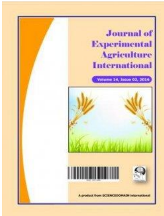

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Quality of Watermelon 'Top Gun' Fruit Submitted to Different Irrigation Depths in the Northwest Region of Espírito Santo

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Authors' contributions

This work was carried out in collaboration between all authors. Author RPP designed the study, conducted the experiment in the field with authors RTOA, FV, VSO, EJS, LHLP and JVGS managing the writing of the manuscript. Authors RPP and RTOA managed the analyses of study. Author RPP and VSO performed the statistical analysis. Authors GSC and RPP performed translation of the manuscript. All authors read and approved the final manuscript.

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ABSTRACT

Watermelon is one of the main vegetable crops in Brazil and allows the management of its irrigation, an indispensable factor for its productive success. This paper aimed to evaluate the quality of watermelon 'Top Gun' fruit (*Citrullus lanatus*), submitted to different irrigation depths. The study took place in the horticulture sector at the Federal Institute of Espírito Santo, Campus Itapina, located in Colatina, Espírito Santo. The experimental design was completely randomized, containing four repetitions of each treatment. The treatments consisted in the application of six irrigation depths: 50,

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75, 100, 125, 150 and 175% of the reference evapotranspiration (ETo), calculated daily, adding up to 598.3; 628.8; 659.7; 690.9; 722.8 and 755.8 mm, respectively, for the applied irrigation depths at the end of the experiment (irrigation + rainfall). After the harvest, the watermelon fruit of each treatment were analyzed for their quality characteristics, being: total soluble solids (TSS), titratable acidity (TA), potential of Hydrogen (pH) and TSS / TA ratio. The application of different irrigation depths interfered with the quality of watermelon 'Top Gun' fruit. The irrigation depth of 658.3 mm provided a higher value of total soluble solids, a characteristic that is used as indicative of sweetness, being the most suitable for the production of higher quality watermelon fruit.

Keywords: Citrullus lanatus; total soluble solids; titratable acidity; potential of hydrogen.

1. INTRODUCTION

The watermelon (*Citrullus lanatus*) belongs to the family *Cucurbitaceae* and it is considered one of the main vegetable species cultivated in Brazil [1]. Water management is indispensable for crop, though, irrigation is often done without proper technical knowledge, leading to losses in productivity and quality. Irrigation management, besides increasing productivity, reduces excessive water use, energy costs and improves the quality of watermelon fruit [2].

The lack or excess of water has a substantial effect on yield in agricultural production [3]. Excess water creates a propitious environment to the occurrence of many diseases, which limit the development of plants, as well as cause cracking in the peel and make the fruit less tasty due to the reduction of the sugar content. The lack of water produces fruit with irregular development and in smaller quantity [2].

Irrigation is very important to obtain satisfactory results in the quality of watermelon fruit [4]. Their quality is not defined by a single characteristic but by a series of particularities responsible for their taste. The potential of hydrogen (pH), the percentage of titratable acidity and soluble solids are important factors in determining the quality of the vegetables [5].

Knowing the behavior of agricultural crops related to the amount of water applied, allows an increase in water use efficiency and more accurate decision making, which reflects economic gains [6]. Therefore, the objective of this work was to evaluate the quality of watermelon 'Top Gun' fruit submitted to different irrigation depths.

2. MATERIALS AND METHODS

The study took place in the horticulture sector at the Federal Institute of Espírito Santo, Campus Itapina, located in Colatina in the state of Espírito Santo, Brazil, located at 19°29 'South, 40°45' West and altitude of 62 meters, from October 15 to December 15, 2017. The region, according to the classification of Köppen, has Tropical Aw climate [7].

The preparation of the experimental area was done in a conventional way, with moldboard plow and disking and opening of holes 20 days before planting. The soil of the area was classified as Dystrophic Red-Yellow Latosol [8]. The fertilization was done, according to Prezotti et al. [9], based on the soil chemical analysis, referring to the 0 to 20 cm layer, presented in Table 1.

