Effect of preharvest application of Silicon and saline water on postharvest quality of beet (*Beta vulgaris* L.)

José Sebastião de Melo Filho [1], Toshik Iarley da Silva [2], Ygor Henrique Leal [1], Ana Gabriela Sousa Basilio [1], Mário Leno Martins Véras [2] and Thiago Jardelino Dias [1]

1 Federal University of Paraíba (UFPB), Areia, PB, Brazil

[2] Federal University of Viçosa (UFV), Viçosa, MG, Brazil

Author's contributions

This work was carried out in collaboration with all authors. Authors JSMF and TIS designed the study, performed statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Author's MLMV and YHL managed bibliographic searches. Author AGSB, TJD transcribed the final version, placed it in the journal's rules and was responsible for submitting it to the publication. Authors TJD and JSMF managed the analyzes of the study as well as the work. All authors read and approved the final manuscript.

ABSTRACT

Beet is one of the vegetables richest in nutrient (bioactive compounds, folic acid and potassium). However, there are few studies on postharvest quality from the crop under irrigation conditions with saline waters, and because of that, the objective of this study was to evaluate effect of saline waters and silicon application in the preharvest on physicochemical quality of the beet. Two experiments were conducted with the objective of evaluating two forms of silicon application: via foliar (experiment 1) and via soil (experiment 2) about its influence in mitigating salt stress. In both experiments was adopted a randomized design with blocks in a 5 x 5 factorial, referring to five levels of electrical conductivity of the irrigation water (ECw): (0.5, 1.3, 3.25, 5.2 and 6.0 dS m^{-1}) five doses of silicon (0.00; 2.64; 9.08; 15.52 and 18.16 mL L^{-1}), they were combined according to the experimental matrix Central composite of Box totaling 10 treatments, with four replicates and three plants per plot. After harvesting, 70 days after transplanting, the following characteristics were evaluated: bulb dry mass, pH, titratable acidity (TA), total soluble solids (TSS), TSS/TA ratio and ash. There was a significant effect for the salinity x silicon (Si) interaction applied via soil to the dry matter mass and titratable acidity. The electrical conductivities of irrigation water (ECw) and Si doses via leaf and soil influenced significantly for analyzed variables, except pH, total soluble solids, TSS/TA ratio, ash and titratable acidity, which were not influenced by ECw and nor by the doses of Si via soil and foliage. Irrigation with water of 6.0 dS m^{-1} promotes better quality beet tuber. The fertilization on preharvest with silicon via soil or foliage improved postharvest quality of beet.

Keywords: *Beta vulgaris* L. Potassium silicate. Salt stress.

1. INTRODUCTION

In recent years soil salinization has been a major agricultural concerns, especially in arid and semi-arid regions [1], since in these regions besides the low rainfall and rainfall irregularity, there are still low-quality of water available for irrigation, then farmers use saline water [2], as in the case of producers of vegetables, especially beets.

Although salinity negatively interfere with the growth and development of crops, studies show that the salinity promotes higher quality postharvest of fruits and vegetables, as an example [3], working with watermelon they verified that the increase in the electrical conductivity of the irrigation water (ECw) from 2.77 to 4.91 dS m^{-1} increased the soluble solids content. In cucumber, [4] also found soluble solids content and titratable acidity increased. The same was observed in tomato crops, where [5] found that use of water with salinity from 2.0 to 3.5 dS m^{-1} increases the quality of tomato by increasing the TSS/TA ratio.

On the other hand, despite the increased quality of fruits and vegetables with the use of irrigation with saline water, crop productivity is reduced under salinity conditions. Restrictions on growth are observed due to the interaction of salts with nutrients in the soil, promoting imbalances in the plant nourishment [6; 7]. Thus, the accumulation of ions in tissues for long periods can cause injury and death of the plant [8].

