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IRRIGATION MANAGEMENT IN REAL TIME FOR ARUGULA CROP IN SERGIPE

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ABSTRACT Irrigation management is a key to the success of vegetables crops. The present study was carried out to evaluate the productive responses of arugula (*Eruca sativa* Mill.) under four different irrigation levels: 50% of the reference evapotranspiration (ETo), 75% ETo, 100% and 125% ETo, provided by an automatic weather station. The planting was done on December 16, 2008 through direct sowing in a nursery with a spacing of 0.1 m per 0.2 m, using a commercial cultivar called Folha Larga. After germination, management and thinning were carried out. The evaluations started from the 25^th day after sowing with three subsequent evaluations on day 31, 37 and 43. The variables evaluated were: plant height (cm), number of leaves, fresh weight ($g.m^{-2}$) and dry weight ($g.m^{-2}$). The results showed significant differences for all variables at 5% of probability for the Scott Knott test. The conditions in which the experiment was carried out permit to infer that the irrigation exerted influence on these variables, and greater efficiency of water use was found for lamina on the basis between 75% and 100% of reference evapotranspiration.

Keywords: weather station, reference evapotranspiration, rational water use

INTRODUCTION In region of Itabaiana city in Sergipe State the crop predominance is leafy cultivation. The municipality is consider a commercial center of the state and supplies the neighbor municipalities and others states with vegetables supplied to supermarket net in the Sergipe. However, the maintenance of this production depends on sustainable practices to assurance the water resource.

Water is a limited natural resource and its use in agriculture has taken place with more elevated restrictions. Hence, any proposal for an irrigated crop should be accompanied by a careful design and management for water irrigation in order to identify accurately the timing and the amount of water that must be applied to plants.

Studies of water use are extremely important for Northeast region of Brazil due to presence of semi-arid and arid regions our focus in this research.

The consumption of water by plants (ETc) is estimated by the product between reference evapotranspiration (ETo) and crop coefficient (Kc). There are several equations for estimating ETo, and a comprehensive review on this topic is presented by Rana & Katerji (2000) and by Camargo & Camargo (2001). It should be noted that the use of these equations is limited, since they need to be calibrated for the region under study, in order to generate inaccurate results. Another limiting aspect is the lack of climate data required by these equations.

In fact, the Kc varies according to the stage of crop development, soil conditions or climate conditions, and the frequency of rain and irrigation. The use of values obtained from other regions may generate considerable errors for crop estimation of water consumption. In a particular case of vegetables, the water consumption is determined mostly by the method of the soil water balance, which is also used universally (Klar & Fernandes, 1997; Trambouze et al., 1998; Sousa & Pereira, 1999).

The arugula (*Eruca sativa* Mill.) is herbaceous annual vegetable belonging to the family Brassicaceae (Filgueira, 2005). The species is rich in protein, vitamins A and C, and minerals, especially calcium and iron, besides being an excellent appetite stimulant, has anti-inflammatory and detoxifying proprieties. In Brazil, it is consumed as salad and on pizzas, and in recent years has increased in popularity and consumption (Purquerio, 2005).

The determination of irrigation and the definition of a rational irrigation management of crops have been the main problem faced by technicians and irrigators (D'Urso & Santini, 1996), especially when water is a scarce and limiting factor in agricultural production.

The continuous progress in the technical development of meteorological sensors have been taken proportional advances in development of electronic components, much more accurate and less costly, used in quantifying the various components of the soil - water - plant - atmosphere, which is one of the most important factors in the process of decision making in irrigated agriculture. One example is the increasing use of automatic weather stations as an essential tool for estimating the reference evapotranspiration (ETo) on continuous time (Campbell Scientific Inc., 1993; Elliot et al., 1994; Muhammad et al., 1997; Sousa & Pereira, 1999). This method allows the deployment of a weather monitoring system for irrigation in real time.

The system of irrigation management by real-time advocates the use of integrated components of the soil-water-plant-atmosphere; to determine the irrigation for crops in plots or areas. In this system, the irrigation to be applied is calculated taking into account the databases on soil, climate, plant-physiology, and the distribution of water to be applied (Quiñones et al., 1999).

