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EFFECT OF IRRIGATION DEPTHS AND FORMS OF FERTILIZATION ON RADISH PRODUCTION AND POST-HARVEST

LÂMINAS DE IRRIGAÇÃO E FORMAS DE ADUBAÇÃO NA PRODUÇÃO E PÓS-COLHEITA DO RABANETE

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ABSTRACT: The objective of this study was to evaluate the effect of different irrigation depths and the form of fertilizer application on the morphological, production and quality characteristics of radish (Raphanus sativus L.) cv. Saxa. The experiment was carried out in the city of Petrolina - PE in a randomized block design, in split plots, with four plots and two subplots (4 x 2). The factors in the plots were 60, 80, 100 and 120% of the reference evapotranspiration (ETo), and the factors in the subplots were the forms of fertilization, conventional and fertigation. The variables analyzed were fresh mass, yield, firmness, root diameter, root length, titratable acidity, soluble solids and ascorbic acid (vitamin C). It was found that the irrigation depth influenced firmness and titratable acidity in a decreasing way. Fertigation promoted higheryield, fresh mass, root length, root diameter and titratable acidity, while conventional fertilization promoted greater firmness and soluble solids. Ascorbic acid showed a divergent behavior with the increase in irrigation depth as a function of the form of fertilization used in the radish crop.

Keywords: *Raphanus sativus L, fertigation, yield, ascorbic acid, titratable acidity.*

RESUMO: Objetivou-se com este trabalho avaliar o efeito de diferentes lâminas de irrigação e da forma de aplicação da adubação nas características morfológicas, produtivas e de qualidade do rabanete (Raphanus sativus L.) cv. Saxa. O experimento foi realizado na cidade de Petrolina – PE em delineamento experimental de blocos casualizados, em parcelas subdivididas, com quatro parcelas e duas subparcelas (4 x 2). Os fatores nas parcelas foram: 60, 80, 100 e 120% da evapotranspiração de referência (ETo) e nas subparcelasa forma de adubação, sendo elas convencional e fertirrigada. As variáveis analisadas foram a massa fresca, a produtividade, a firmeza, o diâmetro, o comprimento da raiz, a acidez titulável, os sólidos solúveis e o ácido ascórbico (vitamina C). Verificou-se que a lâmina de irrigação influenciou a firmeza e a acidez titulável de forma decrescente. A adubação fertirrigada conferiu maior produtividade, massa fresca, comprimento, diâmetro e acidez titulável, enquanto a adubação convencional proporcionou maior firmeza e sólidos solúveis. E o ácido ascórbico apresentou comportamento divergente com o aumento da lâmina de irrigação em função da forma de adubação utilizada na cultura do rabanete.

Palavras-chave: *Raphanus sativus L., fertirrigação, produtividade, ácido ascórbico, acidez titulável.*

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INTRODUCTION

Radish (Raphanus sativus L.) belongs to the Brassicaceae family and is native to the Mediterranean region (FILGUEIRA, 2008). It is a small vegetable crop that produces globular roots of scarlet-bright color and white pulp, with short cycle (average of 30 days) and fast return (CARDOSO; HIRAKI 2001; LINHARES et al., 2011).

It develops in the first layers of soil, being influenced by water and physical conditions (CAETANO et al., 2015). It is considered sensitive to soil water availability, which can reduce shoot growth (SILVA et al., 2012) and cause the roots toassume a spongy aspect and cracks (FILGUEIRA, 2008). Due to its rapid development, the crop requires application of nutrients in a short period of time. Possible nutritional problems are difficult to correct during the cycle (EL-DESUKI et al., 2005; NETO et al., 2010).

Fertigation is a technique that aims to use the irrigation system for more efficient distribution of nutrients (TEIXEIRA et al., 2007). Localizedapplicationof nutrients close to the roots allows smaller loss of fertilizers by leaching and volatilization, in addition to promoting greater splitting of fertilizers, higher cost-benefit ratio compared to the conventional fertilization, and automation of the process (MARCUSSI, 2005; SANTOS, 2017). Evaluating different irrigation depths ensures an understanding of the water needs of crops under specific soil, genetic and climate conditions, being indispensable to minimize yield variations and optimize water use, besides other morphological, physiological and biochemical changes in plants (SOUSA et al., 2011; LACERDA et al., 2017).