One of the strategies to mitigate the salt deleterious effects is the application of substances that mitigate these effects, one of them is silicon [9; 10; 11; 12; 13]. Although considered a non-essential element, silicon is a beneficial element, which has the ability to reduce the impact of stressor agents [14]. Studies evidence that the supply of silicon increases crops growth, since this element indirectly acts on some photosynthetic and biochemical aspects, especially in plants under some sort of stress [15; 16; 17]. Furthermore, the increase in postharvest quality of vegetables with silicon application has been verified, such as lettuce [18] and strawberry [31].

Due to the scarcity in studies vising the effect of irrigation with saline water on postharvest quality of beet tuber, this study aimed to evaluate the effect of saline water and silicon application on physicochemical quality of beet.

2. MATERIAL AND METHODS

Experimental location

Two experiments were conducted in a greenhouse located in the Fruit sector belonging to the Federal University of Paraíba, municipality of Areia-PB, Brazil, located in the geographical coordinates 6º51'47" and 7º02'04" South latitude and West longitude 35º34'13 "and 35º48'28" of the Greenwich meridian.

Experimental design

These experiments were conducted in order to assess two types of silicon application which were via foliar (experiment 1) and via soil (experiment 2) and their influence as a possible salt stress attenuating. Experiment 1 was conducted from August to October 2017 and experiment 2 from January to March 2018. In the experiments were adopted the experimental design with randomized blocks of factorial 5 x 5 combined according to the experimental matrix Central Compound of Box [19], referring to the electrical conductivity of irrigation water (ECw) and silicon doses (Si) with minimum values (- α) and maximum (α), respectively 0.5 to 6.0 dS m^{-1} and from 0.00 to 18.16 mL L^{-1}, totaling nine treatments, with four replicates and three plants per portion.

Beet seedlings cv. Wonder were grown in trays and planted in pots of 22 cm diameter, 16 cm in bottom diameter and 18 cm high, with a volumetric capacity of 8 dm 3, and circular holes of 1 cm diameter on its bottom face, with purpose of allowing better root aeration and percolation of excess water.

The pots were filled with horizon soil A, collected at the depth of 0-20 cm, classified as Planossolo Háplico Eutrófico êndico/Alfisol [20], the physicochemical characteristics (Table 1) were analyzed according to the methodology of [20], respectively. The soil was air dried previously and properly homogenized, and placed in vessels accommodated previously screened (tulle fabric) and 200 g of crushed rock to prevent soil output by the vessels inferior orifices.

Table 1: Physicochemical characteristics of the soil used in the experiment.

Chemicals attributes		Physicals attributes	
pH	6.26	Ds	1.38
P (mg dm^{-3})	11.35	Pd	2.67
K^+ (mg dm^{-3})	40	Tp	0.48
Na^+ (cmol dm^{-3})	0.22	CC	78
H+Al (cmol dm^{-3})	1.82	PMP (g g^{-1})	43
Al^{+3} (cmol dm^{-3})	0	Sand (g kg^{-1})	756.9
Ca^{+2} (cmol dm^{-3})	3	Silt (g kg^{-1})	59.1
Mg (cmol dm^{-3})	1.9	Clay (g kg^{-1})	184
BS (cmol dm^{-3})	5.22	-	-

CEC (cmol dm^{-3})	7.03	-	-
V (%)	74.34	-	-
M (%)	0	-	-
OM (g Kg^{-1})	17.53	Textural classification	Sandy franc

Base sum (BS) = (Na^{+}+K^{+}+Ca^{2+} + Mg^{2+}); CEC = cation exchange capacity; EC = BS + (H^{+} + Al^{3+}); V = (100 x SB/CTC); OM = organic matter. Ds = density of the soil; Pd = particle density; Tp = total porosity; (1- (Ds / Dp) * 100) Ucc =volumetric humidity level of field capacity - 0.033 MPa; Upmp = humidity level of the permanent wilting point - 1.5 MPa.

The plants were irrigated daily, at the beginning raising the soil moisture around 80% of the field capacity (CC). The different ECw were obtained using the NaCl, $CaCl_2.2H_2O$ e $MgCl_2.6H_2O$ salts, in the proportion of 7: 2: 1 according to the characteristics presented in Table 2. Irrigation with the water sources of different salinities was started 10 days after the emergence. In the first DAE, the slide was calculated by the equation proposed by [21]. The total required irrigation (ITN), in mm, was calculated by the equation of [22], considering 100% efficiency of irrigation application.

