Production of watermelon irrigated with saline water in mulched Entisol with potassium fertilization

Produção de melancieira irrigada com água salina em Neossolo com cobertura morta e adubação potássica

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Highlights:
In the Brazilian scenario the Northeast region stands out in watermelon production.
Variations in weather conditions interfere with watermelon yield.
Mulching enhances the yield of watermelon plants.
Irrigation with saline water is feasible for watermelon crop.

Abstract

The adjustment in the growing season associated with cultural practices can mitigate the negative effects of salinity on crop production. In this context, the objective of this study was to evaluate the production components of watermelon cv. Crimson Sweet under the effects of irrigation with saline water, soil cover and potassium doses in crops during dry and rainy seasons. The treatments were arranged in a split plot with 2 x 2 x 4 scheme, with the electrical conductivity of the irrigation water (0.3 and 3.0 dS m^{-1}) in the main plot, and the combinations between soil mulch (without and with) and doses of potassium (0, 40, 80 and 120 kg ha^{-1} of K$_2$O) in the subplots, distributed in randomized blocks. Final stand, number of fruits per plant, average fruit weight, production per plant and yield were evaluated. The data were subjected to analysis of variance and potassium doses were evaluated by regression. In the rainy season, watermelon was more productive than in the dry season even under irrigation, with higher number of fruits and production per plant and yield. Irrigation using water with electrical conductivity of 3.0 dS m^{-1} should be used with moderation in watermelon crop, as it did not compromise yield. Potassium chloride application is not recommended in soil with intermediate potassium content, because it reduced the number of fruits per plant and yield. The use of mulch is recommended in watermelon cultivation, since it increased the number of fruits and production per plant.
Key words: *Citrullus lanatus*. Crimson Sweet. Growing season.

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Resumo

A adequação na época de cultivo associada às práticas culturais pode mitigar os efeitos negativos da salinidade à produção agrícola. Nesse sentido, objetivou-se com esta pesquisa avaliar componentes de produção de melancia cv. Crimson Sweet sob efeitos da irrigação com água salina, cobertura do solo e doses de potássio nos cultivos em épocas de estiagem e chuvosa. Os tratamentos foram organizados em parcela subdividida no esquema 2 x 2 x 4, sendo a condutividade elétrica da água de irrigação (0,3 e 3,0 dS m^{-1}) a parcela principal, e as combinações entre cobertura morta do solo (sem e com) e doses de potássio (0, 40, 80 e 120 kg ha^{-1} de K$_2$O) as subparcelas, distribuídos em blocos casualizados. Avaliou-se o estande final, número de frutos por planta, massa média dos frutos, produção por plantas e produtividade. Os dados foram submetidos as análises de variância e as doses de potássio avaliadas por regressão. Na época chuvosa, a melancieira foi mais produtiva que no período de estiagem mesmo sob irrigação, com maior número de frutos, produção por planta e maior produtividade. A irrigação com água de 3,0 dS m^{-1} de condutividade elétrica pode ser recomendada com moderação na cultura da melancieira, visto que não comprometeu a produtividade. A aplicação de cloreto de potássio não é recomendada em solo com teor médio de potássio, pois reduziu o número de frutos por planta e a produtividade. O uso de cobertura morta é indicado no cultivo de melancieira, uma vez que aumentou o número de frutos e a produção por planta.

Palavras-chave: *Citrullus lanatus*. Crimson Sweet. Época de cultivo.

Introduction

The world watermelon production in 2018 was 103,931,337 tons, with China (60.4%), Iran (4.0%), Turkey (3.9%), India (2.4%) and Brazil (2.2%) as the largest producers (Food and Agriculture Organization of the United Nations [FAOSTAT], 2020). In Brazil, in 2018, 2,240,796 tons of watermelon were produced in 101,975 hectares, with the Northeast region accounting for 36% of this production and, in a national scenario, this region has stood out since 2009 for having the largest harvested area and the highest production (Instituto Brasileiro de Geografia e Estatística [IBGE], 2020). However, the region has one of the lowest yields, which was 19.5 t ha^{-1} in 2018, below the potential of the crop. With the cultivar Crimson Sweet, yields of 19.6 (C. C. Costa, Nóbrega, Barbosa, Cavalcante, & Bezerra, 2018a), 36.0 (Monção, Ribeiro, Moscon, Oliveira, & Nascimento, 2012), 46.2 (Resende & Yuri, 2019) and 50.7 t ha^{-1} (Miranda, Montenegro, & Oliveira, 2005) have been reported in the states of Paraíba, Ceará, Pernambuco and Bahia, respectively, with yield of 87.9 t ha^{-1} in Pará (V. F. A. Silva et al., 2015a). These differences are partly associated with edaphoclimatic variability.

The high spatial-temporal variability of rainfall in northeastern Brazil is a limiting factor, mainly for rainfed agriculture. In this region, the main sources of water, especially in the semi-arid portion, are the dams and aquifers, which often have restrictions caused by excess salts. Increased soil salinity directly affects the availability of water to plants (Ayers & Westcot, 1999; Taiz, Zeiger, Møller, & Murphy, 2017) because of the hygroscopic power exerted by the salts. Excess salts can also have toxic effects, resulting from the continuous absorption and accumulation of these minerals in plants, nutritional effects, due to the imbalance of nutrients in the soil and plant (A. R. F. C. Costa et al., 2018b) and hormonal effects (Taiz et al., 2017). Watermelon is considered moderately sensitive to salinity (Ayers & Westcot, 1999), varying with the cultivar (Zong et al., 2011; A. R. F. C. Costa et al., 2013) and growing conditions (Resende & Yuri, 2019). Excess salts increase plant mortality, reduce the lengths of the main branch and root, as well as fresh biomass, dry biomass and the number of leaves (Ali et al., 2015). Therefore, cultural practices and the use of cultivars less sensitive to salinity can enable the use of lower quality water, without significant losses of yield.

