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Irrigation depth and silicate fertilisation in green maize[1]

Lâminas de irrigação e adubação silicatada na cultura do milho verde

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ABSTRACT - The successful use of irrigation depends on the adoption of efficient management, which in turn depends on determining the correct amount of irrigation water. Due to the water scarcity seen in recent years, there is an obvious need for strategies that would make it possible to reduce the amount of water applied to crops with no reduction in productivity. Among such strategies, the application of silicon, which is associated with several beneficial effects for the plant, can increase water use efficiency. The aim of the present work was to study irrigation-depth management versus silicon doses via foliar application in green maize under a semi-arid climate. The experiment was conducted from August to November 2017 in an area of the Federal Institute of Ceará, Iguatu Campus, Ceará, using the AG1051 hybrid. The experimental design was of randomised blocks, comprising split plots and four blocks. Five irrigation depths (50, 75, 100, 125 and 150% of the ETc) were evaluated in the plots and four doses of silicon (50, 100, 150 and 200% of the recommended dose) were evaluated in the subplots. The following growth variables were analysed 15, 30, 45, 60 and 75 days after sowing (DAS): leaf dry weight, stem dry weight, and total dry weight; the production variables, evaluated at 81 DAS, were ear diameter and ear length with no husks, ear weight with and with no husks, and productivity. The application of silicon had no significant effect on the variables, while the irrigation depths afforded linear growth for each variable, with the highest productivity (10,459.3 kg ha^{-1}) obtained for the greatest irrigation depth of 600 mm (150% of the ETc).

Key words: Zea mays L. Water deficit. Productivity.

RESUMO - O sucesso do uso da irrigação está condicionado a adoção de um manejo eficiente, fato dependente da determinação de uma correta lâmina. Em função da escassez hídrica enfrentada nos últimos anos, evidenciou-se a necessidade de estratégias que possibilitem a redução da quantidade de água aplicada às culturas, sem redução de produtividade, dentre essas, a aplicação de silício, associada a diversos efeitos benéficos para o vegetal, pode aumentar a eficiência do uso da água. Assim, objetivou-se estudar o manejo de lâminas de irrigação versus doses de silício, aplicadas via foliar, na cultura do milho verde, sob clima semiárido. O experimento foi conduzido na área do Instituto Federal do Ceará, Campus de Iguatu, CE, com o híbrido AG1051, de agosto a novembro de 2017. O delineamento experimental foi em blocos ao acaso com parcelas subdivididas, e quatro blocos. Nas parcelas avaliou-se cinco lâminas de irrigação (50, 75, 100, 125 e 150% da ETc) e nas subparcelas quatro doses de silício (50, 100, 150 e 200% do recomendado). As variáveis de crescimento, analisadas aos 15, 30, 45, 60 e 75 dias após a semeadura (DAS), foram: massa seca das folhas, do colmo e total; e as produtivas, avaliadas ao 81 DAS, foram: diâmetro e comprimento da espiga sem palha, massa da espiga com e sem palha e produtividade. A aplicação de silício não influenciou significativamente as variáveis, enquanto as lâminas proporcionaram crescimento linear para todas, com maior produtividade (10.459,3 kg ha^{-1}), obtida para a maior lâmina de 600 mm (150% da ETc).

Palavras-chave: *Zea mays* L. Déficit hídrico. Produtividade.

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INTRODUCTION

Maize is widely grown and consumed on all continents. It is highly adaptable to tropical, subtropical and temperate climates (DUARTE *et al.*, 2016), and in the semi-arid region of north-eastern Brazil, cultivation is often aimed at green-ear production, a typical activity of family farming, with social, economic and nutritional importance (BRITO *et al.*, 2013; SOUZA FILHO *et al.*, 2016), where the AG1051 hybrid is preferred for this type of production (BLANCO *et al.*, 2011).

Variability in the spatial and temporal distribution of the rainfall, characteristic of the semi-arid region of north-eastern Brazil, underlines the use of irrigation to achieve high agricultural production and a reduction in climate dependence (BEZERRA *et al.*, 2020). This has increased the irrigated area of the region, which in 2006, was greater than 1 Mha. However, during the previous decade the area had been relatively stable or even reduced, a consequence of lower investment in water infrastructure and of the water crisis itself. In the state of Ceará, the irrigated area increased from 1960 (11,389 ha) to 2006 (117,381 ha), undergoing a drastic reduction to 70,449 ha in 2015 (AGÊNCIA NACIONAL DE ÁGUAS, 2017).

