control, with T8 means being 18 percentage points lower and T9 means being 17 percentage points higher (Table 6). The other treatments were equal to the control (T1) (Table 6). For ESI, the treatment T8 differed from the control (T1), with a reduction of 25.9% in ESI compared to the control (Table 6). The other treatments were equal to the control (T1) (Table 6).

For SL, the result obtained with treatment T7 was 24.2% higher than that of the control (T1), while the other treatments were equal to the control. For RL, the treatments T8 and T10 obtained results lower than those of the control, respectively,

Table 6. Probability of the F test and means of emergence percentage (EP), emergence speed index (ESI), shoot length (SL), root length (RL), stem diameter (SD) and total dry mass (TDM) of cherry cv tomato seedlings cv. Samambaia produced under different irrigation strategies with saline effluent from fish farming in the phenological stages

Sources of variation	DF	F test (p-value)					
		EP	ESI	SL	RL	SD	TDM
Treatments	9	0.0050	0.0023	0.0001	0.0046	0.0226	0.0064
Coefficient of variation (%)		15.26	14.42	8.39	10.24	10.04	10.08

Treatments and Phenological stage	Means					
	EP (%)	ESI	SL (cm plant^{-1})	RL (cm plant^{-1})	SD (mm plant^{-1})	TDM (mg plant^{-1})
T1 = W1/W2/W3/W4 (Control)	68	2.12	4.05	6.80	0.64	6.72
T2 = W1/E2/E3/E4	64^{ns}	1.97^{ns}	3.80^{ns}	6.05^{ns}	0.73^{ns}	5.27*
T3 = W1/W2/E3/E4	69^{ns}	2.13^{ns}	4.01^{ns}	6.09^{ns}	0.72^{ns}	5.17*
T4 = W1/W2/W3/E4	65^{ns}	2.07^{ns}	3.90^{ns}	6.08^{ns}	0.76^{ns}	5.50*
T5 = E1/W2/E3/E4;	68^{ns}	2.30^{ns}	4.08^{ns}	6.11^{ns}	0.83*	5.57*
T6 = E1/W2/W3/E4	63^{ns}	1.94^{ns}	3.83^{ns}	5.64^{ns}	0.81*	5.15*
T7 = E1/E2/W3/E4	80^{ns}	2.58^{ns}	5.03*	6.25^{ns}	0.75^{ns}	5.57*
T8 = E1/E2/E3/E4	50*	1.57*	3.69^{ns}	5.24*	0.75^{ns}	5.08*
T9 = E/W/W	85*	2.61^{ns}	3.90^{ns}	6.48^{ns}	0.69^{ns}	5.99^{ns}
T10 = E/E/W	74^{ns}	2.22^{ns}	3.61^{ns}	5.28*	0.66^{ns}	5.09*
LSD	16.99	0.54	0.70	1.19	0.15	1.13

DF - Degrees of freedom; LSD - Least significant difference; * and ns - significant and non-significant difference compared to the control treatment by Dunnett's test (p ≤ 0.05), respectively; E - Effluent from fish farming; W – Public-supply water; Phenological stages: growth (1), flowering (2), fruit filling (3) and maturation (4); T9 - One irrigation with E and two irrigations with W, sequentially throughout the cycle; T10 - Two irrigations with E and one irrigation with W sequentially throughout the cycle with reductions of 22.9 and 22.4% in RL, due to the cultivation of cherry tomato with continuous use of the saline effluent, and the other treatments were equal to the control (Table 6). For SD, the values found in treatments T5 and T6 were respectively 29.9 and 26.6% higher than that of the control (T1), and the other treatments were similar to the control (Table 6). For TDM, the treatment T9 was similar to the control (T1), and the values found in treatments T2, T3, T4, T5, T6, T7, T8 and T10 were 21.6, 23.1, 18.2, 17.1, 23.4, 17.1, 24.4 and 24.3% lower than that of the control, respectively (Table 6).

Continuous use of saline effluent throughout the crop cycle (T8), in addition to causing a reduction in seed production (Table 5), also led to the formation of seeds with lower vigor, which according to Silva et al. (2013) are the qualities that give the seed the potential to germinate, emerge and form normal seedlings. According to Demontiêzo et al. (2016), 'Santa Clara' tomato shows a reduction in emergence percentage and emergence speed index under effect of salinity from ECw of 2.5 dS m^{-1}, considered to be the salinity threshold for the crop (Maas & Hoffmann, 1977).

In addition to the effects of high salinity on fruit and seed production, it was found that the effects are passed on to the new generations, which have significant loss of vigor. The effects of salinity can go beyond low fruit and seed production; according to Heslop-Harrison (1987), the number of pollen grains, germination percentage, and pollen tube growth rate are negatively influenced by salinity. These changes are responsible for poor seed formation and, consequently, loss of vigor. According to Pedroso et al. (2009), it has been detected that stress causes a great variability in seed viability and vigor.