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In the literature, it is observed that soil cover in the watermelon crop is linked to advantages such as a decrease in interspecific competition (M. G. O. da Silva et al., 2013), in water requirement (Saraiva et al., 2018; E. M. P. da Silva, Andrade, Bastos, & Viana, 2015b), phenological development (D. R. M. Silva, Cunha, & Felipe, 2014) and, when plant material is used, in addition to the above-mentioned benefits, it works as a source of nutrients to plants (Amaral, Santos, Oliveira, Carvalho, & Silva, 2016). With the cultivar Pérola, in Belém-PA, Lima and Lopes (2009) found higher number of fruits per plant with the use of soil cover. Dantas, Grangeiro, Medeiros, Cruz and Cunha (2013) obtained higher average fruit weight and yield of watermelon cv. Quetzali when using mulching. For Saraiva et al. (2018), the soil cover with rice husk or white mulching increases yield. R. F. Oliveira et al. (2018) obtained the highest yields of watermelons cv. Crimson Sweet using the cover crops *Brachiaria ruzizienses* and pigeon pea in Boa Vista-RR.

Maintenance of soil fertility through the planning of fertilization programs, adjusting the factors source, dose, time and location of fertilizer application, can also contribute to crop yield. Thus, it is essential to know the mineral needs of the crop. The mineral element most extracted from the soil by the watermelon crop cv. Crimson Sweet is potassium, which is the third most exported macronutrient (Vidigal, Pacheco, Costa, & Facion, 2009). The response to potassium supply is also related to the initial content of this element in the soil (Monção et al., 2012; Nascimento, Souto, Cavalcante, Medeiros, & Pereira, 2017; V. F. A. Silva et al., 2015a) and the source used (A. B. Cecílio & Grangeiro, 2004), and the literature has reported both positive effects (Feltrim et al., 2011; P. G. F. de Oliveira, Moreira, Branco, Costa, & Dias, 2012) and negative effects (L. A. B. Cecílio et al., 2015; Borbo, Isla, & Espinosa, 2018) of potassium fertilization. Over-application of potassium chloride can have a detrimental effect on crop quality, with serious implications for soil productivity and human health (Khan, Mulvaney, & Ellsworth, 2013).

In view of the above, the objective of this study was to evaluate the production components of watermelon cv. Crimson Sweet under the effects of irrigation with saline water, mulching and potassium doses in crops in dry and rainy seasons.

Material and Methods

Two experiments were conducted, the first one in the dry season (September to December 2015) and the second one in the rainy season (January to April 2016), at the Macaquinhos farm (7° 0' 4" South latitude, 35° 47' 54" West longitude and 558 m altitude), in the municipality of Remígio, state of Paraíba, Brazil. The climatic zone where the municipality is located is As' type according to Köppen's classification (Alvares, Stape, Sentelhas, Gonçalves, & Sparovek, 2013) and the soil of the experimental area was characterized as *Neossolo Regolítico* (Entisol).

The treatments were arranged in a split plot in 2 x (2 x 4) scheme, with the electrical conductivity of irrigation water (0.3 and 3.0 dS m^{-1}) in the main plot and the combinations between mulch (without and with) and potassium doses (0, 40, 80 and 120 kg ha^{-1} of K$_2$O) in the subplots, respectively. A randomized block design was used and the experimental unit consisted of one cultivation row with seven plants spaced apart by one meter, under density of 5,000 plants per hectare (Filgueira, 2013).

The chemical (fertility and salinity) and physical attributes of the *Neossolo Regolítico* (Entisol), in the 0-20 cm layer, were characterized according to methodologies compiled by P. C. Teixeira, Donagemma, Fontana and Teixeira (2017) and are presented in Table 1. Fertilization was based on soil analysis and on the recommendations of Cavalcanti (2008). The following amounts were applied: 10 m^3 ha^{-1} of aged cattle manure, 30 kg ha^{-1} of P$_2$O$_5$,

120 kg ha^{-1} of N and, according to the treatments evaluated, 0, 40, 80 and 120 kg ha^{-1} of K$_2$O, and this maximum dose of potassium was based on the highest value recommended by Cavalcanti (2008). The planting holes were prepared with bovine manure, phosphorus in the form of single superphosphate (18% of P$_2$O$_5$, 18% of Ca and 8% of S), 25% of nitrogen in the form of urea (45% N) and one third of potassium in the form of potassium chloride (60% K$_2$O). In the first crop, 10 kg ha^{-1} of zinc sulfate (20% Zn and 9% S) were also applied to prepare the planting holes. The remaining nitrogen and potassium were applied as top-dressing, half at 35 days after sowing and the remainder at 55 days. In the last fertilization, calcium nitrate (15% N and 19% Ca) was applied as nitrogen source in order to increase calcium availability to plants.