In this scenario, the use of irrigation has generated concern due to high water consumption, which in many cases is due to inappropriate management; this seems contradictory, since, in order to fully enjoy the benefits of irrigation, it is necessary to have good management without an excess or deficit of water (AZEVEDO *et al.*, 2018). Different irrigation depths have been studied for cultivating maize. In Sumé (DANTAS JUNIOR; CHAVES; FERNANDES, 2016) and Pombal (BRITO *et al.*, 2013) in Paraíba, 528 mm (100% ETc) and 680.4 mm (80% ETc) are necessary to achieve the highest percentage of commercial ears and ear weight, respectively. In Chapadão do Sul, Mato Grosso do Sul (MS), Souza *et al.* (2016) used 346.63 mm (85% ETc) during the winter/spring and 278.3 mm (50% ETc) during the summer/autumn for the greatest ear weight and quality. While in Teresina, Piauí (PI), Blanco *et al.* (2011) obtained the highest technical production of green ears with 530 mm. These results show that the appropriate irrigation depth may vary depending on the soil and climate conditions (SOUZA *et al.*, 2016).

Faced with increasing water scarcity, it is essential to seek and adopt strategies that are able to increase water use efficiency in agricultural production. For example, silicon, a non-essential element for plants, is associated with various beneficial effects, since its presence in plant tissue, especially when subjected to some type of stress, can increase water use efficiency by forming a double layer of cuticular silica that reduces water loss through transpiration due to the accumulation of Si in the organs, and can be of great importance in regions where the dry period is long and severe (CHAVES *et al.*, 2013; LIMA *et al.*, 2011). Furthermore, research has shown that the foliar application of silicon can stimulate absorption of the silicon and of other nutrients (MIRANDA *et al.*, 2018).

In this context, the aim of the present work was to study irrigation-depth management versus silicon doses via foliar application in maize, for green-ear production under the conditions of a semi-arid climate.

MATERIAL AND METHODS

The experiment was conducted in the field, in an experimental area belonging to the Federal Institute of Education, Science and Technology of Ceará (IFCE), Iguatu Campus, located at 06°21' S, 39°17' W, at an altitude of 217.8 m. According to the Köppen methodology, the climate in the region is type BSw'h', hot semi-arid, with mean temperatures always greater than 18 °C during the coldest month. The historical mean annual rainfall in the district of Iguatu is 867 ± 304 mm (1932 to 2011), while the mean potential evapotranspiration is 1,988 mm year^{1}, with greater values during the seven months of lowest rainfall (June to December) (SANTOS *et al.*, 2017).

The monthly mean data for the climate variables collected during the experiment, from August to November 2017, are shown in Table 1.

Before setting up the experiment, subsamples of soil were collected from the 0 to 0.20 m layer, which were then homogenised and submitted to laboratory analysis to determine their physical and chemical characteristics (Tables 2 and 3).

Table 1 - Monthly data for climate variables during the experiment

Month	Temperature (°C)	Relative Humidity (%)	Wind speed (m s^{-1})	Rainfall (mm)	EToPM* (mm day^{-1})
August	28.21	44.37	2.47	0.0	5.65
September	28.76	40.66	2.85	0.0	6.07
October	29.77	43.55	2.41	15.6	5.67
November	29.72	47.33	2.31	0.0	5.24

* ETo PM – Penman-Monteith Reference Evapotranspiration. Source: INMET automatic weather station (Iguatu-A319)

Table 2 - Physical characterisation of the soil in the experimental area in the 0.0 to 0.2 m layer prior to setting up the experiment

Characteristic	Depth 0 to 0.2 m
Coarse sand (g kg^{-1})	388
Fine sand (g kg^{-1})	354
Silt (g kg^{-1})	204
Clay (g kg^{-1})	54
Textural Class	Sandy Loam
Bulk density (kg m^{-3})	1.500
*ECse (dS m^{-1})	0.4

Table 3 - Chemical characterisation of the soil in the experimental area in the 0.0 to 0.2 m layer prior to setting up the experiment

Chemical characterisation										
g kg^{-1}				mmolc dm^{-3}					%	
C	OM	N	K+	Ca^{2+}	Mg^{2+}	Na^{+}	$H^{+} + Al^{3+}$	SB	V	ESP
14.25	24.56	1.53	3.61	37.5	20	0.16	N. D.	24.56	100	0

OM = organic matter; ESP = Exchangeable Sodium Percentage; V% = Base saturation – (Ca^{2+} + Mg^{2+} + Na^{+} + K^{+} / CEC) x 100; CEC = Cation exchange capacity – [Ca^{2+} + Mg^{2+} + Na^{+} + K^{+} + (H^{+} + Al^{3+})]; SB = Sum of bases (Ca^{2+} + Mg^{2+} + Na^{+} + K^{+}). Source: Soil, Water and Plant Tissue Laboratory of IFCE – Limoeiro Campus, 2017

The experimental design was of randomised blocks, with 20 treatments and four blocks. The treatments were arranged in subdivided plots, where the five treatments with the different irrigation depths, comprising the experimental plots, corresponded to irrigation levels of 50%, 75%, 100%, 125% and 150% of the ETc (mm day^{-1}). The subplots consisted of four doses of silicate fertiliser: 0 (control), 0.75, 1.5, and 3 g L^{-1}, corresponding to 0%, 50%, 100% and 200% of the manufacturer's recommended dose for the commercial product used, whose composition was Ca 5.8%, Mg 1.2%, S 1.3%, Cu 3% and Si 10%.

