ISSN 1808-8546 (ONLINE) 1808-3765 (CD-ROM)

PRODUTIVIDADE DO MELÃO RENDILHADO FERTIRRIGADO COM SILÍCIO

FERNANDO ANDRÉ SILVA SANTOS[1]; ROBERTO REZENDE[2]; GUSTAVO SOARES WENNECK[3]; DANILO CÉSAR SANTI[3]; RENI SAATH[2] E DANIELE DE SOUZA TERASSI[3]

[1]Professor do departamento de Agronomia, Universidade do Estado de Mato Grosso (UNEMAT), Av. Santos Dumont, s/n, Cidade Universitária, CEP: 78.200-000, Cáceres, Mato Grosso, Brasil. E-mail: fernan.agr@hotmail.com

[2]Professor do Departamento de Agronomia, Universidade Estadual de Maringá (UEM), Av. Colombo, 5790, Zona 7, CEP:87020-900, Maringá, Paraná, Brasil. E-mail: rrezende@uem.br; rsaath@uem.br

[3]Discente do Programa de Pós-graduação em Agronomia, Universidade Estadual de Maringá (UEM), Av. Colombo, 5790, Zona 7, CEP:87020-900, Maringá, Paraná, Brasil. E-mail:gustavowenneck@gmail.com; danilosantiagro@gmail.com; daniele_terassi@hotmail.com

1 RESUMO

O objetivo do trabalho foi avaliar a produtividade e acúmulo de biomassa na cultura do melão rendilhado, cultivado em ambiente protegido sob diferentes condições hídricas e doses de silício (Si). O experimento foi conduzido em blocos casualizados, esquema fatorial 5x2, sendo cinco doses de Si (0, 50, 100, 150 e 200 kg ha^{-1}) e duas condições de reposição hídrica (40 e 100% da evapotranspiração da cultura (ETc)), com quatro repetições. A fertilização com Si foi realizada após início da formação dos frutos. Foram avaliados a produção por planta, teor de sólidos solúveis totais dos frutos, massa seca foliar, caulinar e radicular, e determinado a razão de produção em função da massa seca da parte aérea. Adotou-se análise estatística de trilha para indicar o efeito de cada variável sobre a produção. A aplicação de Si reduziu linearmente a produção por planta na condição de 100% da ETc. Na irrigação deficitária a produção foi descrita em modelo quadrático. As doses de Si afetaram significativamente a partição de assimilados entre frutos. Na parte aérea, ocorreu influência das doses do elemento sob irrigação deficitária. Com base na análise de trilha, a massa seca foliar e caulinar são diretamente relacionadas à produção, independentemente da disponibilidade hídrica.

Palavras-chave: ambiente protegido, *Cucumis melo*, elemento benéfico, microirrigação.

SANTOS, F. A. S.; REZENDE, R.; WENNECK, G. S.; SANTI, D. C.; SAATH, R.; TERASSI, D. S.
PRODUCTIVITY OF MUSKMELON FERTIRRIGATED WITH SILICON

2 ABSTRACT

This work aimed to evaluate the productivity and accumulation of biomass in the culture of muskmelon grown in a greenhouse under different water conditions and doses of silicon (Si). The experiment was conducted in a randomized block, a 5x2 factorial scheme, with five doses of Si (0, 50, 100, 150 and 200 kg ha^{-1}) and two water replacement conditions (40 and 100% of the crop evapotranspiration (ETc)), with four replications. Fertilization with Si was performed after the begriming of fruit formation. The production per plant, total soluble solids content of

Recebido em 23/10/2020 e aprovado para publicação em 22/01/2021
DOI: http://dx.doi.org/10.15809/irriga.2021v1n2p321-334

the fruits, dry leaf, stem and root mass was evaluated, and the production ratio as a function of the dry mass of the aerial part was determined. Path analysis statistics were adopted to indicate the effect of each variable regarding growth on production. The application of Si linearly reduced production per plant in the condition of 100% of ETc, while in deficient irrigation the production described in a quadratic model. The doses of Si significantly affected the partition of assimilates between fruits. Regarding the aerial part, there was an influence of the doses of the element under deficient irrigation. Based on the path analysis, the dry leaf and stem mass are directly related to production, regardless of water availability.

Keywords: greenhouse, *Cucumis melo*, benefic element, micro-irrigation.

3 INTRODUCTION

Melon production in Brazil has a significant economic and social impact, standing out among global producers. During cultivation, water availability is a limiting factor for production (MELO et al., 2020), and the development of techniques and appropriate management of this resource are needed to ensure efficient and sustainable production (BARBOSA et al., 2020).

Silicon, in fertigation, can be adopted as a strategy to contribute to the optimization of this resource, as it is capable of facilitating development and promoting the reduction of abiotic stresses, such as water stress, in addition to playing important functions in plant metabolism (TAYYAB; ISLAM; ZHANG, 2018; LUDWIG; BEHLING; SCHIMITZ, 2015; MENEGALE; CASTRO; MANCUSO, 2015; TEODORO et al., 2015). Combined with protected cultivation, the adoption of strategies for water and nutrient use allows for increased efficiency without significant losses in production and quality (HERNANDEZ-SANTANA et al., 2017).

Although its main benefit is increased water use efficiency, constant deficit irrigation can negatively interfere with crop growth and production, and preventing these deleterious effects with combined water and nutrient management is prudent (Mennel; CASTRO; MANCUSO, 2015; HACHMANN et al., 2019; LOZANO et al., 2018). With respect to silicon, there are some gaps in its use in vegetable (fruit) cultivation regarding its adequate quantification according to the degree of water deficiency of the plant, which is based on the values obtained from crop evapotranspiration.