The experimental design was completely randomized, with six treatments and four repetitions. Each treatment consisted of 4 lines of 20 plants of the "Top Gun" cultivar, spaced 2.0 m between rows and 1.5 m between plants, totaling 80 plants per treatment and 480 plants throughout the experiment.

The production of the seedlings occurred through the acquisition of seeds in local commerce and planting in polyethylene bags with dimensions of 10 x 20 x 0.5 cm, filled with a conventional substrate composed of 70% of subsoil and 30% of tanned and sifted bovine manure. When the seedlings presented two formed leaves, they were transplanted to the final site.

The treatments consisted in the application of six irrigation depths: 50, 75, 100, 125, 150 and 175% of the reference evapotranspiration (ETo), calculated daily, adding up to 598.3; 628.8; 659.7; 690.9; 722.8 and 755.8 mm, respectively, for the applied irrigation depths at the end of the experiment (irrigation + rainfall). For this, a trickle irrigation system was used, with daily irrigation schedule.

The meteorological variables were measured by an ONSET® weather station, installed near the experiment, and ETo was estimated by the Penman-Monteith method FAO-56 Standard [10], by Equation 1.

Table 1. Chemical characteristics of the soil in the 0-20 cm layer

pH	O.M.	P	K	Na	Ca	Mg	Al	SB	t	CEC	V
(water)	(%)	-----	mg dm^{3}	-----	----------------------		cmolc dm^{3}		----------------		%
6.5	1.84	179.9	244	14	4.60	1.46	0.00	6.74	6.74	7.94	84.9

pH: potential of Hydrogen; OM: organic matter; P: phosphorus; K: potassium; Na: sodium; Ca: calcium; Mg: magnesium; Al: aluminum; SB: sum of bases; t: effective cation exchange capacity; CEC: cation exchange capacity at pH 7; V: percentage base saturation

$$ETo = \frac{0.408\Delta(Rn - G) + \gamma \dfrac{900}{T + 273} u_2(e_s - e_a)}{\Delta + \gamma(1 + 0.34\, u_2)} \quad (1)$$

in which ETo is the daily reference evapotranspiration (mm.d^{-1}); Rn is the daily radiation balance (MJ.m^{-2}.d^{-1}); G is the daily soil heat flux (MJ.m^{-2}.d^{-1}); T is the daily average air temperature (°C); u_2 is the daily average wind speed at 2 m high (m.s^{-1}); e_s is the saturation pressure of the daily average water vapor (kPa); e_a is the daily average water vapor pressure (kPa); Δ is the slope of the vapor pressure curve at the point of T (kPa.°C^{-1}) and γ is the psychrometric coefficient (kPa.°C^{-1}).

The crop evapotranspiration estimate for the day (ETc) was determined by equation 2, using the crop coefficient (Kc) according to the development stages of the watermelon crop, a methodology proposed by Braga & Calgaro [11].

$$ETc = ETo\ x\ Kc \quad (2)$$

in which: ETc = crop evapotranspiration for the day (mm); Kc = crop coefficient in the day; ETo = reference evapotranspiration for the day (mm).

At the end of the development of the crop, the fruit were harvested separately by treatments, presenting productivity of 19.5; 24.5; 28.2; 27.9; 31.8 and 25.3 tons of fruits per hectare in the treatments referring to 50, 75, 100, 125, 150 and 175% of ETo, respectively.

Among the fruits harvested in each treatment, a screening was carried out in order to achieve a standardization of fruits that more fully represent the treatments, removing the damaged ones or those with deviations of structural quality that do not correspond to the majority of fruit harvested in the treatment in question. Five units per treatment were randomly selected by lottery, which were taken promptly to the campus laboratory for a test of their quality characteristics.