Soil tillage consisted of cleaning the area, by manual weeding using a hoe, and opening of the holes at distances of 2 m between rows and 1 m between holes in the rows. The holes were opened with dimensions of 30 x 30 x 30 cm. Sowing was carried out on September 29, 2015, in dry season, and on January 18, 2016, in the rainy season, placing three seeds per hole, and leaving only the most vigorous plant after thinning. The distribution of mulch, obtained from the cleaning of the area and dehydrated in the sun, was carried out in a strip approximately 50 cm wide in the cultivation row of the subplots under the use of mulch on the soil after

plant emergence. Weeds were controlled three times by manual weeding with a hoe. Preventive control of mites and fungi was carried out with spraying of Cuprozeb® (44% of mancozeb and 30% copper oxychloride) at concentration of 200 mg L^{-1} water.

Air temperature and relative humidity (Datalogger, HT-70 from Instrutherm®), rainfall and reference evapotranspiration (Class A pan evaporation x pan coefficient 0.8 (Steduto, Hsiao, Fereres, & Raes, 2012)) were monitored daily. In the dry and rainy seasons, the following values were recorded: average temperatures of 28.6 and 22.6 °C, relative air humidity of 62.3 and 77.4%, accumulated rainfall of 7 and 222 mm, and reference evapotranspiration of 6.1 and 4.4 mm per day, respectively (Figure 1). Irrigation was performed with a dripping tape, Silver Drip model from Golden Tree®, with emitters spaced at 10 cm and flow rate of 0.5 L h^{-1}. Irrigation frequency was daily, and the depth applied was based on the crop coefficients (Santos et al., 2004), on reference evapotranspiration, on the wetting range of 0.5 m (Steduto et al., 2012) and on 94% efficiency of the system. The water used for irrigation was drawn from a surface reservoir with conductivity of 0.3 dS m^{-1}. Saline water was obtained by dissolving ground salt from VitaSal® (59.4% Cl and 38.5% Na) in water from the surface reservoir and measuring the electrical conductivity with a portable conductivity meter (CD-850 model from Instrutherm®).

Table 1
Chemical (fertility and salinity) and physical attributes of the *Neossolo Regolítico* (Entisol), before the cultivation of watermelon cv. Crimson Sweet, at Macaquinhos farm, municipality of Remígio, state of Paraíba, Brazil

Chemical attributes – Fertility[1]

pH	P	K+	Na+	Ca2+	Mg2+	H++Al3+	Al3+	SB	CEC	V	ESP	OM
	mg dm-3	------ cmolc dm-3 ------								----- % -----		g kg-1
6.44	129.11	0.18	0.29	2.20	1.75	0.33	0.0	4.42	4.75	93.1	6.1	10.92

Chemical attributes – Salinity in the saturation extract[2]

pH	ECse	K+	Na+	Ca2+	Mg2+	SO4 2-	CO3 2-	HCO3 2-	Cl-	PS	SAR
	dS m-1	------ mmolc L-1 ------								%	(mmolc L-1)0.5
7.04	0.807	0.77	2.02	5.00	4.38	1.39	0.0	8.25	5.0	16.60	0.93

Physical attributes[3]

Sand	Silt	Clay	WDC	DF	BD	PD	TP	Moisture 0.01 MPa	Moisture 1.5 MPa	Available water
------ g kg-1 ------					--- g cm-3 ---		m3 m-3	------ g kg-1 ------		
858	83	59	0	1000	1.53	2.57	0.40	77.48	27.66	49.82