This study aimed to evaluate the effects of applying silicon doses via fertigation on the production of lace melons with and without water deficit in a protected environment.

4 MATERIALS AND METHODS

The study was conducted in a protected environment located at the Irrigation Technical Center (CTI), belonging to the State University of Maringá (UEM), which is located in the municipality of Maringá-PR. The local climate is characterized as subtropical Cfa according to the Köppen classification (NITSCHE et al., 2019). The experiment was conducted in a randomized complete block design in a 5x2 factorial scheme with four Si rates (50, 100, 150, and 200 kg ha $^{-1}$), a control treatment (no application), and two water replacement conditions (40 and 100% of ETc) with four replicates.

The protected environment, whose dimensions are 30 m long, 7 m wide, and 3.5 m high, was covered with 150 µm thick polyethylene film and wrapped with an anti-aphid screen on the sides. The soil of the experimental area is classified as Dystroferric Red Nitosol (SANTOS et al., 2018), which is physically composed of clay (g kg^{-1}) = 756.8; fine sand (g kg^{-1}) = 72.6; coarse sand (g kg^{-1}) = 50.0; silt (g kg^{-1}) = 120.6; and soil bulk density (Mg m^{-3}) = 1.01. The chemical components of the soil were characterized as follows: pH (H_2O) = 7.2; exchangeable Al ($cmol_c$ dm^{-3}) = 0.0; Ca ($cmol_c$ dm^{-3}) = 11.99; Mg ($cmol_c$ dm^{-3}) = 2.50; K ($cmol_c$ dm^{-3}) = 0.30; P (Mehlich) (mg dm^{-3}) = 46.77; organic matter (g dm^{-3}) = 15.55; base saturation (V%) = 85.35; and Zn, Cu, Fe, Mn and B (mg dm^{-3}) = 20.34, 18.71, 68.87, 94.61, and 0.16, respectively.

In the experimental area, the soil was prepared and turned over to construct the beds. The dimensions of each bed were 3 m long, 0.5 m wide, and 0.1 m high, corresponding to the experimental plots. The soil received organic compost at a dose of 0.5 kg m^{-2} of bed (TRANI, 2014), while the doses of nitrogen, phosphorus, and potassium used in the planting and topdressing fertilizers were made according to the recommendations of Raij, Quaggio, and Furlani (1997). The nutrient sources used were ammonium sulfate (22% N), urea (45% N), simple superphosphate (18% P_2O_5), and potassium chloride (60% K_2O).

Melon planting took place in 50-cell plastic trays with a commercial humus–pine substrate and Sunrise hybrid seeds. Transplanting occurred when the seedlings had three to four permanent leaves, with a spacing of 0.50 m between plants. In each bed, wooden poles were fixed at the ends with two wires for trellizing the crop, spaced 0.20 m above the soil and the other 1.80 m apart. Pollination was performed manually above the eighth leaf, and after fruit set, thinning was performed whenever necessary, guiding one fruit per plant (SILVA et al., 2014).

A drip microirrigation system was used for irrigation, and a portable system for fertigation was used to apply small doses of irrigation water. The microirrigation system in the experimental area had a 16-mm-diameter polyethylene lateral line with an individual valve in each experimental plot, which was pressurized by a 3.7-kW centrifugal pump operating at a pressure of 147 kPa. The lateral lines were installed along the beds, with 12 self-compensating drippers spaced 0.25 m apart, with a nominal flow rate of 8 L h^{-1}. The uniformity of the microirrigation system, as assessed via the Christiansen uniformity coefficient (CUC), was 96.52%.

The fertigation system consisted of a vehicle air compressor to pressurize the system, as well as a valve, a reservoir (75 mm diameter PVC pipe with a capacity of 5 L), two pressure gauges, crystalline plastic tubing, two ball valves with handles, six microirrigation tubes, and six drippers with a nominal flow rate of 8 L h^{-1}. The CUC value for the portable system was 98.99%.

Irrigation management was determined by crop evapotranspiration (ETc) via two constant-level water table lysimeters. ETc readings and water reservoir replenishments were taken daily in the morning (7 a.m.). One plant was transplanted into each lysimeter, with the same dimensions as the beds. Irrigation was administered daily according to the average reading of the water replenishment tanks in the lysimeter system, converting the water mass into laminar replenishment.

The tested doses were divided into four weekly fertigation applications. Fertigation began after pollination and fruit set. The Si source used was the commercial product Agri Sil® (98% SiO_2) in wettable powder form. To prepare the solution, 2 L of water was used to dissolve the treatment doses, and for the control (without Si application), only irrigation water with the same volume was applied.

A dripper was positioned at a distance of ± 0.03 m from each plant's stem. The procedure described was performed for application in one experimental plot, and the process was repeated for all forty plots that composed the experiment.

The harvest point was the rupture of the abscission layer of the fruit stalk and yellowing of the skin. After each harvest, the fruits were taken to the laboratory for individual weighing on a precision digital scale (± 2 g) to determine the yield per plant (PROD). The total soluble solids (TSS) content was obtained through refractometric determination with a sample of fruit pulp juice previously ground in a domestic food processor and expressed in °Brix.

At the end of the experiment, the aerial parts of the plants were partitioned into stems and leaves and subsequently dried in a forced air circulation oven at 65 °C until they reached constant mass to obtain the leaf dry matter (MSF) and stem dry matter (MSC) masses, expressed in grams per plant (g plant $^{-1}$).