The following quality characteristics were evaluated: a) total soluble solids (TSS), defined by the removal of the pulp from different regions of the fruit, homogenized and evaluated with an ATAGO® digital refractometer, model PAL-3, previously calibrated with water, measured in °Brix [12]; b) titratable acidity (TA), defined by the titration of a 20 mL aliquot of the fruit pulp juice and three drops of 1% phenolphthalein with a previously standardized NaOH solution (0.1 N), with results expressed in g of acid/100 ml juice; c) TSS / TA ratio, obtained by the ratio between the values obtained for the total soluble solids and the titratable acidity; d) potential Hydrogen (pH), determined with a Quimis® digital pH meter calibrated with pH 4 and 7 buffer solution [12].

The data of total soluble solids (TSS); titratable acidity (TA) and TSS / TA ratio were submitted to analysis of statistical variance (P < 0.05) by the F test through the R software [13]. When significant, they were adjusted to regression models that better explained the effect of the irrigation depths on the characteristics evaluated. The inflection points were determined through the first derivative of the regression equations.

3. RESULTS AND DISCUSSION

During the experimental period, the maximum, average and minimum temperatures varied from 24.92 to 40.26°C; 22.0 to 29.34°C and 16.87 to 24.0°C, respectively (Fig. 1). Relative humidity had a maximum value of 99.2%, minimum of 29.7% and average of 78.97% (Fig. 2). The reference evapotranspiration (ETo) ranged from 1.35 to 6.63 mm d^{-1}, with an average value of 3.52 mm d^{-1} (Fig. 3). The cumulative volume of precipitation was 270.6 mm, and its distribution can be seen in Fig. 3.

These conditions observed during the experiment, except for the humidity, fit into the ideal conditions for the production of the watermelon crop, which consists of mild to hot climate, long days and low relative humidity, optimum temperature range of 23 to 28°C, supporting from 16 to 39°C [14].

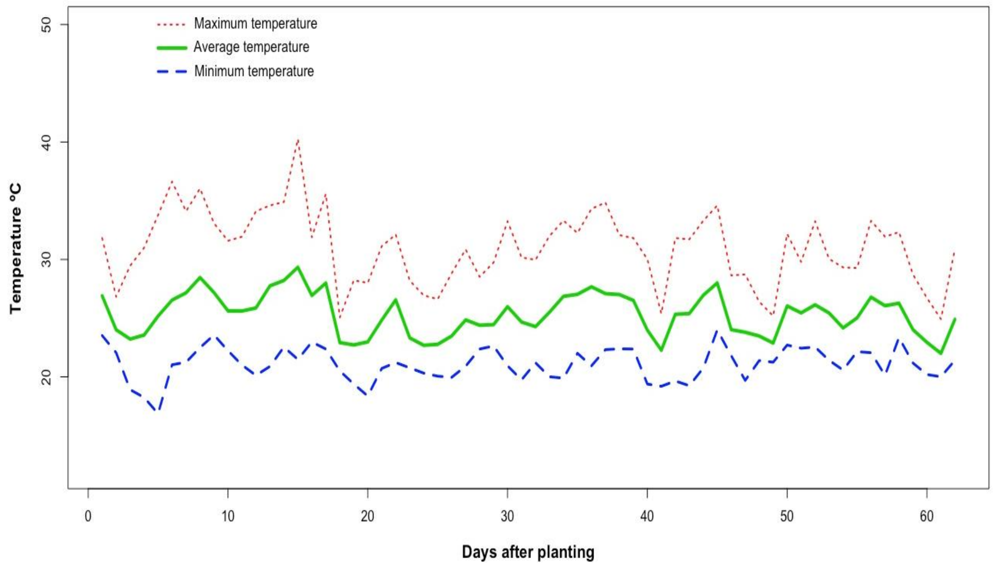

Fig. 1. Maximum, minimum and average temperatures during the experimental period in Colatina, Espírito Santo