The crop used was the AG 1051 double maize hybrid (*Zea mays* L.), sown directly into the soil on 15 August 2017, at a spacing of 1.0 m between rows and 0.2 m between plants, with two seeds per hole at a depth of 0.04 m. Emergence took place five days after sowing (DAS); thinning was carried out at 14 DAS, leaving 1 plant per hole. Each experimental plot occupied an area of 20.0 m^2 (4.0 x 5.0 m), and consisted of 4 rows, 5 m long and 1 m wide, where each individual row comprised one subplot with an area of 5 m^2 and contained 25 plants.

A drip irrigation system was used, with one lateral line per plant row, consisting of a flexible polyethylene drip tape, 16 mm in diameter, containing integrated self-compensating drippers spaced 0.2 m apart, with an individual flow of 1.6 L h^{-1} at a working pressure of 100 kPa.

Irrigation management consisted of replenishing the crop evapotranspiration daily with the water depth obtained from the sequential climatological water balance, simplified in Equation 1.

$$LL = ETc.Ft - Pe \qquad (1)$$

where:

LL - net irrigation depth, mm;

ETc - crop evapotranspiration, mm;

Ft - adjustment factor based on the treatment, of 0.50, 0.75, 1.00, 1.25 and 1.5 (respectively for 50%, 75%, 100%, 125% and 150% of the ETc);

Pe - effective precipitation, mm.

The Pe was calculated as per the method of the US Soil Conservation Service (SMITH, 1992) and was not accumulated the following day (Pe ≤ ETc), while the ETc was obtained by Equation 2.

$$ETc = Eto.Kc \qquad (2)$$

where:

ETo - reference evapotranspiration, mm;

Kc - crop coefficient for each stage of development (dimensionless).

The ETo was estimated using the Penman-Monteith method, FAO-56 (ALLEN *et al*., 1998) with climate data obtained from the INMET automated station installed near the experimental area on the IFCE campus. The values for the crop coefficient (Kc) were presented by Santos *et al.* (2014), for green maize 'AG1051' at four stages of development.

The gross irrigation depth was estimated as per Equation 3.

$$GD = \left(\frac{LL}{CCU}\right) \quad (3)$$

where:

GD - gross irrigation depth, mm;

CCU - Christiansen coefficient of uniformity, decimal.

The different treatments began at 14 DAS (days after sowing). Up to 13 DAS each treatment received an irrigation depth equal to 100% of the ETc. The total depth for each treatment was 229 mm (50% ETc), 321 mm (75% ETc), 413 mm (100% ETc), 507 mm (125% ETc) and 600 mm (150% ETc).

Fertilisation was carried out based on the soil analysis and the recommendations of Pereira Filho, Vasconcelos e Cruz (2003) for green maize, applying 170 kg ha^{-1} nitrogen (urea - 45% N), 60 kg ha^{-1} phosphorus (single superphosphate - 18% P_2O_5) and 40 kg ha^{-1} potassium (potassium chloride - 60% K_2O).

The phosphorus was applied in a single dose of 167 g per row for all treatments as base fertiliser; while the doses of N and K were divided and applied via fertigation as cover based on the absorption rate of the plant.

For the growth analysis, plants were collected for evaluation at 15, 30, 45, 60 and 75 DAS. The variables under analysis were leaf dry weight (LDW), stem dry weight (SDW) and total dry weight (TDW). The harvest was carried out manually at 81 DAS, when the ears were removed and the following variables evaluated: ear diameter with no husks (EDNH), ear length with no husks (ELNH), ear weight with husks (EWWH), ear weight with no husks (EWNH) and productivity (PROD).

The different irrigation depths were analysed in the plots, and the different levels of foliar-applied silicon in the subplots. The periods for evaluating the above growth variables were analysed in the sub-plots. The data for the variables under evaluation were submitted to analysis of variance by F-test at 1% and 5% probability. Whenever a significant effect on the interactions between the factors under study was proven, the data were analysed following the procedures inherent in multiple linear regression analysis and plotted on a response surface chart. In cases where a significant isolated effect was proven for a factor, the data were submitted to regression analysis and represented on a trendline chart. The analysis was carried out using the Microsoft Excel® (v2010), ASSISTAT® (v7.6 beta) and Table Curve® 3D v4.0.01 software.

RESULTS AND DISCUSSION

The results of the analysis of variance for the variables leaf dry weight (LDW), stem dry weight (SDW) and total dry weight (TDW) as a function of the factors irrigation depth and silicon dose for the different periods, showed that the irrigation depth and different periods significantly influenced all the growth variables under study, both when investigating the isolated factors and in the interaction between the factors at a level of 1% probability by F-test; whereas the silicon dose had no effect on the variables.