The total dry matter mass of the aerial part (MSPA) was obtained from the sum of the MSF and MSC values. With the MSPA and production per plant values, the ratio between these two variables was calculated (RFRA = PROD/MSPA) to evaluate the partitioning of assimilates in the melon plants, expressed in grams per gram (gg $^{-1}$).

Root quantification was performed at the end of the crop cycle via a steel plate sampler measuring 0.20 m wide, 0.25 m long, and 0.30 m deep, which was subsequently inserted into the soil in a level manner. After the roots were washed, they were subsequently dried in a forced air circulation oven at 65°C until they reached a constant mass, and the root dry matter mass (RDM), expressed in grams per plant (g plant $^{-1}$), was obtained.

The data were subjected to analysis of variance (ANOVA) via the F test, which uses a minimum probability of 10%, to verify the significance of the tested factors and their interactions on the evaluated characteristics. Regression analysis was applied to the levels of the Si factor, and the F test was used to compare the means of the water replenishment factors. In the regression analysis, the regression equations were chosen on the basis of the significance of the F test and the regression coefficients by Student's t test at a minimum probability level of 10%.

According to Perecin and Cargnelutti Filho (2008), the usual significance level adopted is 5% or 1%. However, in the absence of significant interaction, a less rigorous significance level is adopted. Furthermore, in the case of treatments in a factorial scheme, the unfoldings are performed regardless of the significant interaction between factors.

The effects of the various water depths used in the literature are more evident under biotic (RAMOS et al., 2013) and abiotic (TAYYAB; ISLAM; ZHANG, 2018; MENEGALE; CASTRO; MANCUSO, 2015; TEODORO et al., 2015) stress conditions, which in the present study correspond to water depths of 100% (without water stress) and 40% of ETc (with water stress).

For path analysis, the methodology described by Cruz, Carneiro and Regazzi (2014) was used. Initially, the data were separated according to the replacement water depth, forming two datasets. For each set, analysis of variance was performed, and phenotypic variances and covariances were obtained, generating the matrix of phenotypic correlations between the traits.

Phenotypic correlations were broken down into direct and indirect effects of the independent variables via path analysis. A chain diagram was used to estimate the path coefficients, presenting the cause–and–effect relationships, on the basis of the associations between the basic variable (yield per plant) and the growth variables (MSF, MSC, and MSR) listed as primary components. All analyses were performed via GENES *software* (CRUZ, 2013).

5 RESULTS AND DISCUSSION

According to the analysis of variance (Table 1), all melon variables were significantly influenced by the relative evapotranspiration depth (LRE), and Si influenced only the PROD (p<0.10).

Table 1. Summary of the analysis of variance for the variables analyzed.

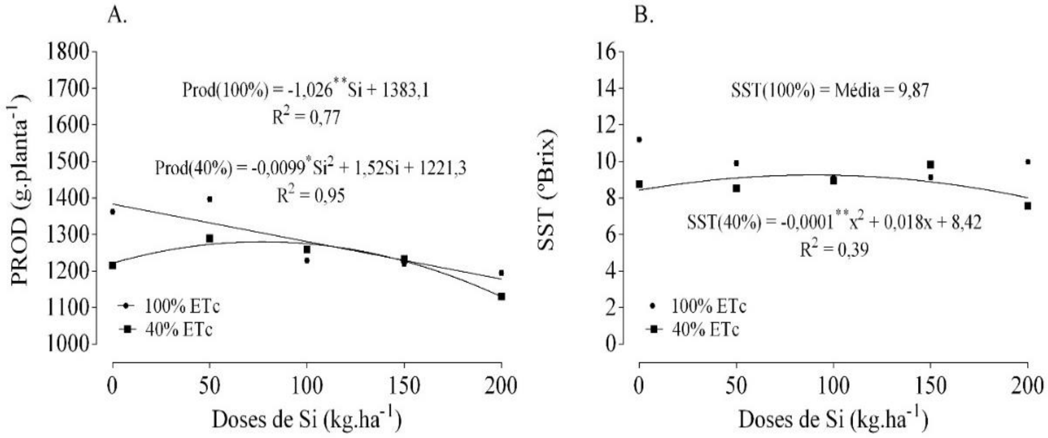
FV	GL	Mean squares					
		PROD	**SST**	**MSF**	**MSC**	**MSR**	**RFRA**
		g plant $^{-1}$	**°Brix**		**g plant $^{-1}$**		**g g $^{-1}$**
Treatments	9	24986.37 **	3.89 ***	71.08 **	22.72 **	0.12 ^{ns}	34.93 **
Silicon (Si)	4	36990.46 ***	1.68 ^{ns}	6.84 ^{ns}	5.11 ^{ns}	0.10 ^{ns}	22.56 ^{ns}
LRE (L)	1	30593.07 *	13 ***	279.44 ***	128.84 ***	0.39 **	110.45 **
Si × L	4	11580.6 ^{ns}	3.84 ***	83.22 **	13.81 ^{ns}	0.08 ^{ns}	26.43 ^{ns}
Block	3	4428.16 ^{ns}	2.93 **	56.11 ^{ns}	17.07 ^{ns}	0.50 ***	43.15 ^{ns}
Residue	27	8721.80	0.81	26.04	9.77	0.08	14.50
CV (%)		7.45	9.68	13.45	20.01	30.62	15.71
Overall average		1252.87	9.29	37.94	15.62	0.85	24,25

*PROD = production per plant; SST = total soluble solids content; MSF = leaf dry matter mass; MSC = stem dry matter mass; MSR = root dry matter mass; RFRA = PROD/MSPA ratio; LRE = depth relative to evapotranspiration; FV = source of variation; GL = degrees of freedom; CV = coefficient of variation; *, ** and *** = significant at 0.10, 0.05 and 0.01, respectively; ^{ns} = not significant according to the F test (p≥0.10).