Table 2: Chemical characteristics of the waters used in the experiment

	Electric conductivity (dS m^{-1})				
Attributes	0.50	1.30	**3.25**	**5.20**	**6.00**
	Values				
pH	7.00	7.50	7.40	7.30	7.40
$SO4^{-2}$	3.22	3.70	3.67	3.35	3.90
Mg^{2+}	1.33	1.78	1.93	2.03	2.98
Na^{+}	1.70	5.92	12.57	20.5	24.20
K^{+}	0.20	0.21	0.20	0.20	0.21
Ca^{2+}	0.73	1.58	1.78	1.88	2.53
CO_3^{-2}	0.00	0.00	0.00	0.00	0.00
HCO_3-$^{-}$	2.75	3.50	4.00	4.25	4.25
Cl^{-}	3.40	10.90	30.40	48.90	58.15
SAR (mmol L^{-1}) $^{0.5}$	1.28	1.87	2.60	3.23	2.96
Classification	*C2S1*	*C3S3*	*C4S4*	*C4S4*	*C4S4*

EC= electrical conductivity at 25 °C; SAR = sodium adsorption ratio [$Na^{+}/(Ca^{2+}+Mg^{2+}/2)^{1/2}$]; CO_3^{2-} = Absent. Water classification acording [23].

Silicon was applied as liquid potassium silicate (K_2SiO_3) with 12% Si and 15% K_2O. In the first experiment, Si doses were applied through a hand sprayer and in the second experiment the application was carried out directly in the vessels. In these experiments, there was compensation of K_2O via foliar and via soil in the applications used in beets with the purpose of supplying the same amount of potassium for all plants. The silicon application was done weekly, totaling 7 applications during the beet cycle. The doses of (Si) were diluted in 1.2 L of distilled water and 50 ml of this solution was applied to each plant according to the each via of application.

During the experiments conduction, the atmospheric data (Figure 1) were recorded daily with the HT-600 Instruthermr® digital thermohygrometer installed inside the experimental area, at plants height. In both experiments, mean temperature and weather values were close to the ideal range (25 °C) during the crop cycle, according to [24].

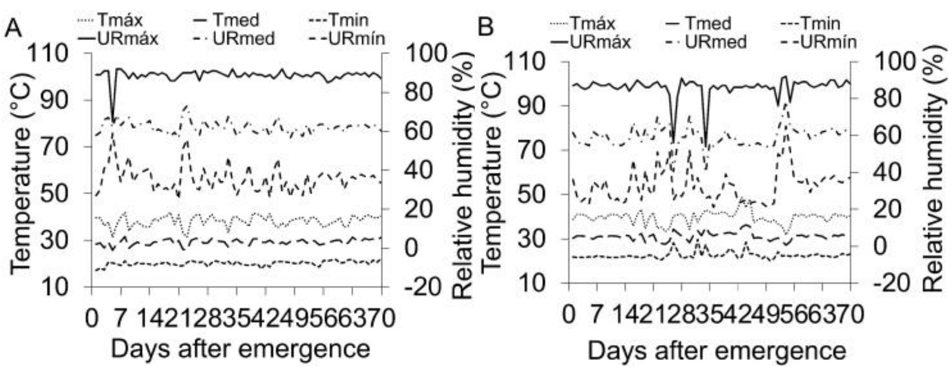

Figure 1: Graphical representation of the relative air humidity and temperature in the experiments conduction period, experiment 1 (A) and experiment 2 (A). Air maximum temperatures (Tmax), mean (Tmeas) and minimum (Tmin) in ° C; maximum relative humidity of the air (URmáx), mean (URmed) and minimum (URmin) in%.

Cover and fertilization of the plantation were done with 40, 180 and 90 kg ha^{-1} of NPK, respectively, with urea, simple superphosphate, and potassium chloride according to the chemical analysis of the soil and fertilization recommendation for the state of Pernambuco, Brazil [25]. Phytosanitary controls of pests and weeds were carried out during the experiment.