Although many studies have already reported the positive effects of fertigation on various crops, there is a need for research on the effect of this practice on radish crop.

Thus, the objective of this study was to evaluate the effect of different irrigation depths associated with the form of fertilizer application (conventional and fertigation) on the morphological, production and quality characteristics of radish.

MATERIAL AND METHODS

The experiment was conducted with radishcrop cv. Saxa, in the Production Sector of the Agroecological Sertão, at the Campus of Agricultural Sciences of the Federal University of the São Francisco Valley (UNIVASF), Petrolina, state of Pernambuco, Brazil (geographical coordinates 09º19’22” S, 40°33’03” W and 391 m altitude), from June 24 to July 27, 2019.

According to Köppen’s classification, the climate of the region is BSh, that is, hot semi-arid with precipitation of less than 500 mm concentrated in three to four months of the year (ALVARES et al., 2013). The soil of the area was classified as Neossolo Quartzarênico (Entisol), with the physical-chemical characteristics described in Table 1.

Table 1. Physical-chemical characteristics of the soil in the 0-0.30 m layer before the experiment.

pH (H_2O)	ECse	P	H + Al	K^+	Na^+	Ca^{2+}	Mg^{2+}	Al^{3+}	C
-	$dS.m^{-1}$	$mg.dm^{-3}$	------------------		$cmol_c.dm^{-3}$	------------------------------			$g.kg^{-1}$
5.0	0.20	7.86	2.97	0.21	0.02	1.20	0.40	0.15	4.20

Physical characteristics of the soil: % sand: 86; % silt: 6; % clay: 8; Bulk density: 1.56 g cm-3andparticle density:2.70 g cm-3.

The experimental design was randomized blocks, in split plots with four plots and two subplots (4 x 2), and six replicates. The factors in the plots were: 60, 80, 100 and 120% of the reference evapotranspiration (ETo) and in the subplots, the forms of fertilization, which were conventional fertilization and fertilization via irrigation water (fertigation).

The experimental area was prepared with harrowing and subsequent raising of the beds, eight in total with dimensions of 1.00 x

6.00 x 0.25 m in width, length and height, respectively. Subsequently, limestone and organic matter were applied as recommended by Raij et al. (1987).

Sowing was carried out directly in the beds at spacing of 0.25 m between rows and 0.10 m between holes with three seeds per hole.

A drip irrigation system was adopted, using drip pipes with nominal diameter of 17 mm, wall thickness of 0.45 mm, service pressure of 10 mwc and unit discharge of 1.60 L/h. The drippers were spaced 0.30 m apart in the irrigation line and 0.50 m between rows (two drip pipes were used in each bed).

After installation, flow rate tests were performed and their results were used to determine the Christiansen uniformity coefficient (CUC) and distribution uniformity coefficient (DUC), whose values were 96.42 and 95.91%, respectively. Irrigation times were calculated based on ETo data obtained from the weather station of the National Institute of Meteorology (INMET), in Petrolina-PE.

The meteorological behavior of the weather for the experimental period is illustrated in Figure 1.