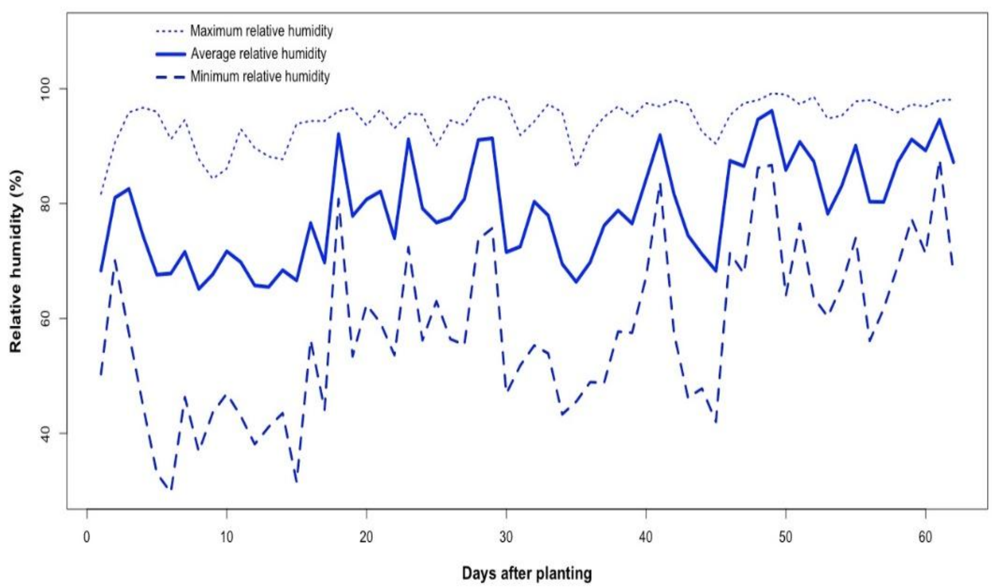

Fig. 2. Maximum, average and minimum relative humidity during the experimental period in Colatina, Espírito Santo

After the analysis of variance, a significant difference was observed at 5% probability ($P < 0.05$) for all evaluated characteristics (total soluble solids (TSS); titratable acidity (TA) and TSS / TA ratio), evidencing that the irrigation depths interfered in the quality of the watermelon 'Top Gun' fruit.

The values of total soluble solids (TSS) presented quadratic adjustment with a maximum point of 8.4°Brix in the 658.3 mm irrigation depth and coefficient of determination (R^2) of 0.85 (Fig. 4A). This value is within the range from 8 to 10°Brix pointed out by Vásquez et al. [15], as reference of market acceptability, however, it is below those indicated by Lima Neto et al. [1], who say that the minimum acceptable content for watermelon fruit is 10°Brix.