Significant interactions were obtained for two of the six variables analyzed: MSF (p<0.05) and SST (p<0.01). However, as established in the methodology, the consequences within each factor were addressed, regardless of whether the interaction was significant. The results obtained with silicon application vary between crops, and some results of the consequences may be more important from a practical perspective.

The PROD data were fitted to a linear model (p<0.05) for the conditions without water stress (Figure 1A). Under water stress (40% of ETc), production was described by a quadratic model (p<0.10) with a maximum value of 77.24 kg ha $^{-1}$ of silicon (Figure 1A), resulting in an estimated maximum production of 1,280.36 g plant $^{-1}$, indicating that doses higher than 77.24 kg ha $^{-1}$ of silicon negatively interfere with melon production.

Figure 1. Influence of Si application under different water conditions. A) Production per melon plant (PROD); B) total soluble solids.



*, ** and *** = significant at 0.10, 0.05 and 0.01, respectively; ns = not significant according to the F test (p≥0.10); R^2 = coefficient of determination.

For the SST data (Figure 1B), at the water level corresponding to 40% of ETc, a quadratic model was adjusted (p<0.05), with a maximum Si value of 92 kg ha $^{-1}$ and a maximum value of 9.11 °Brix. For the water level corresponding to 100% of ETc, the model was not validated, with nonsignificant coefficients (p>0.10), presenting the average observed at this level (9.87 °Brix). Therefore, the PROD and SST values indicate that silicon can be used at low doses to increase resistance to water deficit.

Under protected environmental conditions, Ramos et al. (2013) studied the efficiency of potassium silicate in the development of the bush zucchini crop and reported that foliar application did not influence plant growth, verifying that the application of high doses (2.5 L ha $^{-1}$) resulted in losses in fruit production.

Considering that high doses of silicon, via foliar application, harm the production and development of the crop, attention should be given to the supply of silicon to the melon plant via fertigation, especially when there is no irrigation deficit, as the application of increasing doses under these conditions resulted in few significant changes in the variables analyzed, harming the production and growth of the melon plant (Table 1 and Figure 1).

In the study by Silva et al. (2013), silicon application in strawberry crops, in which Si fertilizers were applied via soil or foliar application, contributed to increased fruit production, with higher production in the soil treatment than in the foliar treatment. The dose also influenced quality variables, such as the anthocyanin content and titratable acidity, but did not influence soluble solids.

Like what was observed in melon crops without water stress, Jayawardana, Weerahewa and Saparamudu (2014) reported that the application of silicon in pepper crops, which uses potassium silicate at a dose of 75 mg/L via foliage or along the roots through a nutrient solution, did not alter the characteristics related to the content of total soluble solids, pH, titratable acidity or fruit diameter.

For SST, the Si doses applied via fertigation were only significant under water stress conditions and do not constitute a direct effect of the element but rather possible modifications linked to mineral nutrition and plant physiology (CANTUÁRIO et al., 2014), which are evidenced by changes in the production and quality of melon fruits.

In this crop, changes in growth, such as a greater number of leaves, result in higher values of total soluble solids, suggesting that the soluble solids content can be influenced by the partitioning of assimilates (QUEIROGA et al., 2008b), suggesting that fertigation with silicon can alter melon growth variables, the partitioning of assimilates and, consequently, the PROD and TSS contents.

The results of the regression analysis for growth variables in response to fertigation in each water layer are shown in Table 2. The MSF variable was significant for the dose factor under both water conditions, in which a decreasing linear model was adjusted ($p<0.01$) when 100% of the ETc was replaced and an increasing linear model ($p<0.05$) when the ETc replacement was 40%.

Table 2. Regression equations adjusted for the productive variables of melon grown under fertigation silicate (SiO_2) under two water replacement conditions (40 and 100% of ETc).

Variable	LRE (% of ETc)	Adjusted regression equations	R^2
MSF (g plant $^{-1}$)	100	-0.04^{***} Si + 45.44	0.89
	40	0.03^{**} Si + 32.22	0.97
MSC (g plant $^{-1}$)	100	Average = 17.42 ^{ns}	ns
	40	0.0003^{*} Si^2 - 0.05Si + 14.57	0.87
MSR (g plant $^{-1}$)	100	Mean = 0.92 ^{ns}	ns
	40	Mean = 0.72 ^{ns}	ns
RFRA (g g $^{-1}$)	100	Average = 22.58 ^{ns}	ns
	40	0.0005^{**} Si^2 - 0.07Si + 26.11	0.90