METODOLOGY Characterization of study area

The municipality of Itabaiana is sited in hydrographic basin of Sergipe at latitude of 10º41'11" and longitude of 37º25'37, 56 kilometers far from Aracaju capital, with climate transition between semi-arid and semi-humidity, with annual average temperatures of 24.7ºC and average pluviosity of 858.5 mm. The city has an average attitude of 180 meters, and is surrounded by Itabaiana Saw.

Weather monitoring for irrigation management in real time

The experiment was installed in area of the Vida Verde farm, which was previously set up a system of micro-sprinkler irrigation. There were four treatments in a randomized block in split plot scheme according to reference evapotranspiration (ETo) measure in loco at 50% of ETo, 75% of ETo, 100% of ETo and 125% of ETo.

The climatic data was performed by daily data collecting of precipitation and humidity, temperature, speed and direction of wind, solar radiation and net of radiation necessary to estimate the reference evapotranspiration (ETo) by Penman - Monteith (Allen et al., 1998), fundamental to the irrigation of crops in these areas, using the following equation:

$$ETo = \frac{0{,}408\Delta(R_n - G) + \gamma \frac{900}{T+273} U_2 (e_s - e_a)}{\Delta + \gamma(1 + 0{,}34U_2)} \quad (1)$$

where:

ETo = Reference evapotranspiration ($mm.dia^{-1}$)
Δ = slope of the vapor pressure of saturation ($kPa.^{o}C^{-1}$)
R_n = net of radiation on surface ($MJ.m^{-2}.day^{-1}$)
G = soil heat ($MJ.m^{-2}.day^{-1}$)
y = psicrometric constant ($kPa.^{o}C^{-1}$)
T = air temperature measure at 2 meters height (^{o}C)
U_2 = velocity of wind measure at 2 meters height ($m.s^{-1}$)
e_s = pressure of saturation of water (kPa)
e_a = pressure of actual water (kPa)

The lamina of irrigation was defined using the automatic agro-meteorological equipment with a system of internet data transmission (Munster et al., 1997). The climatic data was set in a sheet aiming to feed the software, and estimating of ETo for posterior management of crop irrigation by method of balance of water in soil (Teixeira & Pereira, 1992).

Table 1 – Weekly average values of maximum, medium, minimum temperature; relative humidity and reference evapotranspiration (ETo) obtained in December 16th, 2008 trough February 10th, 2009. Data collected by agro-meteorological station. Itabaiana-SE, UFS, 2009

Data	T. Maximum (ºC)	T. Average (ºC)	T. Minimum (ºC)	Humidity (%)	Evapotraspiration (ETo) (mm)
16 to 22/2008	32.58	26.80	21.03	73.89	5.22
23 to 29/2008	32.52	27.35	22.19	74.07	5.20
30 to 05/2009	32.49	26.84	21.19	70.75	5.05
06 to 12/2009	31.30	26.88	22.46	76.18	4.32
13 to 19/2009	33.15	28.13	23.12	75.17	4.56
20 to 26/2009	32.65	27.64	22.64	75.33	3.90
27 to 03/2009	32.05	27.04	22.03	76.47	3.66
04 to 10/2009	32.46	27.30	22.45	73.78	4.46

Management for arugula planting

The experiment was carried out in the Model Farm for vegetable crop production as one action of the pilot project of Federal University of Sergipe. The main goal of this project is the sustainable vegetable production at Viva Verde Farm, in Itabaiana city (SE), in area with sandy soil texture. The experimental design used was the randomized blocks in split plot scheme, with four replications.

Table 2 – Chemical characteristics of the soil in the experimental area. Itabaiana – SE, 2009.

Profundity	pH	M.O	P_{resin}	Al^{+3}	H+Al	K	Ca	Mg	SB	CTC	V%
(cm)	($CaCl_2$)	%	$mg.dm^{-3}$	..................................$cmol_c/dm^3$..							
0-20	7.3	0.94	28.1	ND	0.13	0.43	4.53	6.67	12.7	12.8	99.2
20-40	7.4	1.21	101	ND	0.13	0.32	3.26	4.03	8.41	8.54	98.5

The planting was executed on December 16th, 2008 in nursery of 0,1m X 0.2 m using the arugula seeds cv. folha larga, in an area with soil previously prepared. The fertilization was based on chemical analysis, using 40 $g.m^{-2}$ of N, 10 $g.m^{-2}$ of P_2O_5 and 20 $g.m^{-2}$ of K_2O. The utile plot was composed by eight raw of plants.