An increasing linear adjustment can be seen for the variables under study with the models that were found, where the highest values of 38.25 g plant^{-1} were estimated for LDW, 53.73 g plant^{-1} for SDW and 140.96 g plant^{-1} for TDW, obtained at the greatest applied irrigation depth of 600 mm (equivalent to 150% of the ETc) and at the final period of evaluation, 75 DAS (Figure 1).

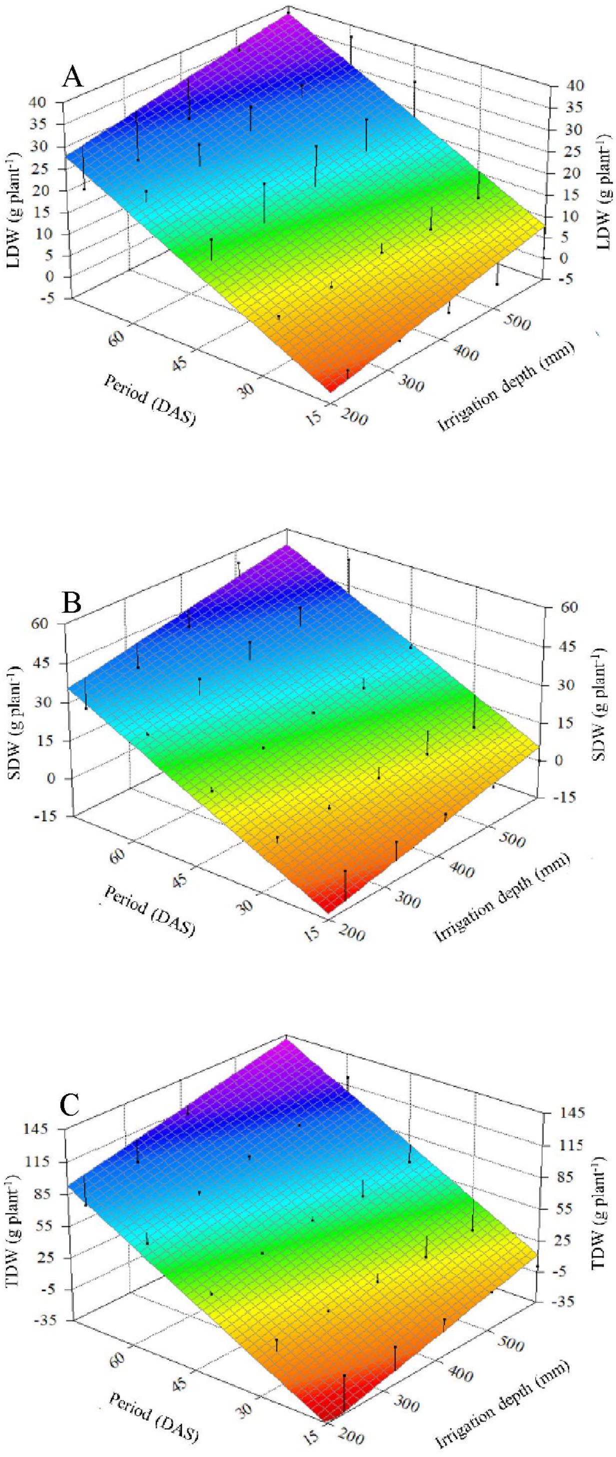
When the values for LDW, SDW and TDW obtained with the best treatment of 150% of the ETc at 75 DAS were compared with the estimated result for the irrigation depth of 100% of the ETc for the same period of evaluation, the former was higher by 14.55%, 19.02% and 19.07%, respectively. This suggests that the irrigation depth of 100% of the ETc obtained using the values for Kc proposed by Santos *et al.* (2014) was not sufficient for maximum crop performance.

In an experiment with irrigation depths in maize in Pombal, Paraíba, Brito *et al.* (2013) also obtained a linear response for leaf biomass in maize plants as a function of the applied depths, obtaining the highest values for the greatest evaluated depth of 854.6 mm, corresponding to 120% of the ETc. The authors in question emphasise that this linear response may be associated with the limitation on the Kc used in the study, and these can be supposed to be limited for maize cultivation in the study region; this can also be said in relation to the Kc described by Santos *et al.* (2014).

The positive response of leaf dry weight to the increases in irrigation depth in both studies is related to the turgor pressure necessary for the flow of organic material in the plant, since, when the cells are turgid, a result of sufficient water availability, the product of photosynthesis can be used to transform CO_2 from the air into more complex molecules that, once formed, are conducted to the drain cells through the phloem using the energy of the pressure exerted by the solution, a process that results in the formation and growth of plant biomass (BRITO *et al.*, 2013; TAIZ; ZEIGER, 2009).