The alterations in the metabolism of plants under salt stress are clearly transferred to their offspring, confirmed in the treatment T8, which showed significant reductions in vigor indices, except for SL and SD (Table 6). The decrease in seed vigor, as observed in T8 and other treatments, is presented by Ferreira et al. (2001) as responses of plants to the application of high-ECw solution, resulting in an increase in the concentrations of Na and Cl and, consequently, reduction in K and Ca levels in the various plant organs, including in the reproductive organs such as fruits and seeds. Lacerda et al. (2004) state that K is extremely important to plant metabolism and the maintenance of higher levels is fundamental for higher dry mass production in stress situations.

The treatment T9, despite having reduced seed production due to the application of saline effluent (Table 5), promoted similar or better vigor indices than the control treatment (T1) (Table 5). This behavior of the data indicates that the application of saline effluent from fish farming alternated with two successive irrigations with low-salinity water did not affect the vigor of cherry tomato seeds, which is related to the dilution of salts from the effluent in the substrate by the water of lower salinity (Table 3), thus maintaining the osmotic potential and the ionic equilibrium in the substrate, and consequently lower export of toxic ions to seeds. Thus, the use of this management improves the vigor of tomato seeds and guarantees the water and nutritional support of cherry tomato, with application of saline effluent from fish farming (Nascimento et al., 2016; Almeida et al., 2017).

The treatments T6 and T10 obtained seed production equal to that of the control (Table 5), with EP and ESI equal to those of the control (Table 6). However, the seedlings from these treatments obtained lower biomass accumulations (Table 6), which may have been caused by the low availability of seed reserve tissues (Marcos Filho, 2015).

Conclusions

1. Application of saline effluent from fish farming throughout a phenological stage of cherry tomato does not reduce fruit production per bunch, but reduces seed production and vigor of the seeds produced.
2. The use of saline effluent from fish farming in the initial and maturation stages of cherry tomato, and the use of effluent with two successive applications, alternated with an irrigation with low-salinity water, is favorable to the production of cherry tomato seeds with satisfactory vigor.
3. Alternated application of the saline effluent from fish farming in cherry tomatoes, with two subsequent successive irrigations with low-salinity water, despite reducing seed production, favors the production of seeds with high vigor.
4. The use of saline effluent from fish farming in the flowering and fruiting stages reduces seed production and vigor of the seeds produced.

Literature Cited

Almeida, J. P. N. de; Freitas, R. M. O. de; Nogueira, N. W.; Oliveira, F. de A. de; Ferreira, H.; Leite, M. de S. Production of *Piptadenia stipulacea* (Benth.) Ducke seedlings irrigated with fish farming wastewater. Revista Brasileira de Engenharia Agrícola e Ambiental, v.21, p.386-391, 2017. https://doi.org/10.1590/1807-1929/agriambi.v21n6p386-391

Ashraf, M. Biotechnological approach of improving plant salt tolerance using antioxidants as markers. Biotechnology Advances, v.27, p.84-93, 2009. https://doi.org/10.1016/j.biotechadv.2008.09.003

Brasil. Ministério da Agricultura, Pecuária e Abastecimento. Regras para análise de sementes. Ministério da Agricultura, Pecuária e Abastecimento. Secretaria de Defesa Agropecuária. Brasília, DF: MAPA/ACS, 2009. 395p.

Calvet, A. S. F.; Pinto, C. de M.; Maia-Joca, R. P. M.; Bezerra, A. Crescimento e acumulação de solutos em feijão-de-corda irrigado com águas de salinidade crescente em diferentes fases de desenvolvimento. Irriga, v.18, p.148-159, 2013. https://doi.org/10.15809/irriga.2013v18n1p148

Costa, D. M. A. da; Santos, P. G. dos. Uso de efluente doméstico de lagoa de estabilização no cultivo do amaranto (*Amaranthus spp*). Revista Ciência Agronômica, v.40, p.27-33, 2009.

Demontiêzo, F. L. L.; Aragão, M. F.; Valnir Junior, M.; Moreira, F. J. C.; Paiva, P. V. V.; Lima, S. C. R. V. Emergência e crescimento inicial de tomate 'Santa Clara' em função da salinidade e condições de preparo das sementes. Irriga, Edição Especial, p.81-92, 2016. https://doi.org/10.15809/irriga.2016v1n1p81-92

Diniz, M. T. M.; Pereira, V. H. C. Climatologia do estado do Rio Grande do Norte, Brasil: Sistemas atmosféricos atuantes e mapeamento de tipos de clima. Boletim Goiano de Geografia, v.35, p.488-506, 2015. https://doi.org/10.5216/bgg.v35i3.38839

Ferreira, D. F. Sisvar: A guide for its bootstrap procedures in multiple comparisons. Ciência Agrotecnologia, v.38, p.109-112, 2014. https://doi.org/10.1590/S1413-70542014000200001