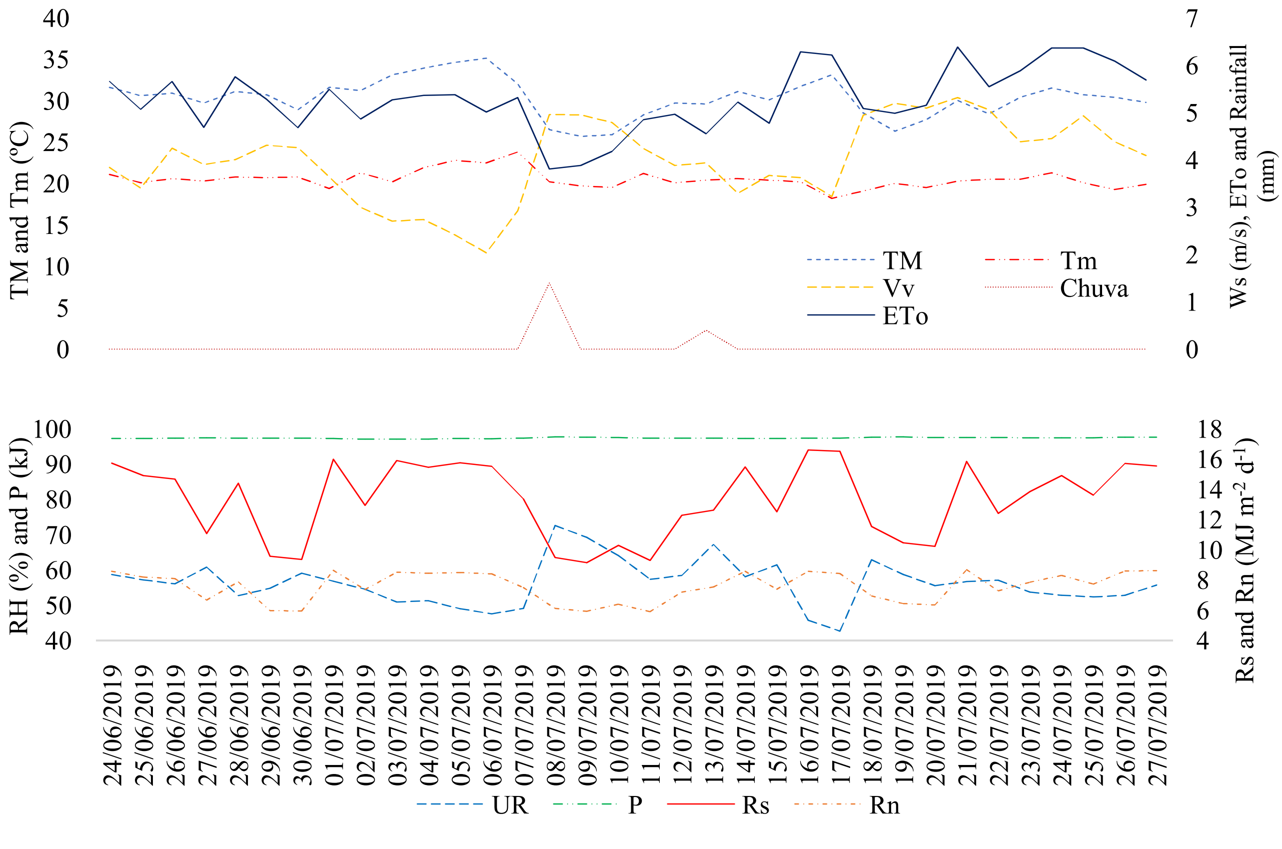

Figure 1. Precipitation (rainfall), reference evapotranspiration (ETo), local atmospheric pressure (P), net radiation (Rn), global solar radiation (Rs), maximum air temperature (TM), minimum air temperature (Tm), relative humidity (RH), and average wind speed (Ws), during the experimental period. Petrolina-PE.

Fertilizers were injected into the irrigation network with the bypass tank system, or "vaquinha", manufactured with 50-mm-diameter PVC pipe.

The amounts of fertilizer used were determined based on the recommendation of Raij et al. (1987) and the nutrient content present in the soil. For conventional management, 600 g of monoammonium phosphate (MAP) were applied at planting, and 128.4 and 24 g of potassium chloride (KCl) and 120 and 29.25 g of urea were applied at 10 and 22 days after sowing, respectively.

For the fertigated management, 4.53 g of urea, 51.00 g of MAP and 21.12 g of KCl were applied every two days from the eighth day after sowing.

At harvest, which occurred 32 days after sowing, all radishes were collected from the usable area of the experimental bed to estimate yield, and of these, ten were separated and taken to the Agroindustry Laboratory of the Federal University of the São Francisco Valley for post-harvest analyses.

Roots were sanitized with chlorinated solution, refrigerated at 4 °C and stored for three days in plastic packaging. After this period, fresh mass (FM), tuberous root length (RL), tuberous root diameter (RD), firmness (F), soluble solids (SS), titratable acidity (TA) and ascorbic acid (AA) were evaluated.

Radish fresh mass determination was performed on a semi-analytical balance, with precision of 0.01 g.Root length and diameter were measuredusing a digital caliper, with precision of 0.01 mm, all in triplicate. Firmness (N) was determined using a penetrometer with an 8 mm tip.