From the value for SDW, it can again be seen that the applied water depth did not meet the water requirements of the plant, preventing maximum crop performance, and

Figure 1 - Response surface for leaf dry weight (LDW) (A), stem dry weight (SDW) (B) and total dry weight (TDW) (C) in green maize as a function of irrigation depth (mm) and period of evaluation (DAS)[1]



LDW (Z) = -15.3362** + 0.0259*x + 0.5071**y; r2 = 0.77

SDW (Z) = -33.93** + 0.0459**x + 0.8013**y; r2 = 0.86

TDW (Z) = -93.1179** + 0.1207**x + 2.1547**y; r2 = 0.86

[1] (**) significant at 1% and (*) 5% probability by t-test

corroborating the statement that the seasonal demand for water by maize can vary with the soil and climate conditions in the region of cultivation. This is reinforced by the present study, since even using Kc values obtained for the same hybrid and under similar climate conditions, the amount of water was not sufficient to meet the demand of the plants. It should be noted that the flowering and grain-filling stages are the most critical in relation to the water demand of the crop, so that water stress at this stage can cause a variety of damage, especially a reduction in both growth and productivity (NASCIMENTO *et al.* al., 2015).

For TDW, in an experiment with green maize in Pombal, Paraíba, Brito *et al.* (2013), evaluating the physiological aspects of the plants, found that irrigation levels mainly influenced photosynthesis (A), stomatal conductance (gs), transpiration (E) and intrinsic carboxylation efficiency (A/Ci), and obtained an increasing linear response for A, gs and A/Ci. The authors also add that stomatal conductance was the physiological variable most sensitive to water stress. As such, under conditions of stress, the plant closes its stomata, which reflects in the formation of carbohydrates via photosynthesis, and in the accumulation of plant biomass, as seen here.

A sufficient increase in water availability is also associated with increased nitrogen uptake, a fact that substantially contributes to a linear increase in biomass in maize plants (CAMPELO *et al.*, 2019).

Thus, when the plant is submitted to better soil water availability, the flow of sap through the vessels is facilitated, generating a greater flow of sap to the shoots, with a consequently larger flow of water to the atmosphere, and greater CO_2 assimilation. In this way, the plant is able to transform CO_2 into organic molecules to be used as required by the plant (TAIZ; ZEIGER, 2009). Hence, with better water availability, it is assumed that more organic compounds were produced, which afforded greater growth for the green maize, with an increase in total dry weight.

For the results of the variables ear diameter with no husks (EDNH), ear length with no husks (ELNH), ear weight with husks (EWWH), ear weight with no husks (EWNH) and productivity (PROD) for green maize, as a function of the irrigation depth and silicon dose, a significant effect can only be seen at a level of 1% probability for the irrigation depths, with the silicon doses and the interaction between the factors showing no significant effect by F-test (Table 4).

The variables EDNH, ELNH, EWWH, EWNH and PROD in the green maize showed increasing linear behaviour for increases in the applied irrigation depth, with the highest values of 41.16 mm, 17.04 cm, 209.2 g ear^{-1}, 138.7 g ear^{-1} and 10,459.3 kg ha^{-1} obtained with application of the highest evaluated depth of 600 mm (150% of the ETc). These values

Table 4 - Summary of the analysis of variance for ear diameter with no husks (EDNH), ear length with no husks (ELNH), ear weight with husks (EWWH), ear weight with no husks (EWNH) and productivity (PROD) in green maize as a function of irrigation depth (L) and silicon dose (Si)

SV	DF	Mean square				
		EDNH	ELNH	EWWH	EWNH	PROD
Blocks	3	41.05^{ns}	34.15*	2543.16*	1163.70*	6357929.96*
Ir. Depth (L)	4	1079.88**	122.16**	57942.14**	28504.72**	144855404.71**
Residual a	12	19.69	9.37	552.11	279.42	1380289.14
Silicon (Si)	3	27.76^{ns}	6.06^{ns}	1661.80^{ns}	559.24^{ns}	4154515.83^{ns}
L x Si	12	18.38^{ns}	7.72^{ns}	603.50^{ns}	375.49^{ns}	1508751.16^{ns}
Residual b	45	32.43	9.35	1000.37	599.64	2500928.68
Total	79	-	-	-	-	-
CV - L (%)	-	14.09	22.06	17.56	19.55	17.56
CV - Si (%)	-	18.09	22.03	23.63	28.65	23.63

** significant at 1% by F-test; * * significant at 5% by F-test; $^{(ns)}$ not significant by F-test. SV - Source of variation; DF - Degrees of freedom

are, respectively, 31.01%, 22.93%, 56.8%, 61.72% and 56.8% greater than those obtained with the recommended irrigation depth of 413 mm, which was equivalent to 100% of the ETc (Figure 2).

Similar to the present study, Blanco *et al.* (2011), in an experiment with the AG-1051 green maize hybrid intercropped with cowpea under different irrigation depths and phosphorus doses in Teresina, PI, also found a positive linear response for diameter and ear length as a function of the applied irrigation depth, the authors having evaluated depths of up to 220% of the ETc (565 mm) in their study.