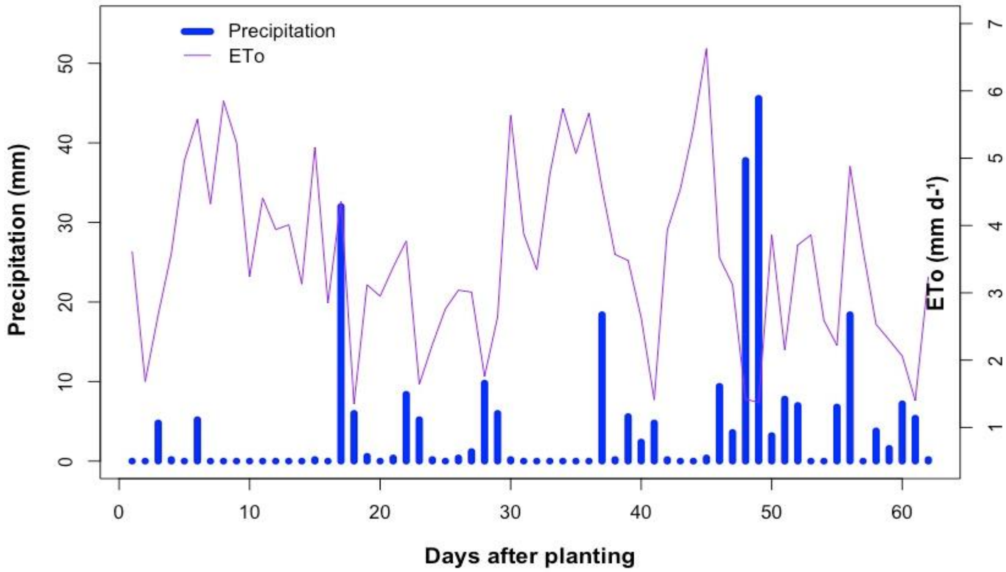

Fig. 3. Precipitation (mm) and ETo (mm d^{-1}) during the experimental period in Colatina, Espírito Santo

The maximum value of TSS found in this study is lower than those reported by Morais et al. [3], evaluating the response of watermelon plants under different levels of irrigation and nitrogen with a maximum value of 10,22°Brix in the water depth of 316 mm. On the other hand, they are similar to the values found by Lima Neto et al. [1], that analyzing the fruit quality of five watermelon varieties, reported TSS values ranging from 8.1 to 9.0°Brix. This value is still higher than that found by Pessoa et al. [16], which evaluating physical and physical-chemical characteristics of watermelon fruit, observed an average of 5.8°Brix.

The content of soluble solids (SS) is an important organoleptic characteristic and a fundamental parameter for the quality evaluation, expressed in the concentration of sugars and other solids diluted in the fruit pulp, thus relating to the flavor [17,18]. So, the higher the soluble solids value the higher the sugar content, because of that, the fruits become more desirable as raw material by the industrial sector [5].

The lack or excess of water impairs the growth of the plant, reducing or limiting the synthesis of photoassimilates, which can be noticed in the depths with smaller irrigation replacement, corresponding to 50% of the ETo, and especially in the larger ones, with 150 and 175% of ETo [19]. In the absence of water, the first line of defense of the plants is the reduction of leaf area to avoid transpiration and loss of water to the atmosphere, which limits the process of photosynthesis, reducing the production of assimilates [19]. Welles & Buitelaar [20], report that the solids content decreases significantly with the reduction of leaf area, because it reduces the photosynthetic capacity of the plants and the production of assimilates. In the same way, the excess water, especially in the final stage of the plant cycle, can cause a reduction of the TSS values due to the dilution effect of the solids through the high amount of water contained in the fruit pulp [21;22], a factor that may have provoked a certain degree of interference in the present study, due to the precipitations that occurred in the days that preceded the harvest.

The titratable acidity (TA) found in the different treatments presented a regression with quadratic behavior and maximum point of 0.19 g of citric acid/100 ml of watermelon juice in the 684.8 mm irrigation depth, with a coefficient of determination of 0.83 (Fig. 4B). The acidity is related to the organic acids and serves as a parameter of palatability of several fruits, presents a reduction in its content, with the advancement of the maturation process, thus evolving toward the neutralization, making the fruit sweeter [23,24,25].