Determination of physico-chemical parameters

After harvesting, 70 days after transplanting, the following characteristics were evaluated: bulb dry mass, pH, titratable acidity (TA), total soluble solids (TSS), TSS/TA ratio and ash.

Dry matter mass was obtained after weighing the bulb in an analytical balance, after drying in oven at 65ºC; pH was measured with bench PH meter; the titratable acidity (g pulp 100 g^{-1} citric acid), by titration of the juice with NaOH a 0,1 M solution; Soluble solids content, determined with digital refractometer; the TSS/TA ratio was through division; for ash determination, the methodology of the [26] was adopted, from the incineration in muffle for 6 hours at a temperature of 550 °C.

Data analysis

The obtained data were submitted to analysis of variance and polynomial regression, and the mixed model (MIXED) was used for the repeated evaluations in time using the statistical software SAS® University [27].

3. RESULTS AND DISCUSSION

There was a significant effect for the salinity x silicon (Si) interaction applied via soil to the dry matter mass and titratable acidity. The electrical conductivities of irrigation water (ECw) and Si doses via leaf and soil influenced significantly for analyzed variables, except pH, total soluble solids, TSS/TA ratio, ash and titratable acidity, which were not influenced by ECw and nor by the doses of Si via soil and foliage.

The increase of salinity in the irrigation water promoted a linear increase in the beet bulb dry matter mass, presenting maximum values in the irrigated plants with water of 5.2 and 6.0 dS m^{-1}, obtaining up to 18 g. Plants irrigated with the salt water of 1.3 dS m^{-1} presented the lowest dry matter mass of the bulb, obtaining 14.2 g, a reduction of 21.11% in plants irrigated with water of 0.5 dS m^{-1} compared to those under 5.2 and 6.0 dS m^{-1} (Figure 2A).

The dry matter mass presented decrease with the increase of the water salinity and with silicon doses via soil, the highest values were obtained when these plants were irrigated with water of low salinity (0.5 dS m^{-1}) and without application of silicon (0 ml L^{-1}) was obtained 23 g of dry matter mass of the bulb. By increasing the values of ECw and the silicon doses there was a reduction until 5.2 dS m^{-1} and 9.08 ml L^{-1}, in this order, with later addition until a dose of 18.16 ml L^{-1} of silicon (Figure 2B).

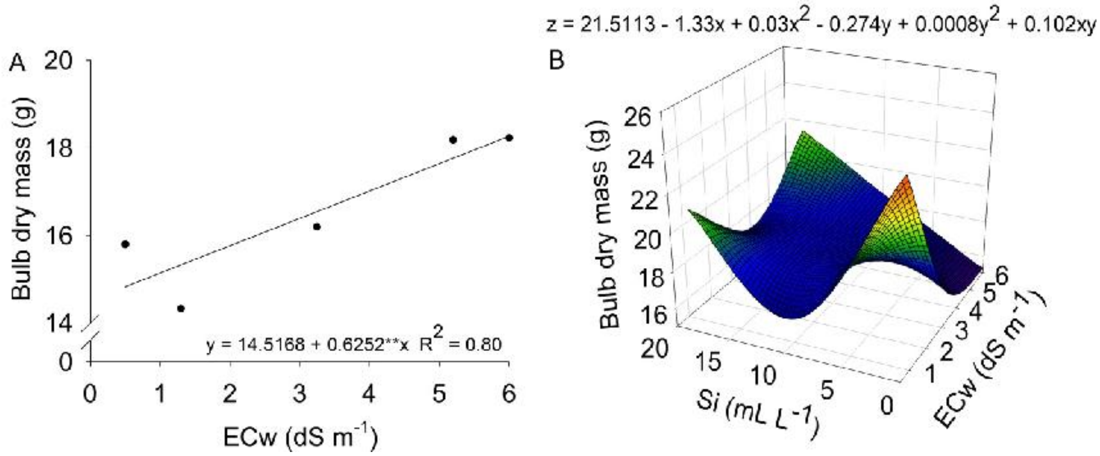

Figure 2: Electrical conductivity effect of the irrigation water (A) and the electric conductivity of silicon doses applied to the soil and in the irrigation water (B) in the dry matter of beet bulb