Analyzing the productivity of green maize ears as a function of different water regimes in Teresina, PI, using the AG-1051 hybrid, Nascimento *et al.* (2017) obtained a positive linear response for the diameter and ear length with and with no husks as a function of the increases in water availability for the crop. The authors evaluated five irrigation depths from 25% of the ETo at regular intervals up to 125% of the ETo, ranging from the application of 165.51 mm to 340.57 mm of water. Such results show the strong dependence of the characteristics of the ears of the AG-1051 green maize hybrid on the application of water, with this response, despite having shown positive behaviour to the increases in irrigation, showing variable amplitude, considering that the behaviour shown here was obtained for different intervals of irrigation depth.

Regarding ear weight, in Chapadão do Sul, MS, Souza *et al.* (2016), evaluating the behaviour of green maize as a function of irrigation depths from 50% to 125% of the ETc, found quadratic behaviour for ear weight with no husks, with a maximum value of 244 g ear^{1} for an irrigation depth of 87.8% of the ETc.

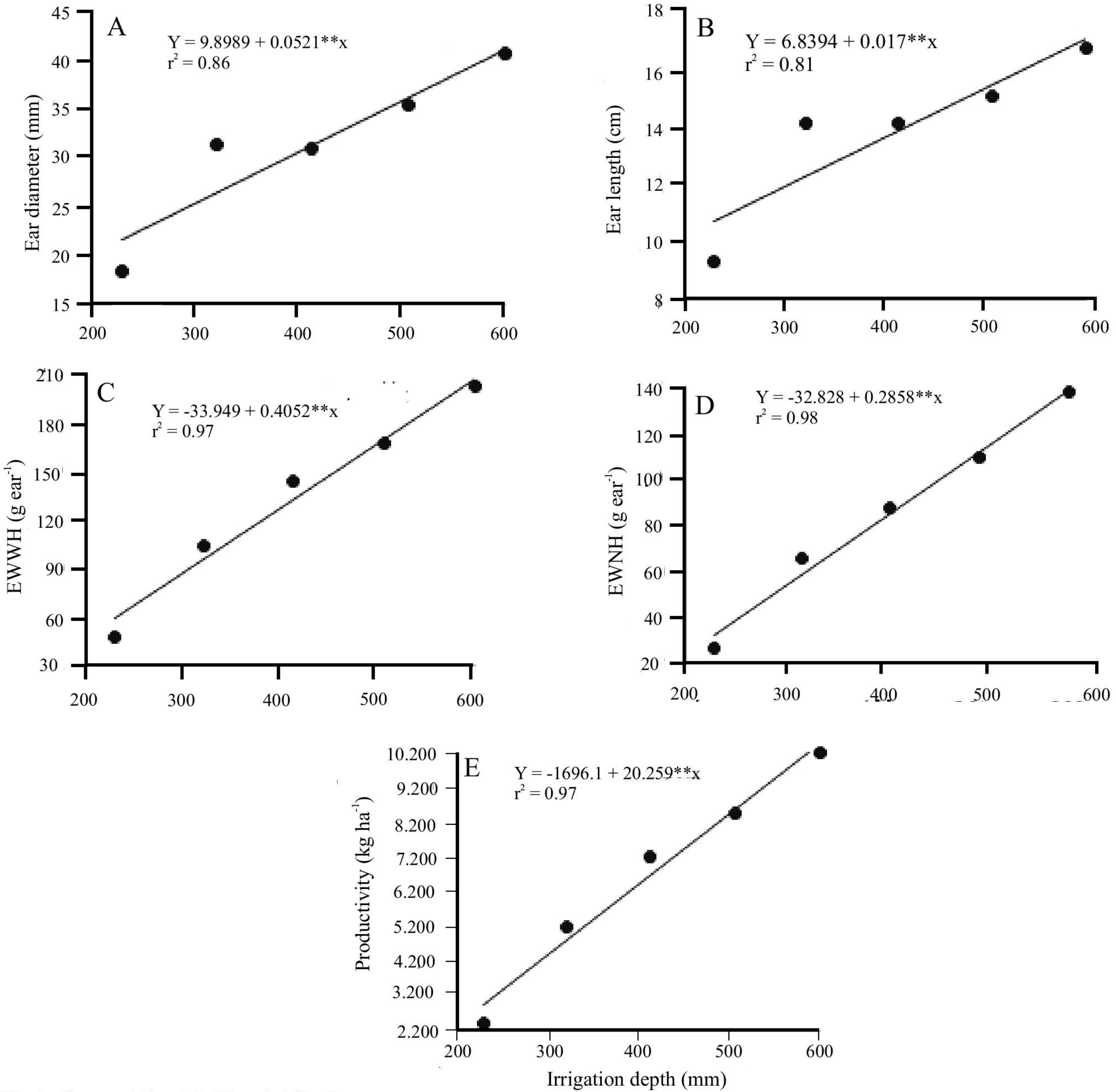
Ear weight is an important factor in maize cultivation, since, among the most important characteristics researched by Liao (2014), ear weight stood out for its positive contribution to grain yield.