After the seed germination it was executed the management and thinning necessary leaving three seedlings per planting hole. The water in soil was kept at field capacity with irrigation of micro-aspersion in the morning supplied at 6h30 to 7h30 with emitters spaced every 4.65 m x 4.65 m, until the 15th day of planting. This period was necessary for plant differentiation under irrigation with water lamina in according to ETo (50%, 75%, 100% and 125%) (Figure 2C). The cover fertilization with nitrogen was supplied with 40 $g.m^{-2}$ of urea as source of N.

The evaluation beginning took place in the 25th day after sowing (DAS) followed by evaluations at 31st, 37th and 43th days. The evaluation included analysis of plant height (cm), number of leaves, fresh matter ($g.m^{-2}$), dry matter ($g.m^{-2}$). The variance analysis for statistical design was carried out in randomized blocks in split plot scheme and the data analyzed by SISVAR software (Ferreira, 2003). The joint analysis of the variables was estimated, and the mean values compared by the Scott Knott test at 5% probability.

RESULTS AND DISCUTION

The mean values for the height of leaves (HL), number of leaves (NL), fresh weight (FW) and dry matter (DM) of arugula growing under different irrigation lamina, assessed for different periods is displayed on Table 3. There are significant differences among the treatments ($P \leq 0.05$) for all periods of evaluation.

The variable differentiation took place at 37 days after sowing and remained until the harvesting time. The water depth corresponding to 100% of reference evapotranspiration (ETo) presented the best results, followed by treatment at 75% ETo. Both, the irrigation at 50% and at 125% of Eto, presented significant differences for the variables studied. The deficit or excess of water resulted on damage in arugula development.

The vegetables grown on field conditions are submitted to a strongly influence in their development by soil humidity conditions. The deficiency of water is usually the most limiting factor for achieving high productivity and good quality for products, but the excess may also be harmful (Silva & Marouelli, 1998).

One of the first effects of water stress is reflected on plant growing (Kramer, 1983). The plant growth is the result of numerous physiological processes strongly integrated, but that present individual interactions with the environment. The water restriction reduces the turgor and consequently the cell expansion, which in fact reduces the leaf area and productivity.

Table 3 – Mean values of leaves height, number of leaves, fresh and dry matter of arugula cv folha larga in different periods under different lamina of irrigation in Itabaiana city, Sergipe State, 2009.

Days after sowing	Lamina of irrigation (mm)	Evaluated characteristics			
		Height (cm)	Leaves (nº)	Fresh Matter (g.m^{-2})	Dry matter (g.m^{-2})
25	50% ETo	7.19 a	5.56 a	487.5 a	72.0 a
	75% ETo	7.88 a	6.89 a	670.5 a	96.0 a
	100% ETo	7.25 a	5.75 a	640.5 a	85.5 a
	125% ETo	8.16 a	6.13 a	724.5 a	87.7 a
31	50% ETo	10.13 a	7.44 a	805.5 a	133.5 a
	75% ETo	11.63 a	7.13 a	1315.5 a	199.5 a
	100% ETo	10.25 a	7.69 a	1204.5 a	148.5 a
	125% ETo	10.06 a	7.13 a	843.0 a	133.5 a
37	50% ETo	9.38 b	6.93 b	540.0 b	130.5 b
	75% ETo	16.26 a	12.40 a	3904.5 a	385.5 a
	100% ETo	15.25 a	12.50 a	3912.0 a	403.5 a
	125% ETo	14.25 a	12.10 a	3424.5 a	421.5 a
43	50% ETo	10.89 d	7.08 c	1012.5 c	172.5 d
	75% ETo	20.90 a	15.50 a	6487.5 a	616.5 b
	100% ETo	18.85 b	18.00 a	6702.0 a	733.5 a
	125% ETo	16.65 c	12.93 b	4158.0 b	456.0 c
CV 1 (%)	------	6.49	29.40	40.03	29.80
CV 2 (%)		10.29	22.43	24.30	25.69