[1]pH (hydrogen potential) in water; P (phosphorus), K+ (potassium) and Na+ (sodium) with Mehlich-1 extractant; Ca2+ (calcium), Mg2+ (magnesium) and Al3+ (aluminum) with 1 M KCl extractant; H+ + Al3+ (hydrogen plus aluminum) with 0.5 M calcium acetate extractor at pH 7.0; SB (sum of bases) = K+ + Na+ + Ca2+ + Mg2+; CEC (cation exchange capacity) = SB + H+ + Al3+; V (base saturation) = (SB/CEC) x 100; ESP (exchangeable sodium percentage) = (Na+/CEC) x 100; OM (organic matter) = organic carbon x 1.724, Walkley-Black method; [2]ECse (electrical conductivity of soil saturation extract); SO4 2- (sulfate); CO3 2- (carbonate); HCO3 2- (bicarbonate); Cl- (chloride); PS (percentage of soluble sodium) = 100 x Na+/(K+ + Na+ + Ca2+ + Mg2+); SAR (sodium adsorption ratio) = Na+/[0.5(Ca2+ +Mg2+)]0.5; [3]Granulometry by the pycnometer method, 1 M NaOH dispersant; WDC (water-dispersible clay); DF (degree of flocculation) = ((total clay – WDC)/total clay) x 100; BD (bulk density); PD (particle density); TP (total porosity) = (PD – BD)/PD.
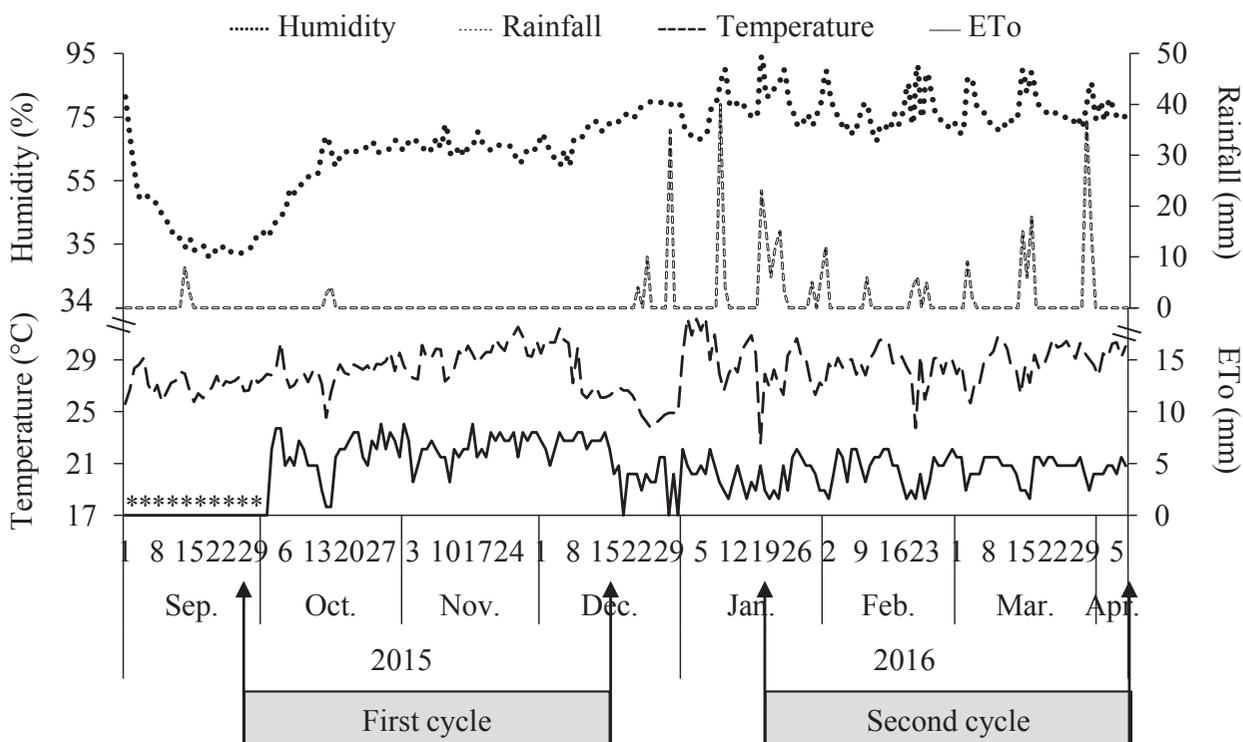
Figure 1. Daily mean values of air temperature and relative humidity, rainfall and reference evapotranspiration (ETo) at Macaquinhos farm, municipality of Remígio, state of Paraíba, Brazil. ********: data not available.

The production components were: final stand, obtained by quantifying the number of live plants in the harvest period; number of fruits (NF) per plant, relationship between harvested fruits and number of plants in the plot; average fruit weight (AFW), relationship between total production (kg) of fruits and number of fruits in the plot; production per plant (PP), product between number of fruits per plant and average fruit weight; and yield (Y), obtained by multiplying production per plant by the final stand.

Homogeneity of residual variances between growing seasons was analyzed using Hartley's test. Under homogeneous residuals between growing seasons, the analyses were carried out jointly, using analysis of variance to assess the effects of the factors. Quantitative effects of potassium doses were evaluated by linear regression, using the F test ($p \leq 0.10$) to verify the fit of the models (Pimentel-Gomes, 2009). Analyses were performed using the software program SAS® University Edition.

Results and Discussion

The residual variances between growing seasons for the number of fruits per plant, average fruit weight, production per plant and yield were homogeneous, based on the F test of Hartley ($p \leq 0.05$), and the analyses of variances of these variables were performed jointly (Table 2). The final stand was analyzed by growing season, due to the lack of homogeneity of residual variances between the growing seasons.

The stands at the end of the crops were 4,844 plants per hectare in the dry season and 4,330 plants per hectare in the rainy season, respectively representing reductions of 3 and 13% in the initial density of 5,000 plants per hectare (Table 2). In the dry season, there was no effect of the studied factors, while in the rainy season the potassium doses factor and its interaction with the electrical conductivity of irrigation water were significant. In

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this period, a difference for the final stand, in relation to the electrical conductivity of irrigation water, was obtained only under the K_2O dose of 120 kg ha^{-1}, when the use of 0.3 dS m^{-1} water caused reduction of 10% compared to the water of 3.0 dS m^{-1} (Figure 2). As for potassium doses, in areas irrigated with 0.3 dS m^{-1} water, there was a reduction of 1% in the final stand with each increment of 10 kg ha^{-1} of K_2O. In areas irrigated with 3.0 dS m^{-1} water, the increase in potassium doses also reduced the final stand, with the largest reduction of 17% obtained under the K_2O dose of 63 kg ha^{-1}, but the increase in potassium application beyond this dose contributed to obtaining a larger stand.

Smaller final stand in the rainy season compared to the cultivation in the dry season may be associated with higher intraspecific competition; because environments or periods with higher relative air humidity promote the development of more vigorous branches and accelerate the production of leaves (A. H. de C. Teixeira, 2014), as observed in the cultivation of the rainy season. In this same context, the reduction in the stand is justified by application of potassium, as the increase in the doses of this macronutrient favors the growth of plants, increasing competition. High doses of potassium can also reduce plant growth, as observed by Sousa, Coelho, Souza and Holanda (2005) in melon. Reduction in the population, up to a certain limit, may favor fruit production and yield of watermelon (L. A. B. Cecílio et al., 2015).