The pH of the beet pulp adjusted itself to the quadratic regression model, with an increase due to the increase in Si doses via foliage; the pH values were raised to 5.94 relating to estimated optimal dose of 9.08 ml L^{-1} (Figure 3). Si doses above 9.08 mL^{-1} have reduced the beet pulp pH to the dose of 15.52 mL L^{-1} with further increase up to 18.16 mL L^{-1}. The values found in this study are considered low. pH works as an indication of the vegetable flavor, having relation inverse to the acidity [28].

These results corroborate to those obtained by Korkmaz et al. (2017) in tomato, they found that the increase in ECw from 0 to 4.4 dS m^{-1} promoted an increase of the fruit pulp pH. [5] also observed that which pH of the tomato pulp increased with salinity increasing in irrigation water, with a maximum value of 4.8 in plants under 5.0 dS m^{-1}.

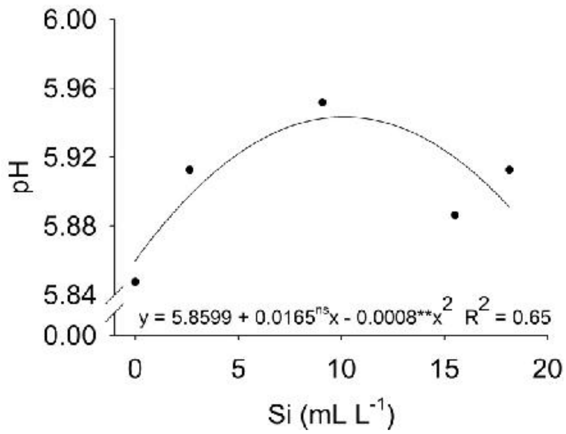

Figure 3: Effect of silicon doses via foliage in the pH of beet pulp

It was observed that the increase in ECw promoted increase in titratable acidity of beet pulp, then plants subjected to the highest ECw (6.0 dS m^{-1}) had the highest titratable acidity (0.23 g citric acid) and plants irrigated with water of lower ECw (0.5 dS m^{-1}) had the lowest titratable acidity (0.17 g citric acid), 29.16% reduction comparatively (Figure 4A).

As increased salt concentration in the irrigation water has been found that the titratable acidity of 0.08 g of citric acid under 0.5 dS m^{-1} increased 0.16 g of citric acid in the beet pulp irrigated with water of highest salinity, increasing up to 50%. [29] also found that the titratable acidity on melon had increased with the increase of the salinity of irrigation water, which observed increase of 0.107% citric acid ECw 0.49 and 1.75 dS m^{-1}, however, the authors also noted that from these salinity the titratable acidity reduced 4.7% when had water salinity increased until 2.4 dS m^{-1}.

On the other hand, it was verified that the increase in Si doses reduced the titratable acidity of the beet pulp up to the Si dose of 9.08 mL L^{-1} with subsequent increase until reaching the maximum dose (18.16 mL L^{-1}), yielding 0.10 g of acid with the this application (Figure 4B). This behavior was also verified by [18] in lettuce, which observed that the treatment with 28 mg L^{-1} of silicon, obtained 140 mg of citric acid 100 g^{-1} of fresh matter, being greater than in the plants of the control that presented average values of 114 mg of citric acid 100 g^{-1}.

The increase in the titratable acidity of the beet pulp in function of the silicon doses corroborates the data obtained by [31] in strawberry, in which the highest values for titratable acidity were with the application of Si via foliage, in which 1.19 mg of citric acid 100 g^{-1} was obtained with the application of 69 mg kg^{-1} of Si, and via soil the highest value was 1.13 mg of citric acid 100 g^{-1}, with the application of 97.5 mg kg^{-1} of Si.