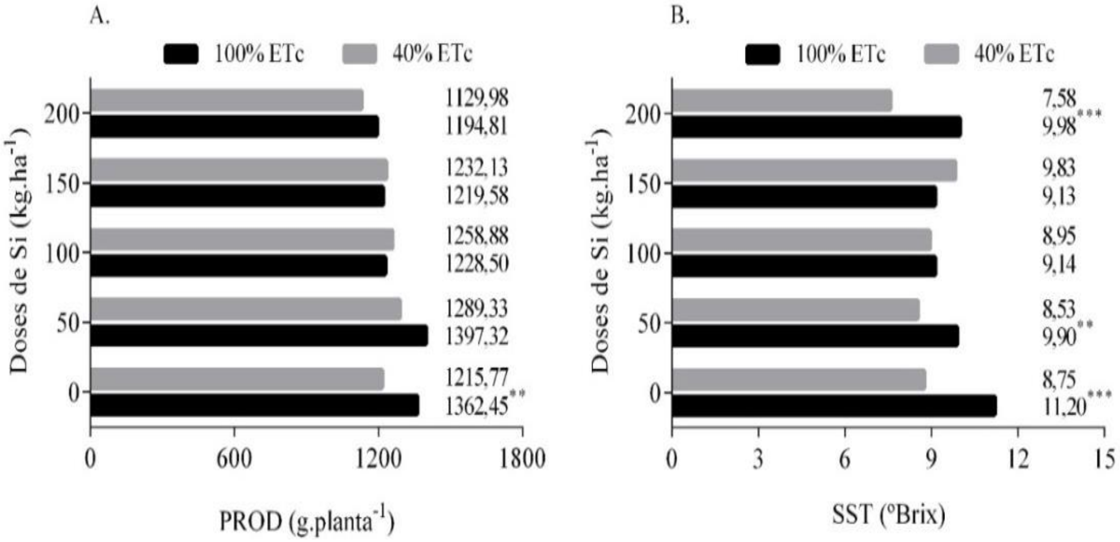
MSF = leaf dry matter mass; MSC = stem dry matter mass; MSR = root dry matter mass; RFRA = PROD/MSPA ratio; LRE = depth relative to evapotranspiration.
*, ** and *** = significant at 0.10, 0.05 and 0.01, respectively; ^{ns} = not significant according to the F test ($p \geq 0.10$).

For MSC and RFRA, it was possible to fit quadratic models only at the LRE of 40%. For MSC ($p<0.10$), the estimated minimum value (11.93 g plant $^{-1}$) is obtained with the application of 94 kg ha $^{-1}$ of Si, and for RFRA, the estimated maximum value (28.83 g g $^{-1}$) is obtained with a dose of 73.7 kg ha $^{-1}$ of Si .

It was not possible to fit an explanatory model to the data on the root dry matter mass (RSM) of melon plants, which are presented as the average observed for each water condition (0.92 and 0.72 g plant $^{-1}$ at LRE values of 100 and 40% of ETc, respectively).

When the slides were subjected to each silicon dose, significant differences were observed for PROD only in the control treatment (Figure 2A), and for SST, differences were detected between the control treatment and the 50 and 200 kg ha^{-1} Si treatments (Figure 2B). Si has a beneficial effect under water stress conditions, as the plants that received silicon applications did not differ between 100 and 40% ETc.

Figure 2. Characteristics of melon cultivated with different Si doses and water conditions. A) Average production values (PRODs); B) total soluble solids (TSSs).



*, ** and *** = significant at 0.10, 0.05 and 0.01, respectively; ns = not significant according to the F test ($p \geq 0.10$).

The mean MSF value at the 100% LRE differed from and exceeded that at the 40% LRE without silicon addition (0 kg ha $^{-1}$ Si) ($p < 0.01$) and at the 50 kg ha $^{-1}$ dose ($p < 0.05$) (Figure 3A). For the MSC means, differences were observed between the water depths when 0, 100, and 150 kg ha $^{-1}$ Si were applied (Figure 3B). At the 0, 100, and 150 kg ha -1 doses, the 100% LRE significantly differed from and exceeded the 40% LRE at the 5% probability level. The MSR value differed statistically only at the 100 kg ha $^{-1}$ dose (Figure 3C), in which the highest value was obtained at the 100% LRE ($p < 0.05$).

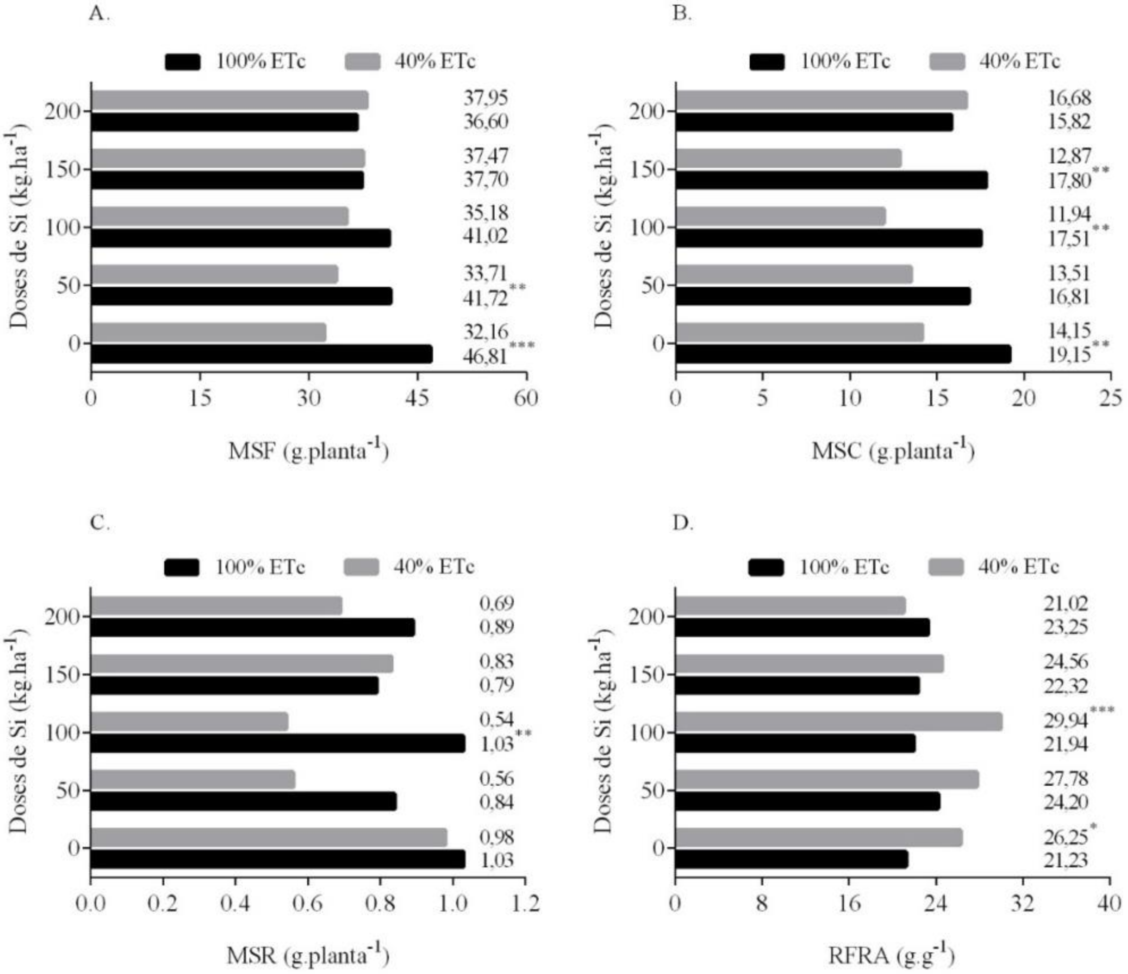
As shown ~~in~~ Figure 3D, the average RFRA value at 40% LRE differed from and exceeded 100% LRE of ETc, without the supply of silicon (0 kg ha $^{-1}$ Si) ($p < 0.10$) and at a dose of 100 kg ha $^{-1}$ ($p < 0.01$). The differences observed between the water depths can be explained by possible inequalities in the energy supply to the process under each water condition.