The number of fruits per plant was affected by potassium doses, growing season and mulching, individually, and by the interaction between these last two factors (Table 2). Fruit yield as a function of potassium doses was evaluated in the interaction between growing season and mulch. In the dry period, the effect of potassium was observed only in areas without mulch, reducing the number of fruits per plant by 1% for each 10 kg ha^{-1} of K_2O (Figure 3A). In the rainy season, regardless of the mulch, the increase of 10 kg ha^{-1} of K_2O reduced the number of fruits per plant by 2% (Figure 3B). There was also an average increase from 0.9 to 1.4 fruits per plant, equivalent to 56%, between the crops in the dry season and rainy season, respectively. In the rainy season, the use of mulch promoted an average increase of 17% in the number of fruits per plant.

Table 2
Homogeneity tests ($F_{Hartley}$) between the residual variances of the growing seasons and summary of analyses of variance for final stand (FS), number of fruits per plant (NF), average fruit weight (AFW), production per plant (PP) and yield (Y) of watermelon cv. Crimson Sweet under the effects of electrical conductivity of irrigation water (ECiw), mulching (ML), Potassium (K) and growing season (GS)

Homogeneity test		FS^1	FS^2	NF	AFW	PP	Y
		$F_{Hartley} = \sigma^2_{max}/3\sigma^2_{min}$					
		------ 5.27** -----		0.92^{ns}	0.55^{ns}	0.57^{ns}	0.75^{ns}
Sources of variation	DF	Mean Square					
Block/GS	5	520833*	414541^{ns}	0.0614^{ns}	13.1327**	5.77^{ns}	153.33^{ns}
ECiw	1	127551^{ns}	95663^{ns}	0.0000^{ns}	5.3033^{ns}	2.16^{ns}	369.19^{ns}
GS	1	-	-	4.5373**	15.3220*	262.82**	3292.19**
ECiw x GS	1	-	-	0.0269^{ns}	12.5316*	15.67*	123.15^{ns}
Residual (a)	5	21259	2582908	0.0588	1.1634	1.96	129.52
ML	1	31888^{ns}	265731^{ns}	0.7241**	0.0002^{ns}	33.76**	83.64^{ns}
K	3	95663^{ns}	1201105**	0.2443**	3.8142*	0.523^{ns}	123.71^{ns}
ECiw x ML	1	$0,0000^{ns}$	95663^{ns}	0.0612^{ns}	0.1370^{ns}	2.097^{ns}	41.53^{ns}
ECiw x K	3	403912^{ns}	1257795**	0.0271^{ns}	0.3385^{ns}	0.37^{ns}	72.92^{ns}
ML x K	3	223214^{ns}	67319^{ns}	0.0345^{ns}	0.0608^{ns}	2.48^{ns}	67.29^{ns}
ML x GS	1	-	-	0.2669*	0.6142^{ns}	5.69^{ns}	48.48^{ns}
K x GS	3	-	-	0.0828^{ns}	0.7691^{ns}	2.88^{ns}	145.48^{ns}
ECiw x ML x K	3	63773^{ns}	294076^{ns}	0.0439^{ns}	0.2448^{ns}	1.94^{ns}	31.27^{ns}
ECiw x ML x GS	1	-	-	0.0237^{ns}	0.1238^{ns}	2.61^{ns}	45.03^{ns}
ECiw x K x GS	3	-	-	0.0030^{ns}	0.3667^{ns}	0.31^{ns}	21.84^{ns}
ML x K x GS	3	-	-	0.0598^{ns}	0.3009^{ns}	2.74^{ns}	166.37*
ECiw x ML x K x GS	3	-	-	0.0290^{ns}	0.1042^{ns}	0.96^{ns}	68.47^{ns}
Residual (b)	70	155643	211067	0.0503	1.1115	3.21	55.58
CV(a) (%)		3.01	37.12	21.66	17.09	19.99	34.91
CV(b) (%)		8.14	10.61	20.02	16.71	25.59	22.87
Means		4,844	4,330	1.1	6.3	7.0	32,268.3
		plants per hectare	fruits	kg	kg	kg ha^{-1}	