The content of soluble solids (SS) was determined using a portable refractometer, with values expressed in ºBrix; titratable acidity (TA) was determined by neutralization titration using sodium hydroxide and bromothymol blue indicator, expressed in mg of malic acid 100 g-1; and ascorbic acid (AA) was determined according to the methodology of the Manual Instituto Adolfo Lutz (2008), expressed in mg 100 g-1.

The collected data were subjected to the test of normality and homogeneity of variances. Subsequently, analysis of variance was performed by the F test and, in the occurrence of statistical significance, classification of means by Tukey's methodology at 5% significance level. Regression analysis was also performed for the irrigation depth, when necessary.

Data analysis was performed using the statistical software R version 4.55 (R CORE TEAM, 2022) and Sigma Plot version 14.5.

RESULTS AND DISCUSSION

According to Table 2, the ascorbic acid variable showed a significant interaction between the factors irrigation depth and fertilization. The irrigation depth factor had a significant individual effect on the variables firmness and titratable acidity, while the fertilization factor had a significant effect on all variables studied, except for ascorbic acid.

Table 2. F test values and classification of means of yield (Y), fresh mass (FM), firmness (F), root length (RL), root diameter (RD), ascorbic acid (AA), soluble solids (SS) and titratable acidity (TA) in radish (R. sativus L.) cv. Saxa as a function of the irrigation depth and form of application of fertilizers.

Source of Variation	Y (kg m^{-2})	FM (g)	F (N)	RL (mm)	RD (mm)	AA (mg 100g^{-1})	SS (°Brix)	TA (mg of malic acid 100 g^{-1})
Irrig. Depth (ID)	2.31^{ns}	0.77^{ns}	4.29*	0.88^{ns}	0.79^{ns}	1.08^{ns}	1.67^{ns}	21.99*
60% ETo	1.30	28.03	73.64a	43.70	35.44	31.07	4.95	1.69b
80% ETo	1.22	32.88	68.16b	45.58	37.06	30.26	4.77	2.12a
100% ETo	0.98	28.53	67.66b	42.12	35.02	31.17	4.80	0.99c
120% ETo	0.94	26.59	63.83b	40.98	34.42	35.04	4.88	1.13c
CV (%)	36.53	36.87	9.87	17.11	12.40	22.46	5.24	25.99

Fertilization (FT)	19.80*	28.62*	6.20*	25.38*	20.53*	0.03^{ns}	5.26*	7.67*
Conventional	0.95b	23.27b	71.25a	39.35b	33.08b	31.76a	4.94a	1.28b
Fertigation	1.26a	34.75a	65.39b	46.83a	37.89a	32.01a	4.74b	1.68a
CV (%)	21.88	25.62	11.94	11.94	10.36	16.74	6.24	34.09
ID * FT	1.22^{ns}	1.47^{ns}	1.00^{ns}	1.22^{ns}	2.93^{ns}	4.04*	2.21^{ns}	1.25^{ns}

CV: coefficient of variation; ns: not significant; *: significant at 5% probability level. Means followed by the same letter in each column do not differ statistically by Tukey test. Note: The degrees of freedom (DF) for the above data were 5, 3, 15, 1, 3 and 20, respectively, for Blocks: (B– 1) – not significant, Irrigation Depth: (ID– 1), Error 1:[(B–1) x (ID– 1)],Fertilization: (FT– 1), Interaction:[(ID – 1) x (FT - 1)]and Error 2:[ID x (FT – 1) x (B – 1)], with B = 6, ID = 4 andFT = 2.

As shown in Table 2, for the yield variable, fertigation promoted the highest values, surpassing conventional fertilization by 32.63%. Similar effects can also be observed for fresh mass (FM), tuberous root length (RL), tuberous root diameter (RD) and titratable acidity (TA), whose values were49.33%, 19% and 14.54%, 31.25%, respectively, under fertigated fertilization.

For firmness and soluble solids, conventional fertilization outperformed fertigation by 8.96% and 4.21%, respectively. These variables were also significantly influenced by the irrigation depth factor, with the highest F value observed for the 60% ETo irrigation depth, while the highest titratable acidity value was observed for the 80% ETo irrigation depth.