With 100% ETc replacement, the soil moisture remained at adequate levels, not limiting plant development, justifying the relatively high average values of the variables. Despite potential limitations due to water deficit conditions, silicon triggered changes in melon growth under these conditions, especially in the partitioning of assimilates.

Given the interactions between nutrient doses and applied water depths, it is reasonable to assume that melon growth variables are affected unequally, considering the effects of silicon doses at each of the applied depths.

Path analysis revealed that the dose influences the growth variables differently, which could explain some of the changes in melon yield and total soluble solids (Figure 2). At the 100% level, the greatest direct effect on yield was related to MSF, followed by MSC and MSR (Table 3), with correlation values with the dependent variable in the same order. At 40% LRE, the greatest direct effect on yield was attributed to MSC, followed by MSF and MSR.

Figure 3. Breakdown of ETc replacements within each silicon dose applied via fertigation. A) Average values for the variables leaf dry matter mass (MSF); B) stem dry matter mass (MSC); C) root dry matter mass (MSR); D) ratio (RFRA) production per plant (PROD)/total shoot dry matter (MSPA).



*, ** and *** = significant at 0.10, 0.05 and 0.01, respectively; ^{ns} = not significant according to the F test ($p \geq 0.10$).

For the SST, the same order of direct effects obtained on production at 100% LRE was maintained. The direct effects on the SST at 40% LRE follow the order of MSC>MSR>MSF (Table 4). This finding demonstrates that silicon doses, by altering the variables with the greatest direct effects, also alter production and quality under ETc replacement conditions.

Considering the LRE of 100%, the reduction in MSF with increasing Si dose (Table 2) is explained by the accentuated deposition of the element in the melon leaves, and during this process, there were interactions between the deposited Si and the cell wall (GUERRIERO; HAUSMAN; LEGAY, 2016), limiting leaf mass and expansion, and leaf mass, with little effect on the stem and root. Thus, leaf dry mass is the variable that most influences the production and soluble solids content of melon without water deficit (Tables 3 and 4).

The results of the study by Duarte and Peil (2010) on the effect of source:sink relationships on the vegetative growth of melon indicated no differences in the distribution of dry matter between stems and leaves, indicating that the indiscriminate competition between sinks (fruit) and aerial vegetative parts, that is, stems and leaves, constitute unique compartments for the temporary storage of photoassimilates. This unique compartment is supplied by photosynthesis and is where plant organs extract the basic photoassimilates necessary for growth and functional processes.

Table 3. Direct and indirect effects of the components on the basic variable production in replacement blades (40 and 100% of ETc).

Variable	Effect	Water replacement (% ETc)	
		40	**100**
MSF	Direct about PROD	-0.38	1.77
	Indirect via MSC	-0.19	-0.46
	Indirect via MSR	0.05	-0.57
	Total	0.53	0.73
MSC	Direct about PROD	-0.67	-0.60
	Indirect via MSF	-0.11	1.38
	Indirect via MSR	-0.06	-0.38
	Total	-0.84	0.39
MSR	Direct about PROD	-0.27	-0.83
	Indirect via MSF	0.07	1.20
	Indirect via MSC	-0.14	-0.27
	Total	0.34	0.08
	Coefficient of Determination	0.87	0.98
	Effect of the residual variable	0.35	0.12

MSF = leaf dry matter mass; MSC = stem dry matter mass; MSR = root dry matter mass; PROD = production per plant.

Under water deficit, the addition of silicon may have altered the source–sink relationship in melon plants, with differences in the supply of assimilates by the vegetative aerial parts (Figures 3B and 3D), with the stem being the vegetative part that contributed most to the supply of photoassimilates to the drain (fruit); therefore, in the path analysis, this variable has greater weight in the production (-0.84) and SST (-0.80), resulting in an LRE of 40% (Tables 3 and 4).