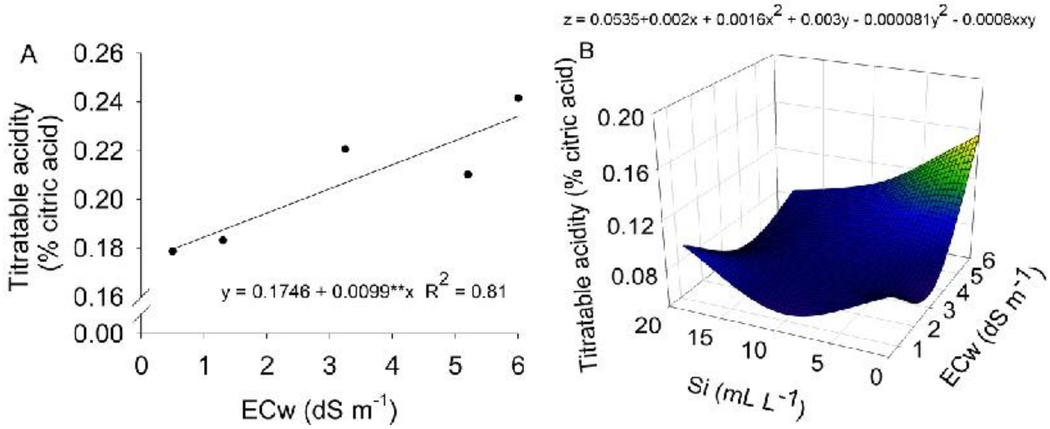

Figure 4: Electrical conductivity effect of the irrigation water and doses of silicon applied via foliage (A) and via soil (B) in the titratable acidity of beet

There was an increase in the soluble solids contents of the pulp when the beet plants were irrigated with saline water and silicon application, in both Experiment I (Figure 5A) and Experiment II (Figure 5B). In the experiment I, data were adjusted to the linear model increasing, and then the increase in the ECw promoted an increase in the soluble solids content, in which the maximum value of 15.7º Brix was obtained in the plants irrigated with water of 6.00 dS m^{-1} (Figure 5A). In the experiment II, data were adjusted to the quadratic regression model, where the maximum value in the soluble solids content was obtained in the plants that have received 9.08 mL L^{-1} of silicon, obtaining 14.3º Brix (Figure 5B).

Similar results were observed by [3] in melon, when they verified that the increase in salinity in the irrigation water from 2.77 to 4.91 dS m^{-1} promoted an increase in the soluble solids content of the 'Shadow' cultivar, increasing the soluble solids values from 3.58 to 5.08%, respectively. [4] also verified that saline increase in irrigation water increases the content of soluble solids in cucumber.

The increase in soluble solids content in the beet pulp with increase of water salinity may have been due to the increase in the concentration of photoassimilates (solutes), since the increase in the soluble solids is mainly due to the deleterious effects of the salts that reduce the bulbs average weight, but they increase soluble solids [30].

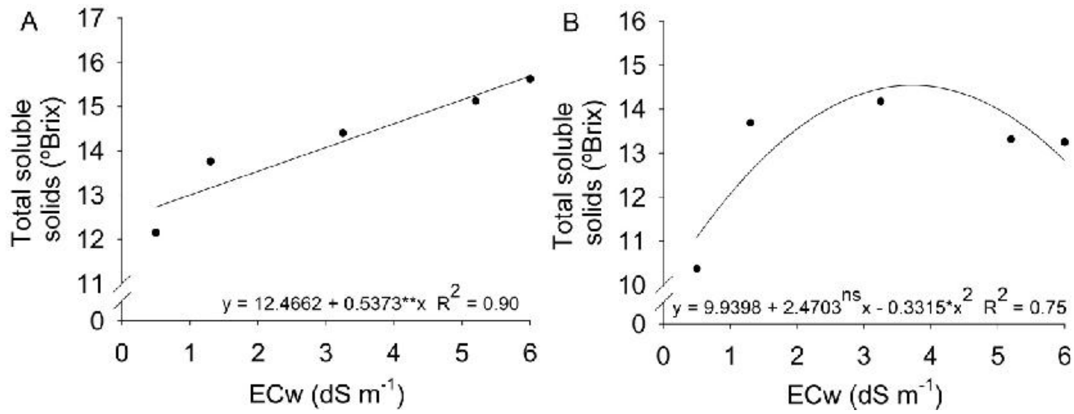

Figure 5: Electrical conductivity effect irrigation water (A) and application of silicon via soil (B) on soluble solids contents of beet pulp

4. CONCLUSION

Using water with an electrical conductivity of 6.0 dS m^{-1} promotes better tuber beet quality;
The fertilizations on preharvest with silicon, applied via soil or foliage, improved the postharvest quality of the beet.