These results may have been generated because the application of fertilizers via irrigation water favors the best use of nutrients due to greater efficiency in their use, because they are supplied at the right time and in adequate quantities (ANDRADE JUNIOR,1994).

This splitting allows maintaining soil fertility close to the optimal level throughout the crop cycle, enabling yield gains and reducing nutrient losses (SOUSA et al., 2011).

Andriolo et al. (2011) point out that the fertigation of radish crop allows maintaining the availability of water and nutrients close to the values considered optimal for its growth and yield, because the size of the radish root depends among other factors on the efficient fertility of the soil. Therefore, the results found in the present study demonstrate that fertigation allows a greater increments in FM, RL, RD and Y of radish.

Lacerda et al. (2017), when evaluating different irrigation depths (50, 75, 100 and 150% ETo) in radish cultivation, found similar results, with no difference in root weight gain as a function of the increase in the applied depth, although this same study reported an increase in radish diameter with the greatest availability of water, diverging from the data of the present study.

Slomp et al. (2011), when studying the effect of different levels of irrigation, based on fractions of the evaporation of the Class A Pan(ECA), 40, 60, 80, 100 and 120%, observed that the different depths applied did not significantly affect radishyield, stating that the lowest irrigation depth is as efficient for yield as the others.Cunha et al. (2017), in a study with the radish cultivars Saxa, Sparkler and Cometa, noticed an increase in root length only in the comparison between rainy and dry seasons, regardless of the irrigation depths applied, corroborating the results of the present study.

The gains with fertigation may be due to the fact that fertilizers are applied in the region of highest concentration of roots. This potentiates the absorption of nutrients and, consequently, generates increments in the assimilation of plant material (TEIXEIRA et al., 2007). Figure 2 shows that firmness decreased as the irrigation depth based on ETo increased, with a reduction of 12.69% between the lowest and the highest depth.

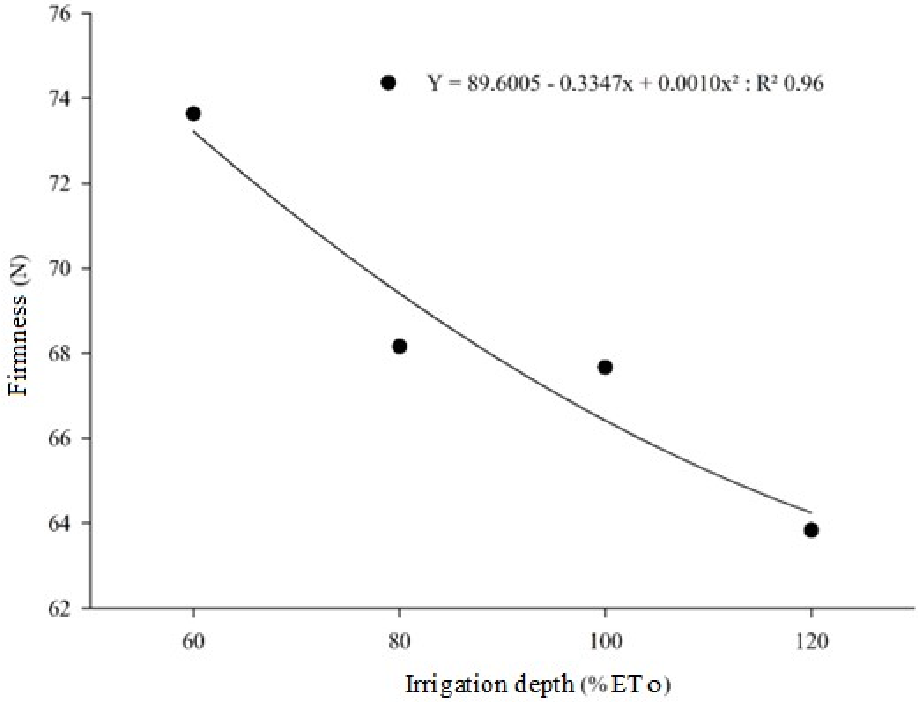

Figure 2. Radish firmness as a function of the irrigation depth applied (ETo fraction).