In addition to changes in production, fruits are also qualitatively influenced by the partitioning of assimilates. Because the fruit constitutes the main sink, its flavor depends on the synthesis and translocation of photoassimilates in the shoot during the development (ripening) phase. It can be inferred that soluble solids levels may be influenced by competition between sources and sinks (QUEIROGA et al., 2008a). Furthermore, there is a need to increase carbohydrate availability by reducing the number of sinks (number of fruits) or modifying the leaf apparatus so that there is an increase in sugars stored in the fruit, represented by increased TSS (LONG et al., 2004).

Path analysis confirmed that melon growth was distinct in each LRE, which also modified the distribution of assimilates between the fruit and other vegetative parts. The primary variables MSF, MSC, and MSR were sufficient to explain the variations in yield and soluble solids, as evidenced by the high coefficients of determination in the analyses.

The coefficients of determination of the path analyses ranged from 0.59 to 0.98, indicating the effectiveness of the independent variables in determining the main variables. However, the coefficient of determination for the soluble solids path at

100% LRE was the lowest (0.59), indicating that other variables may influence the TSS under nondeficit conditions. Similar trends were obtained by Silva et al. (2016) in papaya crops.

Table 4. Direct and indirect effects of primary components on the basic variable total soluble solids in replacement slides (40 and 100% of ETc).

Variable	Effect	Water replacement (% ETc)	
		40	100
MSF	Direct about SST	0.35	1.16
	Indirect via MSC	-0.30	-0.31
	Indirect via MSR	-0.11	-0.12
	Total	-0.05	0.72
MSC	Direct about SST	-1.03	-0.39
	Indirect via MSF	0.10	0.90
	Indirect via MSR	0.11	-0.08
	Total	-0.80	0.42
MSR	Direct about SST	0.54	-0.18
	Indirect via MSF	-0.07	0.79
	Indirect via MSC	-0.22	-0.18
	Total	0.25	0.41
	Coefficient of determination	0.95	0.59
	Effect of residual variable	0.21	0.63

MSF = leaf dry matter mass; MSC = stem dry matter mass; MSR = root dry matter mass; SST = total soluble solids.

When interpreting the analysis, it is clear that the direct effect generally has the same sign as the total effect; however, some variables do not follow this premise, such as MSF in the 40% condition, whose total effect is positive, but its direct effect on production is negative (Table 3).

Variables that have a direct effect in the opposite direction to the total effect may indicate an absence of cause and effect, suggesting that such a variable is not the main determinant of changes in the basic variable and that there are others that may have a greater effect on the response variables (CRUZ; CARNEIRO; REGAZZI, 2014).

In summary, the supply of silicon represents an option to prevent possible reductions in production and quality in crops that use deficit irrigation, with the advantage of reconciling irrigation and fertigation operations, resulting in savings in water supply and better distribution of this nutrient to protected crops compared with applications commonly carried out with other methods, such as nutrient applications via foliar and soil methods (SILVA et al., 2013).

RAMOS et al., 2013), can be evaluated to support the application of silicon to melon plants via irrigation water.

6 CONCLUSIONS

Silicon has a beneficial effect under water stress conditions, and plants that received silicon applications did not differ between blades with 100% and 40% ETc replacement.

For melon, the recommended dose is 50 kg ha $^{-1}$ for application via irrigation water in a protected environment via deficit irrigation with 40% ETc.

Fertigation is recommended to improve the partitioning of assimilates and maintain production in melon plants under deficit irrigation.

To determine production values and soluble solids contents, leaf and stem dry matter masses are the most important variables associated with irrigation with and without water deficit, respectively.

7 REFERENCES

BARBOSA, JR; PEREIRA FILHO, JV; OLIVEIRA, VM; SOUSA, GG; GOES, GF; LEITE, KN Productivity of irrigated soybean crop with regulated water deficit in the Piauí cerrado. **Brazilian Journal of Irrigated Agriculture** , Fortaleza, v. 14, n. 4, p. 4200-4210, 2020.

CANTUÁRIO, FS; LUZ, JMQ; PEREIRA, AIA; SALOMÃO, LC; REBOUÇAS, TNH Blossom-end rot and scald in bell pepper fruits subjected to water stress and silicon doses. **Brazilian Horticulture** , Vitoria da Conquista, v. 32, n. 2, p. 215-219, 2014.

CRUZ, CD Genes: a software package for analysis in experimental statistics and quantitative genetics . **Acta Scientiarum Agronomy** , Maringá, v. 35, n. 3, p. 271-276, 2013.

CRUZ, CD; CARNEIRO, PCS; REGAZZI, AJ **Biometric models applied to genetic improvement** . 3rd ed. Viçosa: UFV, 2014. v. 2.

DUARTE, TDS; PEIL, RM Source–sink relationships and vegetative growth of melon. **Brazilian Horticulture** , Victory of Conquest, v. 28, n. 3, p. 271-276, 2010.

GUERRIERO, G.; HAUSMAN, JF; LEGAY, S. Silicon and the plant extracellular matrix . **Frontiers in Plant Science** , Lausanne, vol. 7, no. 1, p. 1-8, 2016.

HACHMANN, TL; REZENDE, R.; PINTRO, PTM; SAATH, R.; ANGEL, FA; MENEZES, CSL Yield, antioxidant activity and shelf-life of cauliflower inflorescences under drought stress and foliar spraying of selenium. **Science and Agrotechnology** , Lavras , v. 43, p. e017819, 2019.

HERNANDEZ-SANTANA, V .; FERNÁNDEZ, JE; CUEVAS, MV; PEREZ-MARTIN, A.; DIAZ-ESPERO, A. Photosynthetic limitations by water deficit: effect on fruit and olive oil yield, leaf area and trunk diameter and its potential use to control vegetative growth of superhigh density olive orchards. **Agricultural Water Management** , Amsterdam, vol. 184, n. 1, p. 9-18, 2017.