5. REFERENCES

1. Silva AOD, Klar AE, Silva ÊFDF, Tanaka AA, Junior S, Josué F. Relações hídricas em cultivares de beterraba em diferentes níveis de salinidade do solo. *Revista Brasileira de Engenharia Agrícola e Ambiental*. 2013; 17: 1143-1151.

2. Pedrotti A, Chagas RM, Ramos VC, Prata ADN, Lucas AAT, Santos PD. Causas e consequências do processo de salinização dos solos. *Revista Eletrônica em Gestão, Educação e Tecnologia Ambiental*. 2015; 19: 1308-1324.

3. Costa AR, Medeiros JF, Porto Filho F, Silva JS, Costa FG, Freitas DC. Produção e qualidade de melancia cultivada com água de diferentes salinidades e doses de nitrogênio. *Revista Brasileira Engenharia Agrícola Ambiental*. 2012; 17: 947–954.

4. Medeiros PR, Duarte SN, Dias CT, Silva, M. F. Tolerância do pepino à salinidade em ambiente protegido: efeitos sobre propriedades físico-químicas dos frutos. *Irriga*. 2010; 15: 301-311.

5. Paiva FIG, Oliveira FA, Medeiros JF, Targino AJO, Santos ST, Silva RCP. Qualidade de tomate em função da salinidade da água de irrigação e relações K/Ca via fertirrigação. *Irriga*. 2018; 23: 168-193.

6. Yadav S, Irfan M, Ahmad A, Hayat S. Causes of salinity and plant manifestations to salt stress: A review. *Journal of Environmental Biology*. 2011; 32: 667-685.

7. Shahzad M, Witzel K, Zörb C, Mühling KH. Growth-Related Changes in Subcellular Ion Patterns in Maize Leaves (*Zea mays* L.) under Salt Stress. *Journal Agronomy & Crop Science*. 2012; 198: 46-56.

8. Hasanuzzaman M, Nahar K, Fujita M. Plant Response to Salt Stress and Role of Exogenous Protectants to Mitigate Salt-Induced Damages. In: Ahmad, P. et al. (eds.), *Ecophysiology and Responses of Plants under Salt Stress*. 2013: 25-87p.

9. Ashraf M, Afzal M, Ahmed R, Mujeeb F, Sarwar A, Ali, L. Alleviation of detrimental effects of NaCl by silicon nutrition in salt-sensitive and salt-tolerant genotypes of sugarcane (*Saccharum officinarum* L.). *Plant Soil*. 2010; 326: 381-391.

10. Parveen N, Ashraf M. Role of silicon in mitigating the adverse effects of salt stress on growth and photosynthetic attributes of two maize (*Zea mays* L.) cultivars grown hydroponically. *Pakistan Journal of Botany*. 2010; 42: 1675-1684.

11. Ali A, Basra SM, Hussain S, Iqbal J. Increased growth and changes in wheat mineral composition through calcium silicate fertilization under normal and saline field conditions. *Chilean Journal of Agricultural Research*. 2012; 72: 98-103.

12. Mendonça AO, Tavares LC, Brunes AP, Monzón DLR, Villela FA. Acúmulo de silício e compostos fenólicos na parte aérea de plantas de trigo após a adubação silicatada. *Bioscience Journal*. 2013; 29: 1154-1162.

13. Zhu Y, Gong H. Beneficial effects of silicon on salt and drought tolerance in plants. *Agronomy for Sustainable Development*. 2014; 34: 455-472.