[1]Data collected in the cycle conducted in the dry season, with degrees of freedom of Block, Residual (a) and Residual (b) of 3, 3 and 42, respectively;
[2]Data collected in the cycle conducted in the rainy season, with degrees of freedom of Block, Residual (a) and Residual (b) of 2, 2 and 28, respectively;
ns, ** and *: not significant and significant at 5 and 1% probability levels by F test, respectively.
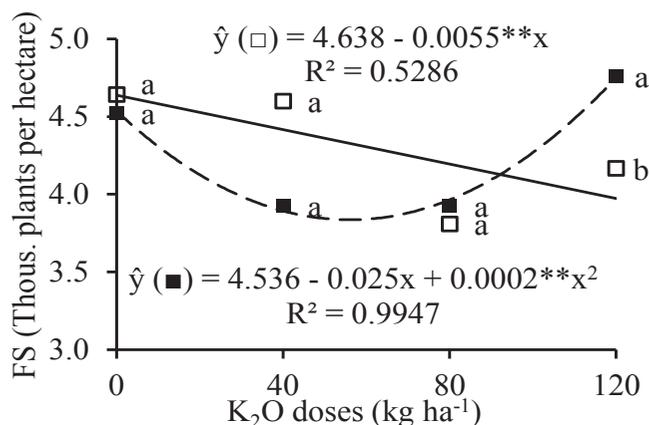
Figure 2. Final stands (FS) of populations of watermelon cv. Crimson Sweet, cultivated in the rainy season, as a function of potassium doses and irrigation using water with electrical conductivity of 0.3 ($\square$, —) and 3.0 ($\blacksquare$, ---) dS m^{-1}. Means followed by the same letter, within each potassium dose, do not differ by F test (p $\leq$ 0.05); **: significant at 1% probability level by F test.
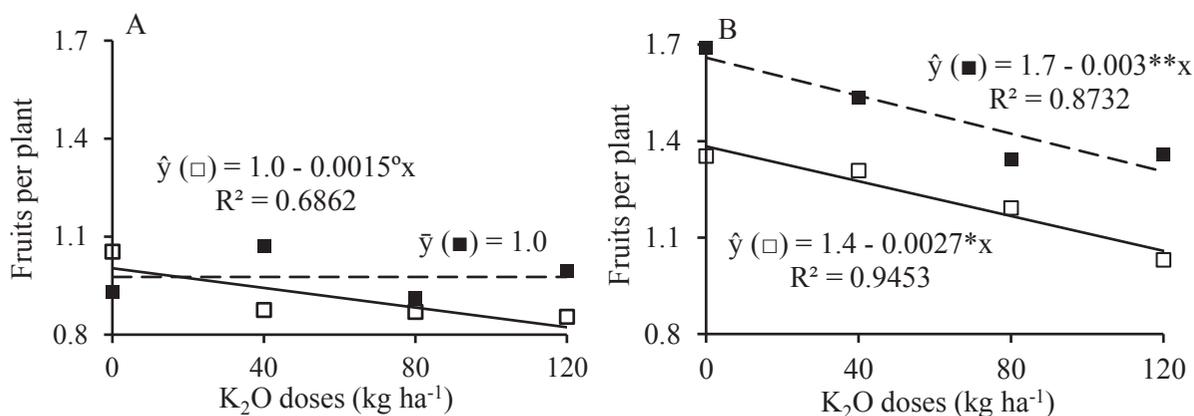
Figure 3. Number of fruits in watermelon cv. Crimson Sweet, cultivated in dry (A) and rainy (B) seasons in areas without ($\square$, —) and with ($\blacksquare$, ---) mulch, as a function of potassium doses. º, * and **: significant at 10%, 5% and 1% probability levels, respectively, by F test.

The reduction in the number of fruits per plant caused by potassium may be related to the initial content of this macronutrient (0.18 cmol$_c$ dm^{-3}) in the *Neossolo Regolítico* (Entisol) of the present study, considered as an intermediate content (Raij, 2011), which can also be influenced by the type of soil. In *Latossolo Amarelo* (Oxisol) with intermediate potassium content (V. F. A. Silva et al., 2015a) and in *Neossolo Flúvico* (Entisol) with high potassium content (Nascimento et al., 2017), there were no effects of potassium doses on the number of fruits of Crimson Sweet. Conversely, A. B. Cecílio and Grangeiro (2004), in *Argissolo Vermelho-Amarelo* (Ultisol) with low potassium content, observed an increase in the number of fruits per plant as potassium doses increased, and the effects are also related to the source used. The influence of mulching is related to the nutritional quality of the

material that will provide nutrients (Amaral et al., 2016). Lima and Lopes (2009) observed a higher number of fruits in watermelon plants cv. Pérola in soil covered with straw and coconut fiber and lower values in soil without cover and with plastic film. Dantas et al. (2013) also found no effect of mulching on Quetzali watermelon. However, D. R. M. Silva et al. (2014) found better development (higher production of branches, internodes and fixed flowers) of watermelon plants when using straw and mulch (black polyethylene film). The results of mulching are related to weather conditions, as observed in the present study, as they directly interfere in the performance of the crop, altering metabolism and interfering in field activities, including the number of fruits in watermelon plants (A. B. Cecílio & Grangeiro, 2004).

The average fruit weight was affected by potassium doses and growing season, individually,

and by the interaction of the latter factor with the electrical conductivity of irrigation water (Table 2). The fits as a function of potassium doses were evaluated within the interaction. In the dry season, under irrigation with non-saline water, the increase in potassium doses led to an increase of 102 g in the average fruit weight for each 10 kg ha^{-1} of K_2O applied, that is, it increased from 5.9 to 7.1 kg under the K_2O doses 0 and 120 kg ha^{-1}, respectively (Figure 4A). In the rainy season regardless of water salinity (Figure 4B) and in the dry season under irrigation with saline water (Figure 4A), no effect of potassium was observed. It is also worth pointing out that the increase in irrigation water salinity from 0.3 to 3.0 dS m^{-1}, in the dry season, reduced fruit weight on average by 17% (6.5 to 5.4 kg, respectively), an effect that did not occur in the rainy season, when the average fruit weight was 6.8 kg.

Figure 4. Average fruit weight of watermelon cv. Crimson Sweet, cultivated in the dry (A) and rainy (B) seasons and irrigated using water with electrical conductivity of 0.3 (□, —) and 3.0 (■, ---) dS m^{-1}, as a function of potassium doses. *: significant at 5% probability level by F test.