These observations point to the importance of estimating the correct irrigation depth for the crop in order to increase the weight of the ears, considering that increases in this variable are responsible for increases in productivity, and are even more relevant due to a strong dependence on the increase in water, determined by means of the linear responses obtained.

Assessing the response of green maize ‘AG1051’ to irrigation depths and potassium doses in the state of Paraíba, where they evaluated irrigation depths ranging from 25% to 150% of the ETpc, Dantas Júnior, Chaves e Fernandes (2016) found quadratic behaviour for husked-ear productivity, with a maximum of 11,340 kg ha^{-1} for a depth of 660 mm, equivalent to 125% of the ETpc. Such a comparison shows that the authors in question obtained greater productivity than found in the present work, albeit using a greater amount of water, even though this was equal to a lower percentage of the ETpc; it is therefore suggested that an increase in the applied irrigation depth would probably increase the productivity of the maize crop in the region under study, showing once again, that the values for Kc used are not sufficient for the growing conditions employed.

In a study of the BRS Gorutuba cultivar in Petrolina, Pernambuco, Melo *et al.* (2018) obtained a linear response for green-ear productivity (9,187.2 kg ha^{-1}) as a function of the irrigation depth, which ranged from 30% to 120% of the ETc (559.41 mm). According to the authors, the positive response of the maize is related to water availability favouring nutrient absorption due to an adequate flow of water being absorbed by the plant, where the larger amount of water stored for the crop at

Figure 2 - Ear diameter with no husks (A), ear length with no husks (B), ear weight with husks (EWWH) (C), ear weight with no husks (EWNH) (D) and productivity (E) in green maize as a function of irrigation depth (mm)[1]



[1] (**) significant at 1% and (*) 5% probability, by t-teste

the greatest irrigation depths affords a reduction in the stress resulting from water deficit during the formation and development period of the ears, and results in an increase in crop productivity (OLIVEIRA *et al.*, 2017).

However, similar to the present work, it was not possible for the authors to extract the maximum crop response, possibly due to using values for Kc that limited full development of the crop.

Furthermore, in an experiment with irrigation depths in a crop of green maize (AG1051 hybrid) in Teresina, PI, Nascimento *et al.* (2015), evaluating depths from 25% to 125% of the ETo also obtained a positive linear response for ear productivity, with a value of 8,465.62 kg ha^{-1} for a depth of 125% of the ETo (340.57 mm). It can be seen that, similar to those presented by Melo *et al.* (2018) (above), the productivity obtained, and the respective water depth applied were lower than those found in the present work.

Corroborating the answers of the authors presented above, the behaviour for productivity obtained here is evidence of the strong dependence and response of the green maize crop to adequate water availability. As such, for the greatest irrigation depth, the increase in productivity is associated with the largest amount of water stored in the soil for the crop that affords a reduction in the stress resulting from water deficit during the formation and development period of the ears and results in an increase in productivity (OLIVEIRA *et al.*, 2017). This greater water availability is further responsible for better leaf development, which affords greater production of photoassimilates and a consequent increase in ear productivity (NASCIMENTO *et al.*, 2017).

The linear response obtained for each of the variables under study as a function of the irrigation depth, show that for the study region, the amount of water applied was less than the amount needed to obtain the best crop performance (AG 1051 hybrid). Percentage values of the ETc greater than those that were analysed should be evaluated, with a view to reaching the inflection point of the variables in order to correct the Kc values, for distribution and use in the region, providing irrigation management suited to the local conditions.

CONCLUSIONS

1. The growth variables of the green maize were linearly influenced by the irrigation depths and the different periods of evaluation, with higher values obtained for the depth of 600 mm, equivalent to 150% of the ETc, 75 days after sowing;
2. The production variables of the green maize responded with linear growth to the irrigation depths, obtaining greater values at the irrigation depth of 600 mm, equivalent to 150% of the Etc;
3. The foliar application of silicon had no effect on the crop of green maize.

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REFERENCES

AGÊNCIA NACIONAL DE ÁGUAS (BRASIL). **Atlas irrigação**: uso da água na agricultura irrigada. Brasília: ANA, 2017. 86 p.

ALLEN, R. G. *et al.* **Crop evapotranspiration**: guidelines for computing crop water requirements. Roma: FAO, 1998. 328 p.

AZEVEDO, B. M. de *et al.* Irrigation depths and yield response factor in zucchini cultivation. **Revista Brasileira de Engenharia Agrícola e Ambiental**, v. 22, n. 6, p. 401-406, 2018.