Ferreira, R. G.; Távora, F. J. A. F.; Hernandez, F. F. F. Distribuição da matéria seca e composição química das raízes, caule e folhas de goiabeira submetida a estresse salino. Pesquisa Agropecuária Brasileira, v.36, p.79-88, 2001. https://doi.org/10.1590/S0100-204X2001000100010

Heslop-Harrison, J. Pollen germination and pollen-tube growth. International Review of Cytology, v.107, p.1-78, 1987. https://doi.org/10.1016/S0074-7696(08)61072-4

Huang, R. D. Research progress on plant tolerance to soil salinity and alkalinity in sorghum. Journal of Integrative Agriculture, v.17, p.739-746, 2018. https://doi.org/10.1016/S2095-3119(17)61728-3

Lacerda, C. F. de; Cambraia, J.; Oliva, M. A.; Ruiz, H. A. Influência do cálcio sobre o crescimento e solutos em plântulas de sorgo estressadas com cloreto de sódio. Revista Brasileira de Ciência do Solo, v.28, p.289-295, 2004. https://doi.org/10.1590/S0100-06832004000200007

Maas, E. V.; Hoffman, G. J. Crop salt tolerance - Current Assessment. Journal of Irrigation and Drainage Division of ASCE, v.103, p.115-134, 1977.

Maguire, J. D. Speed of germination: aid in selection and evaluation for seedling emergence and vigour. Crop Science, v.2, p.176-177, 1962. https://doi.org/10.2135/cropsci1962.0011183X000200020033x

Maia, J. T. L. S.; Martinez, H. E. P.; Clemente, J. M.; Ventrella, M. C.; Milagres, C. C. Growth, nutrient concentration, nutrient accumulation and visual symptoms of nutrient deficiencies in cherry tomato plants. Semina: Ciências Agrárias, v.40, p.585-598, 2019. https://doi.org/10.5433/1679-0359.2019v40n2p585

Marcos Filho, J. Fisiologia de sementes de plantas cultivadas. 2. ed. Londrina: ABRATES, 2015. 660p.

Nascimento, T. S.; Monteiro, R. N. F.; Sales, M. A. de L.; Floriano, L. S.; Pereira, A. I. de A. Irrigação com efluente de piscicultura no cultivo de mudas de tomate. Revista Brasileira de Agricultura Irrigada, v.10, p.866-874, 2016. https://doi.org/10.7127/rbai.v10n400462

Novais, R. F.; Neves, J. C. L.; Barros, N. F. Ensaio em ambiente controlado. In: Oliveira A. J. (ed.) Métodos de pesquisa em fertilidade do solo. Brasília: Embrapa-SEA. p.189-253, 1991.

Pedroso, T. Q.; Scalco, M. S.; Carvalho, M. L. M. de; Resende, C. A. de; Otoni, R. R. Qualidade de sementes de cafeeiro produzidas em diferentes densidades de plantio e regimes hídricos. Coffee Science, v.4, p.155-164, 2009.

Rhoades, J. D.; Kandiah, A.; Mashali, A. M. The use of saline waters for crop production. Rome: FAO, 1992. 133p.

Santos, A. N.; Silva, Ê. F. de F. e; Silva, G. F. da; Barnabé, J. M. C.; Rolim, M. M.; Dantas, D. da C. Yield of cherry tomatoes as a function of water salinity and irrigation frequency. Revista Brasileira de Engenharia Agrícola e Ambiental, v.20, p. 107-112, 2016. https://doi.org/10.1590/1807-1929/agriambi.v20n2p107-112

Silva, A. C. da; Costa, C. A. da; Sampaio, R. A.; Martins, E. R. Avaliação de linhagens de tomate cereja tolerantes ao calor sob sistema orgânico de produção. Revista Caatinga, v.24, p.33-40, 2011.

Silva, P. F. da; Lima, C. J. G. da S.; Barros, A. C.; Silva, E. M.; Duarte, S. N. Sais fertilizantes e manejo da fertirrigação na produção de tomateiro cultivado em ambiente protegido. Revista Brasileira de Engenharia Agrícola e Ambiental, v.17, p.1173-1180, 2013. https://doi.org/10.1590/S1415-43662013001100007

Turan, S.; Tripathy, B. C. Salt and genotype impact on antioxidative enzymes and lipid peroxidation in two rice cultivars during de-etiolation. Protoplasma, v.250, p.209-222, 2013. https://doi.org/10.1007/s00709-012-0395-5

Viol, M. A.; Carvalho, J. A.; Lima, E. M. de C.; Rezende, F. C.; Gomes, L. A. A. Efeito da salinidade no crescimento e produção do tomate cultivado em ambiente protegido. Revista Brasileira de Agricultura Irrigada, v.11, p.2120-2131, 2017.