According to Câmara et al. (2007), the higher the soil moisture and the lower the evaporation from the surface, the lower the firmness of the fruit. Thus, as all plants were subjected to the same evaporation from the surface, with differences only in the irrigation depth, as the irrigation depths increase there is a greater moisture in the soil and thus lower firmness.The same is affirmed by Costa (1999), when describing that the more water is applied to a crop, up to a certain limit, it produces fruits that have less resistance to penetration and, consequently, lower values of firmness.

The higher values of firmness observed for conventional fertilization in the present study corroborate the results found by Branco et al. (2016), who evaluated the effects of irrigation and conventional fertilization and fertigationon apple trees.

Such behavior can be explained by the fact that conventional fertilization resulted in tubers of smaller diameter, so that the concentration of cell wall materials and firmness may decrease with the increase in fruit size, due to excessive cell elongation (TAIZ et al., 2017).

According to Figure 3, the contents of ascorbic acid (AA), as a function of the form of fertilization, showed divergent behaviors with the increase in irrigation depth. For conventional fertilization, the lowest AA value occurred under the 77.14% ETo depth, 27.51 mg of ascorbic acid per 100 g of fruit.For fertigated fertilization, the highest AA content, 30.00 mg 100 g-1, was observed with the 63.58% ETo depth. In both forms of fertilization, the 103.55% ETo depth promoted the content of 32.04 mg 100 g-1, the intercept point of the regressions.

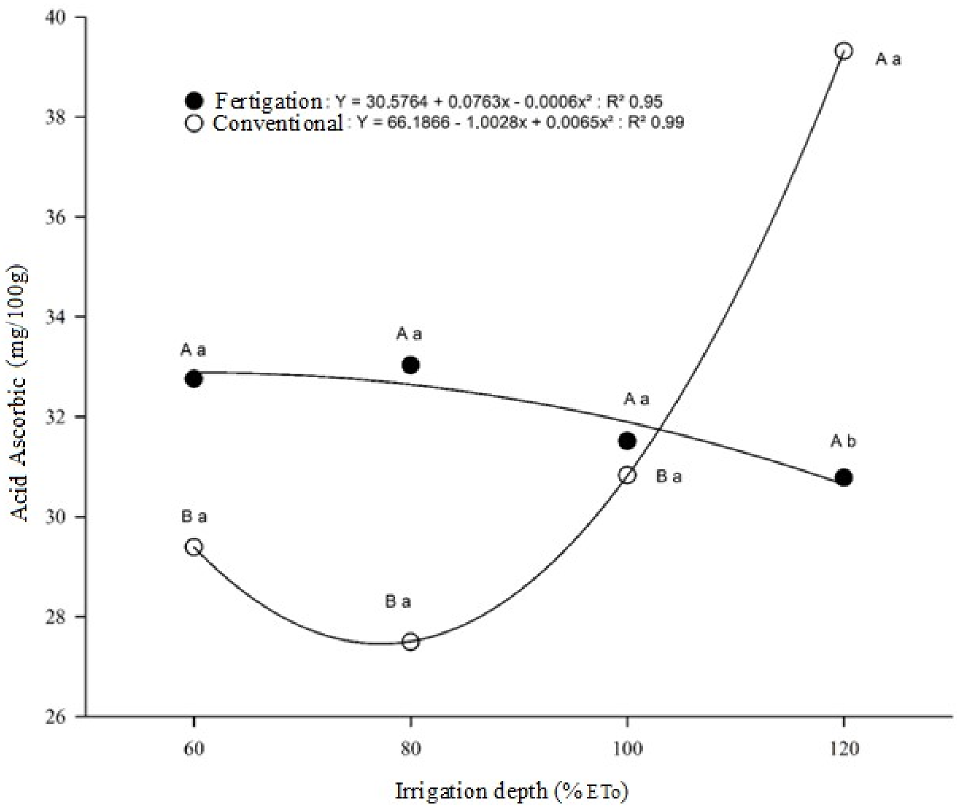

Figure 3. Ascorbic acid (AA) as a function of irrigation depth (ETo fraction) and forms of fertilizer application (fertigation and conventional fertilization).

The ascorbic acid content can be used as a quality index of vegetable products, varying according to species and conditions of cultivation, storage and processing (CHITARRA; CHITARRA, 2005) as it is influenced by light, oxygen, pH, temperature and humidity (GABAS et al., 2003).