BEZERRA, R. U. *et al.* Produção e qualidade da abóbora maranhão sob influência de lâminas de irrigação e doses de nitrogênio. **Irriga**, v. 25, n. 1, p. 87-101, 2020.

BLANCO, F. F. *et al.* Milho verde e feijão-caupi cultivados em consórcio sob diferentes lâminas de irrigação e doses de fósforo. **Pesquisa Agropecuária Brasileira**, v. 46, n. 5, p. 524-530, 2011.

BRITO, M. E. B. *et al.* Crescimento, fisiologia e produção do milho doce sob estresse hídrico. **Bioscience Journal**, v. 29, n. 5, p. 1244-1254, 2013.

CAMPELO, D. H. *et al.* Growth, production and water and nitrogen use efficiency of maize under water depths and nitrogen fertilization. **Revista Brasileira de Engenharia Agrícola e Ambiental**, v. 23, n. 10, p. 747-753, 2019.

CHAVES, L. H. G. *et al.* Adubação silicatada e lâminas de irrigação no crescimento e produção da cana-de-açúcar. **Global Science and Technology**, v. 6, n. 3, p. 67-78, 2013.

DANTAS JUNIOR, E. E.; CHAVES, L. H. G.; FERNANDES, J. D. Lâminas de irrigação localizada e adubação potássica na produção de milho verde, em condições semiáridas. **Revista Espacios**, v. 37, n. 27, p. 26, 2016.

DUARTE, E. C. da C. *et al.* Manejo de herbicidas no controle de plantas daninhas e sua influência no crescimento e produção do milho híbrido AG 1051. **Revista AGROTEC**, v. 37, n. 1, p. 71-80, 2016.

LIAO, C. Study on two agronomic traits associated with kernel weight in a maize RIL segregation population. *In:* LI, S. *et al.* (ed.) **Frontier and future development of information technology in medicine and education**. Netherlands: Springer Netherlands, 2014. cap. 79, p. 811-817.

LIMA, M. de A. *et al.* Aplicação de silício em milho e feijão-de-corda sob estresse salino. **Revista Ciência Agronômica**, v. 42, n. 2, p. 398-403, 2011.

MELO, R. F. de *et al.* Desenvolvimento e produtividade do milho brs gorutuba sob diferentes lâminas de irrigação e adubação orgânica. **Revista Científica Intelletto**, v. 3, n. 1, p. 1-14, 2018.

MIRANDA, P. S. *et al.* Aplicação de silício na cultura do milho. **Revista de Ciências Agroambientais**, v. 16, n. 1, p. 1-6, 2018.

NASCIMENTO, F. N. do *et al.* Desempenho da produtividade de espigas de milho verde sob diferentes regimes hídricos. **Revista Brasileira de Milho e Sorgo**, v. 16, n. 1, p. 94-108, 2017.

NASCIMENTO, F. N. do *et al.* Parâmetros fisiológicos e produtividade de espigas verdes de milho sob diferentes lâminas de irrigação. **Revista Brasileira de Milho e Sorgo**, v. 14, n. 2, p. 167-181, 2015.

OLIVEIRA, F. C. C. *et al*. Características químicas de um argissolo e a produção de milho verde nos tabuleiros costeiros sergipanos. **Revista Brasileira de Ciências Agrárias**, v. 12, n. 3, p. 354-360, 2017.

PEREIRA FILHO, I. A.; VASCONCELOS, C. A.; CRUZ, J. C. Adubação para o cultivo do milho verde. *In:* PEREIRA FILHO, I. A. (ed.). **O cultivo do milho-verde**. Brasília, DF: Embrapa Informações Tecnológicas, 2003. p. 68-79.

SANTOS, J. C. N. *et al*. Land use impact on soil erosion at different scales in the Brazilian semi-arid. **Revista Ciência Agronômica**, v. 48, n. 2, p. 251-260, 2017.

SANTOS, W. de O. *et al*. Coeficientes de cultivo e necessidades hídricas da cultura do milho verde nas condições do semiárido brasileiro. **Irriga**, v. 19, n. 4, p. 559-572, 2014.

SMITH, J. A. Precipitation. *In:* MAIDMENT, D. R. (ed.). **Handbook of hydrology**. New York: McGraw-Hill, 1992. p. 3.1-3.47.

SOUZA, E. J. de *et al*. Características da espiga do milho doce produzido sob diferentes lâminas de irrigação e doses nitrogenadas. **Revista Engenharia na Agricultura**, v. 24, n. 1, p. 50-62, 2016.

SOUZA FILHO, A. L. *et al*. Nitrogen and phosphate fertilizer on green corn grown in succession to the melon crop. **Horticultura Brasileira**, v. 34, n. 3, p. 392-397, 2016.

TAIZ, L.; ZEIGER, E. **Fisiologia vegetal**. 4. ed. Porto Alegre: Artmed, 2009. 819 p.

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