JAYAWARDANA, HARK; WEERAHEWA, HLD; SAPARAMADU, MDJS Effect of root or foliar application of soluble silicone on plant growth, fruit quality and anthracnose development of capsicum. **Tropical Agricultural Research** , Peradeniya , vol. 26, no. 1, p. 74-81, 2014.

LONG, R.L.; WALSH, K.B.; ROGERS, G.; MIDMORE, D. Source–sink manipulation to increase melon (*Cucumis melo* L.) fruit biomass and soluble sugar content. **Australia Journal of Agricultural Research** , Victoria, vol. 55, no. 12, p. 1241-1251, 2004.

LOZANO, CS; REZENDE, R.; HACHMANN, TL; SANTOS, FAS; LORENZONI, MZ; SOUZA, Á. HC Productivity and quality of melon under silicon doses and irrigation depths in a protected environment. **Tropical Agricultural Research** , Goiânia, v. 48, n. 2, p. 140-146, 2018.

LUDWIG, F.; BEHLING, A.; SCHMITZ, JAK Silicon in the production and phytosanitary quality of tomato (*Lycopersicum esculentum)*. **Scientia Agraria Paranaensis** , Marechal Cândido Rondon, v. 14, n. 1, p. 60-66, 2015.

MELO, AS; DIAS, VG; DUTRA, WF; DUTRA, AF; SÁ, FVS; BRITO, MEB; VIÉGAS, PRA Physiology and yield of melon sapodilla skin (*Cucumis melo* l.) under water deficit in semiarid region , Brazil . **Bioscience Journal** , Uberlândia, v. 36, n. 4, p. 1251-1260, 2020.

MENEGALE, MLC; CASTRO, GSA; MANCUSO, MA Silicon: interaction with the soil–plant system. **Journal of Agronomic Sciences** , Umuarama, v. 4, special issue, p. 435-454, 2015.

NITSCHE, PR; CARAMORI, PH; RICCE, WS; PINTO, LFD **Climate Atlas of the State of Paraná** . Londrina: IAPAR, 2019.

PERECIN, D.; CARGNELUTTI FILHO, A. Effects by comparisons and by experiment in interactions of factorial experiments. **Science and Agrotechnology** , Lavras, v. 32, n. 1, p. 68-72, 2008.

QUEIROGA, RCF; PUIATTI, M.; FONTES, PCR; CECON, PR Partitioning of assimilates and physiological indices of melon cultivars of the cantalupensis group influenced by number and position of fruits on the plant, in a protected environment. **Ceres Magazine** , Viçosa, MG, v. 55, n. 6, p. 596-604, 2008a.

QUEIROGA, RCF; PUIATTI, M.; FONTES, PCR; CECON, PR Productivity and quality of melon fruits varying in number of fruits and leaves per plant. **Horticultura Brasileira** , Vitoria da Conquista, v. 26, n. 2, p. 209-215, 2008b.

RAIJ, BV; QUAGGIO, JA; FURLANI, AMC **Fertilization and liming recommendations for the state of São Paulo** . 2nd ed. Campinas: Agronomic Institute of Campinas, 1997. (Technical Bulletin, 100).

RAMOS, ARP; SANTOS, RL; AMARO, ACE; FUMES, LAA; BOARO, CSF; CARDOSO, AII Efficiency of potassium silicate in the control of powdery mildew and in the development of zucchini. **Horticultura Brasileira** , Vitoria da Conquista, v. 31, n. 3, p. 432-438, 2013.

SANTOS, HG; JACOMINE, PKT; ANJOS, LHC; OLIVEIRA, V. Á.; LUMBRERAS, JF; COELHO, MR; ALMEIDA, JA; ARAÚJO FILHO, JC; OLIVEIRA, JB; CUNHA, TJF **Brazilian Soil Classification System** . 5th ed. Brasília, DF: Embrapa, 2018.

SILVA, CA; SCHMILDT, ER; SCHMILDT, O.; ALEXANDRE, RS; CATTANEO, LF; FERREIRA, JP; NASCIMENTO, AL Phenotypic correlations and path analysis in morphoagronomic traits of papaya. **Agro@mbiente On-line Magazine** , Boa Vista, v. 10, n. 3, p. 217-227, 2016.

SILVA, MC; SILVA, TJA; BONFIM-SILVA, EM; FARIAS, LN Productive and qualitative characteristics of lace melon fertilized with nitrogen and potassium. **Brazilian Journal of Agricultural and Environmental Engineering** , Campina Grande, v. 18, n. 6, p. 581-587, 2014.

SILVA, MLS; RESENDE, JTV; TREVIZAM, AR; FIGUEIREDO, AST; SCHWARZ, K. Influence of silicon on the production and quality of strawberry fruits. **Semina** : Sciences Agrarian , Londrina, v. 34, n. 6, p. 3411-3424, 2013.

TAYYAB, M.; ISLAM, W.; ZHANG, H. Promising role of silicone to enhance drought resistance in wheat. **Communications in Soil Science and Plant Analysis** , New York, v. 49, no. 22, p. 2932-2941, 2018.

TEODORO, PE; RIBEIRO, LP; OLIVEIRA, EP; CORRÊA, CCG; TORRES, FE Soybean dry mass in response to foliar application of silicon under water deficit conditions. **Bioscience Journal** , Uberlândia, v. 31, n. 1, p. 161-170, 2015.

TRANI, PE **Liming and fertilization for vegetables under protected cultivation** . Campinas: IAC, 2014.