In this context, Lu et al. (2008) evaluated 42 radish cultivars and found variation from 14.16 to 33.41 mg 100 g-1, so the values of ascorbic acid obtained in the present study are within this range.

Soluble solids are constituted by sugars dissolved in the aqueous extract of fruits and vegetables, with a trend of increase with the advance of the maturation or ripening of the product, and varies depending on the cultivar, species, maturation stage and climate (CHITARRA; CHITARRA, 2005; GOUVEIA, 2016). The values found in the present study (Table 2) are within the appropriate range (2 to 25%).

For the titratable acidity (TA) variable, a decreasing effect is observed with the increase in irrigation depth, so that the maximum value of 1.80 mg of malic acid 100 g-1 was observed with irrigation depth of 45.50% ETo (Figure 4).

The values found are consistent with those presented by Chitarra and Chitarra (2005) for radish (from 1.5 to 2.0 mg of malic acid 100 g-1). The value of 1.50 mg of malic acid 100 g-1 would be reached at the depth of 84.22% ETo.

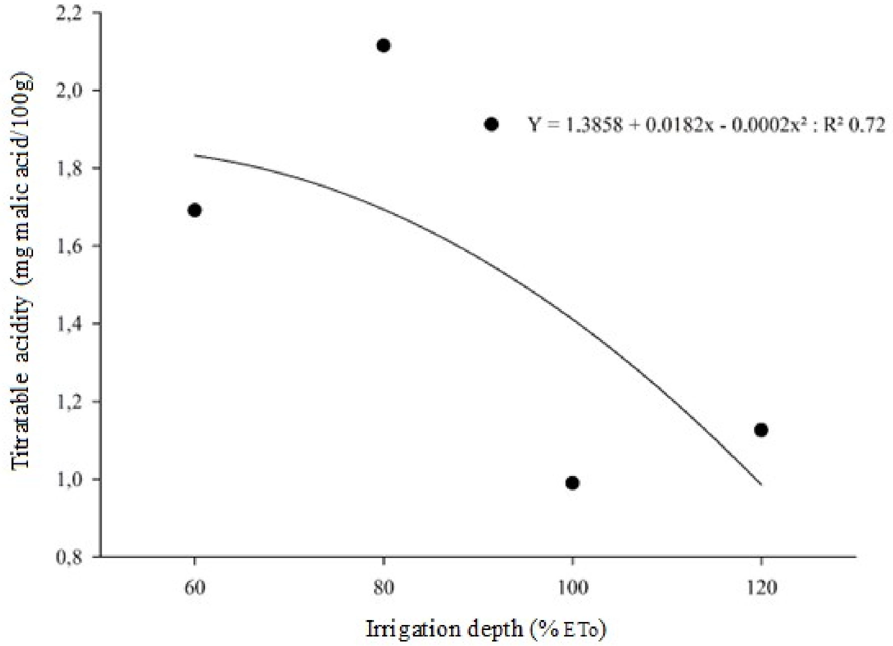

Figure 4. Titratable acidity as a function of the irrigation depth applied.

The reduction in TA contents with the increase in irrigation depth corroborates the results found by Siqueira et al. (2009), who studied the quality of yellow melon under different irrigation depths and observed a decrease in TA levels with increasing irrigation depths.The authors attributed this reduction to the probable dilution of organic acids due to the greater volume of water in the plant tissues. According to Morgan (2012), organic acids are accumulated during growth and used in the maturation of the crop, serving as an energy reserve in oxidation in the Krebs cycle. Therefore, due to the split supply of nutrients in fertigation, radish plants were able to absorb them more efficiently in this form of fertilization, given the lower leaching and larger amounts of stored organic acids, consequently generating higher levels of titratable acidity.

CONCLUSIONS

Irrigation depth influenced the firmness and titratable acidity of radish cv. Saxa, which decrease with increasing irrigation depth. Fertigation promoted higher yield, fresh mass, root length, root diameter and titratable acidity, while conventional fertilization promoted greater firmness and soluble solids for radish. Ascorbic acid showed different behavior with the increase in irrigation depth as a function of the form of fertilization used in the radish crop.

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