14. Shi Y, Wang Y, Flowers TJ, Gong H. Silicon decreases chloride transport in rice (*Oryza sativa* L.) in saline conditions. *Journal of Plant Physiology*. 2013; 170: 847- 853.

15. Tahir MA, Aziz T, Farooq M, Sarwar G. Silicon-induced changes in growth, ionic composition, water relations, chlorophyll contents and membrane permeability in two salt-stressed wheat genotypes. *Archives of Agronomy and Soil Science*. 2012; 58: 247-56.

16. Bae EJ, Lee KS, Huh MR, Lim CS. Silicon significantly alleviates the growth inhibitory effects of NaCl in salt-sensitive ‘Perfection’ and ‘Midnight’ Kentucky bluegrass (*Poa pratensis* L). *Horticulture Environment and Biotechnology*. 2012. 53: 477-483.

17. Yin L, Wang S, Li J, Tanaka K, Oka M. Application of silicon improves salt tolerance through ameliorating osmotic and ionic stresses in the seedling of Sorghum bicolour. *Acta Physiologiae Plantarum*. 2013; 35:1-9.

18. Galati VC, Guimarães JER, Marques KM, Fernandes JDR, Cecílio Filho AB, Mattiuz BH. Aplicação de silício, em hidroponia, na conservação pós-colheita de alface americana 'Lucy Brown' minimamente processada. *Revista Ciência Rural*. 2015; 3: 34-39.

19. Mateus NB, Barbin D, Conagin A. Viabilidade de uso do delineamento composto central. *Acta Scientiarum Agronomy*. 2001; 23: 1537-1546.

20. Embrapa - Empresa Brasileira de Pesquisa Agropecuária. *Sistema Brasileiro de Classificação de Solo*. 4. ed., Brasília, DF: Embrapa Solos. 2014. 376 p.

21. Mantovani EC, Bernardo S, Palaretti LF. *Irrigação: princípios e métodos*. Viçosa: UFV. 2009. 355p.

22. Bernardo S, Soares AA, *Mantovani*. *Manual de irrigação*. 8. Ed. Viçosa: UFV Impressa Universitária, 2008. 625 pg.

23. Richards LA. *Diagnóstico e rehabilitación de suelos salinos e sódicos*. México: Editorial Limusa. 1954. 172 p.

24. Filgueira FAR. *Novo manual de olericultura*: Agrotecnologia moderna na produção e comercialização de hortaliças. 2.ed. Viçosa: UFV. 2008. 412 p.

25. IPA - Instituto Agronômico de Pernambuco. *Recomendação de adubação para o Estado de Pernambuco*: 2° aproximação. 3.ed. Recife: Instituto Agronômico de Pernambuco, IPA. 2008. 212p.

26. Instituto Adolfo Lutz. Normas analíticas do Instituto Adolfo Lutz. *Métodos físico-químicos para análise de alimentos*. 4. ed. Brasília: Ministério da Saúde, Agência Nacional de Vigilância Sanitária, 2005. 1018 p. (Série A – Normas e Manuais Técnicos).

27. Cody R. *An introduction to SAS*. Cary: SAS Institute, 2015.

28. Chitarra MIF, Chitarra AB. *Pós-colheita de frutos e hortaliças*: fisiologia e manuseio. 2. ed. rev. e ampl. Lavras: UFLA, 2005.

29. Pereira ED, Queiroga RCF, Silva ZL, Ferreira RP, Assis LE, Sousa FF. Produção e qualidade do meloeiro sob osmocondicionamento da semente e níveis de salinidade da água. *Revista Verde de Agroecologia e Desenvolvimento Sustentável*. 2018; 13: 08-15.

30. Pereira FADL, Medeiros JFD, Gheyi HR, Dias NDS, Preston W, Vasconcelos CB. Tolerance of melon cultivars to irrigation water salinity. *Revista Brasileira de Engenharia Agrícola e Ambiental.* 2017; 21: 846-851.

31. Silva MLS, Resende JTV, Trevisan A, Figueiredo AST, Schwarz K. Influência do silício na produção e na qualidade de frutos do morangueiro. *Semina: Ciências Agrárias*. 2013; 34: 3411-3424.