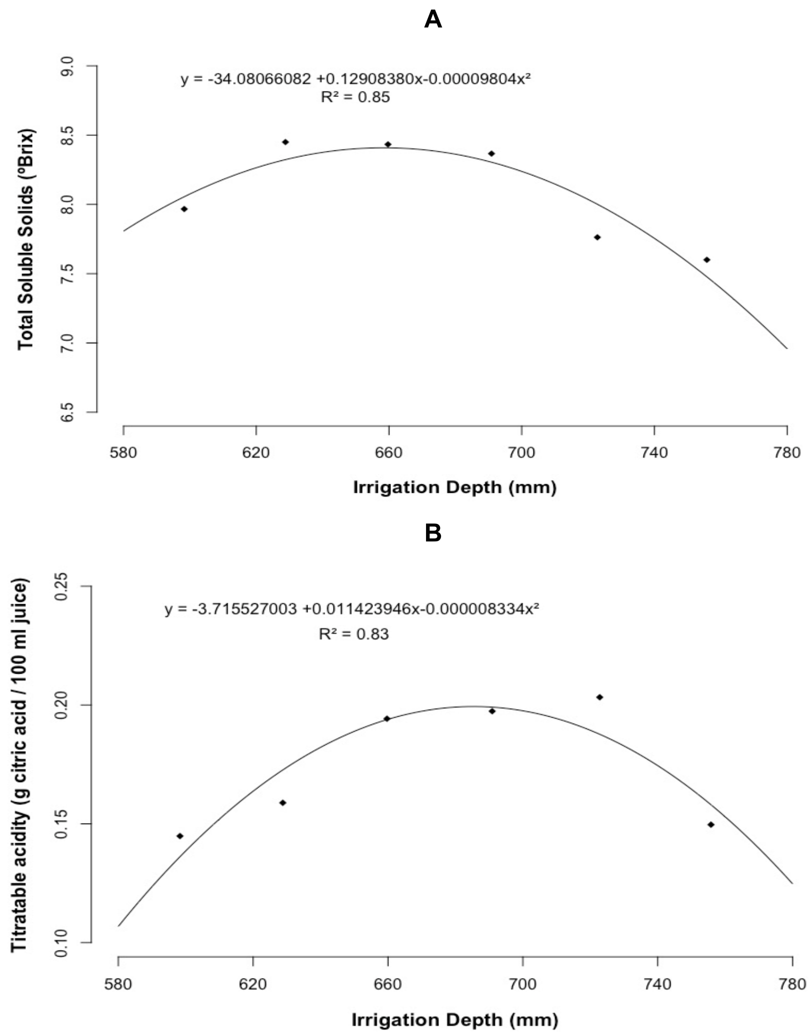

Fig. 4. Variation of total soluble solids (°Brix) (A) and titratable acidity (g of citric acid/100 ml of juice) (B) in watermelon fruit, submitted to different irrigation depths

The results found in this study corroborate those presented by Silva et al. [26], which evaluating the effect of different irrigation depths in the post-harvest of watermelon 'BRS Opara' fruit, found that the lack or excess of water interfered in the accumulation of TSS and TA. Grangeiro & Cecílio Filho [25], studying the quality of watermelon fruit using sources and potassium doses found maximum values of 0.260 and 0.268 g of acid/100 ml of juice at two different growing seasons, amounts higher than those found in this study.

The ratio between total soluble solids and titratable acidity (TSS/TA) presented a regression with quadratic behavior and it was 76% influenced by the applied irrigation depth (R^2 of 0.76). A decrease in the TSS/TA ratio was observed with the increase of the irrigation depths applied until the minimum point of 41.5%, in the 694.1 mm irrigation depth, where, from this point, the regression shows increasing behavior with the increment of the applied depths (Fig. 5A). The minimum value found in this study is similar to the maximum one observed by Ferreira [6], that evaluating the optimum irrigation depth for watermelon in Teresina/Piauí microregion presented 41.1% TSS/TA ratio for Crimson Sweet cultivar with the total irrigation depth of 145.25 mm.

The ratio TSS/TA is a good indicative of the taste of watermelon fruit, considered by Lima Neto et al. [1], as being more representative than measurements of sugars and acidity done in a separated way. This is an organoleptic and fruit maturation indicative, since, during maturation, the sugars / acids ratio presents higher values, due to the degradation of the acids and increase of the sugar content [27]. However, in situations where the soluble solids content and acidity are low, as it happened in the lowest and highest depths in this study, can generate high TSS/TA ratios causing false evaluation of the fruit flavor [25].

The pH had a decreasing linear adjustment to the increase of the applied irrigation depth, presenting R^2 0.95, being the lowest pH value observed in the highest irrigation depth of 755.8 mm, corresponding to 175% of ETo (Fig. 5B).

Lower values of pH and higher titratable acidity are considerable characteristics of quality of watermelon fruit for both *in natura* consumption and industrialization [1].