Several factors interfere in the tolerance of plants to salinity, and there are differences between species of the same genus and even between cultivars of the species, in addition to environmental factors. For Zong et al. (2011), with melon cultivar Huanghe melon-3 and watermelon cultivar Seed melon-1, water with electrical conductivity of 6.1 dS m^{-1}

did not reduce fruit weight. A. R. F. C. Costa et al. (2013), in *Argissolo Vermelho-Amarelo* (Ultisol) irrigated with water of up to 4.9 dS m^{-1}, observed greater reductions in the fruit weight Quetzali followed by Leopard, finding no effect for the cultivar Shadow. The effects of salinity are also related to management, which is influenced by

edaphoclimatic conditions, because periods of higher water demand require greater irrigation depth, increasing salinity in the soil via irrigation water. A. B. Cecílio and Grangeiro (2004), using the watermelon hybrid Tide, obtained higher average fruit weight in the spring compared to the summer. Conversely, in the present study difference between growing seasons was observed only under management with saline water, with lower average weight in the dry season due to higher irrigation depth. The average fruit weight of Crimson Sweet is little influenced by potassium fertilization when it is grown in soil with intermediate potassium content. V. F. A. Silva et al. (2015a), in *Latossolo Amarelo* (Oxisol) with 0.18 $cmol_c$ dm^{-3} of K and Nascimento et al. (2017), in *Neossolo Flúvico* (Entisol)with 0.40 $cmol_c$ dm^{-3} of K, found no response in the average fruit weight to the application of up to 200 and 30 kg ha^{-1} of K_2O, respectively. Differently, Monção et al. (2012), in *Latossolo Amarelo* (Oxisol) with 0.02 $cmol_c$ dm^{-3} of potassium, obtained higher average weight without potassium application.

The production per plant was affected by the single factors mulching and growing season, and the interaction of the latter factor with the electrical conductivity of irrigation water was also significant (Table 2). The responses as a function of potassium doses were not significant for production per plant. In the dry season, production was reduced from 6.2 to 5.2 kg per plant as the electrical conductivity of irrigation water increased from 0.3 to 3.0 kg dS m^{-1}, representing a loss of 16% or 1 kg per plant (Figure 5A). In the rainy season, there was no difference between irrigation waters, with an average of 8.8 kg per plant. In the rainy season, watermelon plants produced more than in the dry season, with increments of 2.3 kg per plant (37%), under irrigation with water of 0.3 kg dS m^{-1}, and 3.8 kg per plant (73%), in areas irrigated with 3.0 dS m^{-1} water, for cultivation in dry season and rainy season, respectively. Regarding the use of mulch, it was observed that this practice increased the production per plant to 7.5 kg compared to the 6.5 kg obtained without mulch, with an estimated gain of 15%, that is, average increase of 1 kg per plant (Figure 5B).
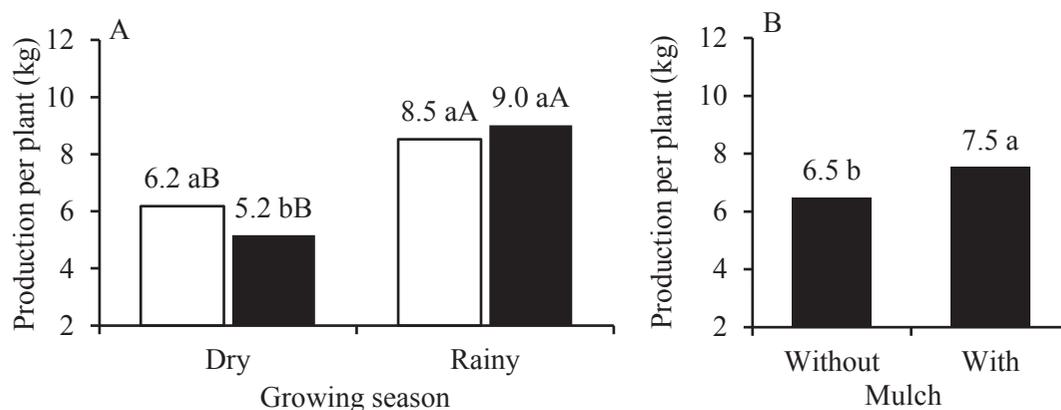
Figure 5. Production of watermelon cv. Crimson Sweet, irrigated using water with electrical conductivity of 0.3 (□) and 3.0 (■) dS m^{-1} cultivated in dry and rainy seasons (A), and in areas without and with mulch (B). Means followed by the same letter, lowercase between levels of electrical conductivity of irrigation water or mulch and uppercase between growing seasons, do not differ by F test (p ≤ 0.05).

Production per plant is directly related to the number of fruits per plant and the average fruit weight, and changes even in one of these components can change the variable. The magnitude of the differences between production per plant and yield depends on the final stand. The effects of salinity are linked, in addition to the specific tolerance of crops and/or cultivars, to both the electrical conductivity of irrigation water and the volume of water applied. In the watermelon cultivar melon-1, electrical conductivity of irrigation water up to 6.12 dS m^{-1} did not reduce the number of fruits per plant and yield (Zong et al., 2011), whereas for Shadow, Quetzali and Leopard the reduction was observed from the water of 0.57 dS m^{-1} (A. R. F. C. Costa et al., 2013). Increased salinity reduces osmotic potential (Ayers & Westcot, 1999), leading to higher energy expenditure for absorbing the soil solution, also resulting in lower nutrient absorption by watermelon plants (A. R. F. C. Costa et al., 2018b). As the effects of growing season on the production per plant followed the same trend observed in the average fruit weight, this behavior is attributed mainly to the higher rainfall. Rainfall improves soil moisture distribution, besides promoting lower salt addition via irrigation water.