It is worth to emphasize that the quality of vegetables is not defined by a single factor, but by a group of them, thus the pH allied with the titratable acidity and soluble solids contents are responsible for the taste, through the balance of acidity and sweetness of the products [5].

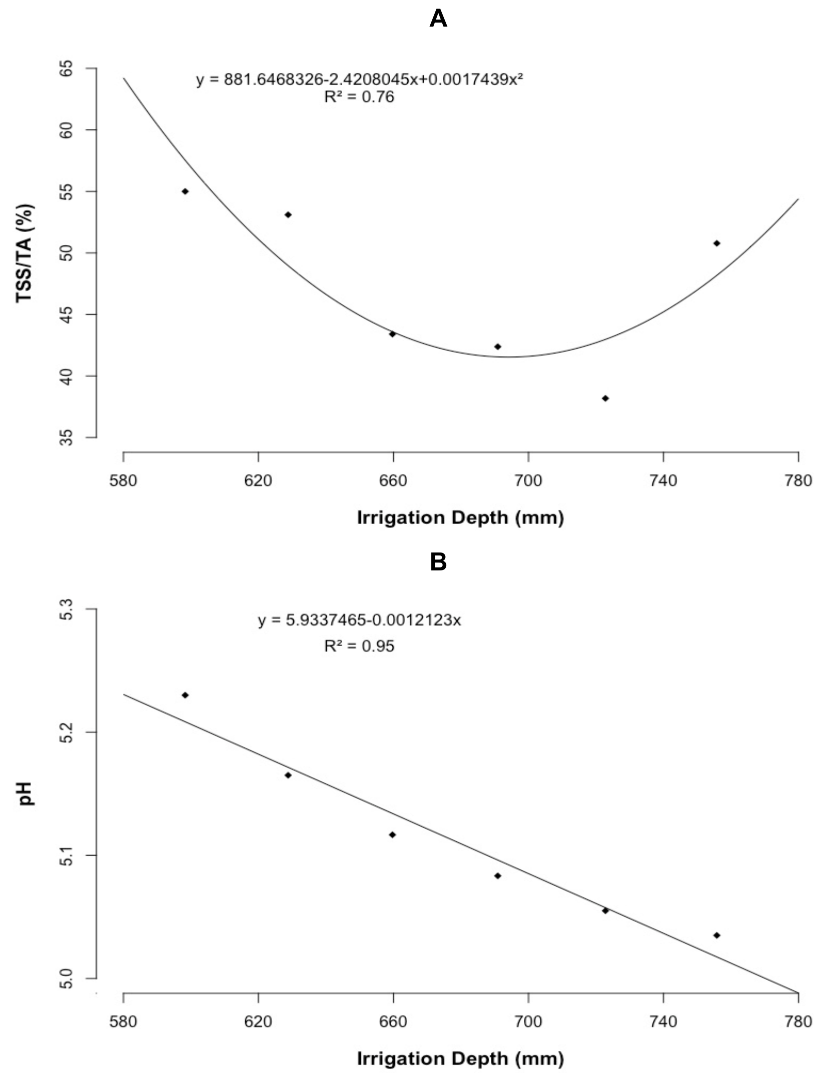

Fig. 5. TSS/TA ratio (%) (A) and pH (B) of watermelon fruit submitted to different irrigation depths

4. CONCLUSION

The application of different irrigation depths interfered in the quality of watermelon ‘Top Gun’ fruits, with variations of the characteristics analyzed (total soluble solids (TSS); titratable acidity (TA) and TSS / TA ratio).

The TSS/TA ratio provided a better value in the smallest applied irrigation depth (50%), however, isolated values of TSS and TA found in this depth were low, and they did not attribute quality to the fruit.

The 658.3 mm irrigation depth provided a higher value of total soluble solids, a characteristic that is used as an indication of sweetness and is, therefore, it is the most suitable tool for the production of watermelon ‘Top Gun’ fruit with better quality.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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