Watermelon yield was influenced by the growing season, individually, and by the interaction between this factor with mulching and potassium doses

(Table 2). In the dry season, there was no effect of potassium doses (Figure 6A). In the rainy season, yields were reduced by 1.0 t ha^{-1} (2%), areas without mulch, and by 0.5 t ha^{-1} (1%), in areas with mulch, for each application of 10 kg ha^{-1} of K$_2$O (Figure 6B). The average yield gain from the dry season to the rainy season was 10 t ha^{-1} (14%), and mulching also contributed to the increase in watermelon yield, with more intensity during the dry season (12%) than in the rainy season (5%). Responses to potassium doses are related, among other factors, to its availability in the soil. In *Latossolo Amarelo* (Oxisol) with 0.02 cmol$_c$ dm^{-3} of K, the highest yield was obtained at K$_2$O dose of 55 kg ha^{-1} (Monção et al., 2012), while under concentration of 0.18 cmol$_c$ dm^{-3} doses up to 200 kg ha^{-1} of K$_2$O did not affect watermelon yield (V. F. A. Silva et al., 2015a). Nascimento et al. (2017), in *Neossolo Flúvico* (Entisol) with 0.40 cmol$_c$ dm^{-3} of K and under application of 1.1 kg of cattle manure in the hole, observed a reduction in watermelon yield with K$_2$O doses above 20 kg ha^{-1}. The literature reports higher yields in watermelon under lower doses of potassium (L. A. B. Cecílio et al., 2015; Borbo et al., 2018), as well as gains under higher doses (P. G. F. de Oliveira et al., 2012), and the production response is related to both the applied doses and sources of this macronutrient (A. B. Cecílio & Grangeiro, 2004).
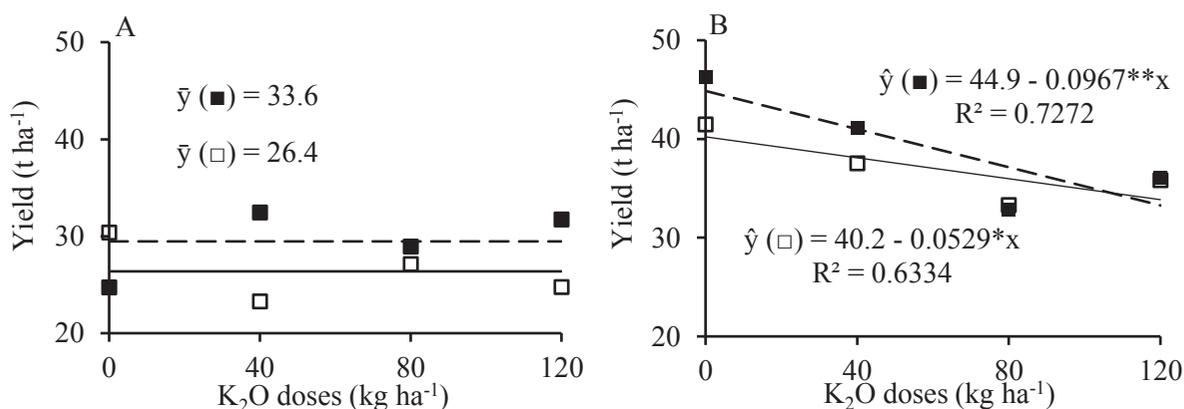
Figure 6. Yield of watermelon cv. Crimson Sweet, cultivated in dry (A) and rainy (B) seasons in areas without (□, —) and with (■, ---) mulch, as a function of potassium doses. * and **: significant at 5 and 1% probability levels by F test, respectively.

During the study, relative air humidity and rainfall were the environmental factors that varied the most, being lower in the dry season and higher in the rainy season (Figure 1). Lower water availability reduces the growth, leaf area and consequently the yield of watermelon (Najafabadi, Soltani, Noory, & Díaz-Pérez, 2018), and the irrigation depth is decisive for crop yield (P. G. F. de Oliveira et al., 2012; Abdelkhalik et al., 2019). Therefore, supplementary irrigations are essential to maintain adequate water availability, especially in regions with long drought periods. In the State of São Paulo, the highest yield of the Tide hybrid was obtained in the period with the highest rainfall (A. B. Cecílio & Grangeiro, 2004), while in the city of Mossoró-RN the watermelons were more productive when sown in August (J. B. de Oliveira, Grangeiro, Espinola, Moura, Carvalho, 2015). However, performance is also dependent on the material used (Resende & Yuri, 2019). Soil cover can also contribute to yield. According to M. G. O. da Silva et al. (2013), soil cover increases watermelon yield and can be performed with plastic film, but the gain is higher when using straw from corn intercropped with *Brachiaria brizantha*. Conversely, Saraiva et al. (2018) observed no differences between soil cover with rice husk or white mulching, but obtained higher yield and water use efficiency when compared to soil without cover.

Conclusions

Even under irrigation, watermelon is more productive in the rainy season than in the dry season, with a higher number of fruits, production per plant and yield;

Irrigation using water with electrical conductivity of 3.0 dS m^{-1} in *Neossolo Regolítico* (Entisol) can be used for watermelon crop, as it did not compromise yield;

Application of potassium chloride is not recommended in *Neossolo Regolítico* (Entisol) with 0.18 cmol$_c$ dm^{-3} of potassium, as it reduces the number of fruits per plant and yield;

The use of mulch is recommended in watermelon cultivation, since it increased the number of fruits and production per plant.

Acknowledgments

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