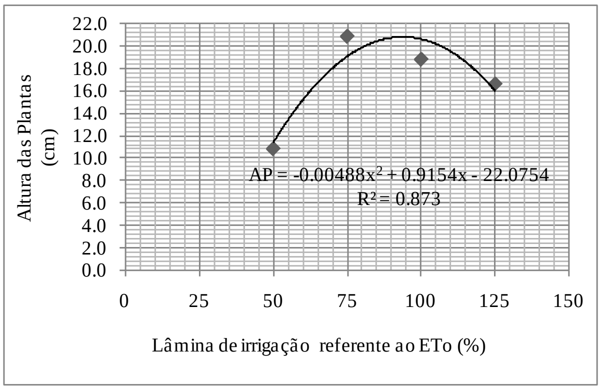
Mean values followed by the same letter doesn´t differ by Scott Knott test t 5% of probability.
ETo – reference evapotranspiration

Another possibility could be considered with plant-size reduction is a survival strategy in according to reports of Ungar (1987) and Houle et al. (2001) considering the reduction on transpiration rate and consequently water absorption by the roots (Long & Mason, 1983).

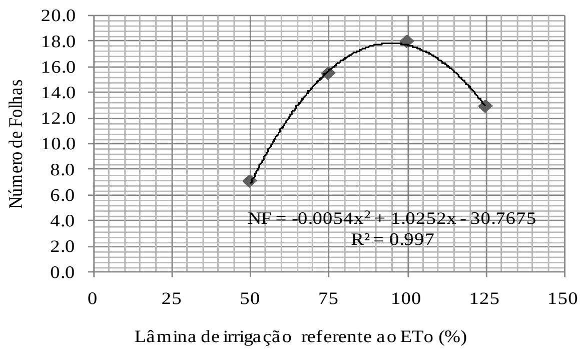
The plant-size reduction also is explained by Lobato et al. (2009), this occurrence due to lower rate of cell division and ethylene presence in plants subjected to water restriction. Besides of this, it promotes the reduction of length and increasing of the diameter of root as demonstrated by several authors in different species (Rodrigues et al., 2002; Dantas el al., 2007).

The response for variables subjected to different irrigation levels shows quadratic high significance, as shown in Figure 4. In Figures 4A and 4B, the behaviors are shown for plant height and number of leaves of arugula for water depth applied. Probably the deficit and excess for irrigation depths promoted lower mean values for the corresponding variables. According to the regression equations, the income level (maximum point of the equation) for the variables HP and NL were 20.9 (cm) and 18 at irrigation levels of 93.8 and 94.9% of ETo, respectively.

For the production of FM and DM most physical productivity was found when the lamina was irrigated with 75% and 100% of ETo. Similar results were observed with the lettuce (Santana et al., 2001).



(A)



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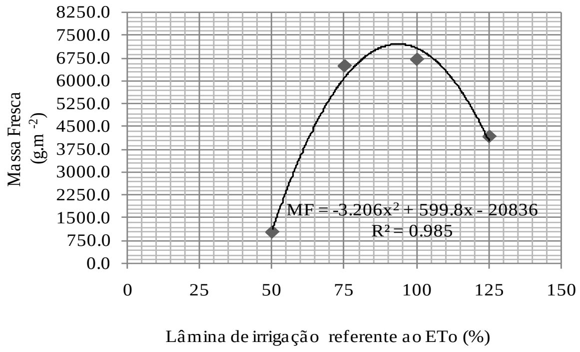
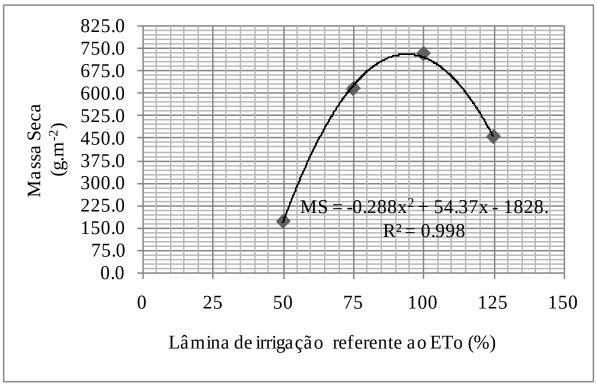


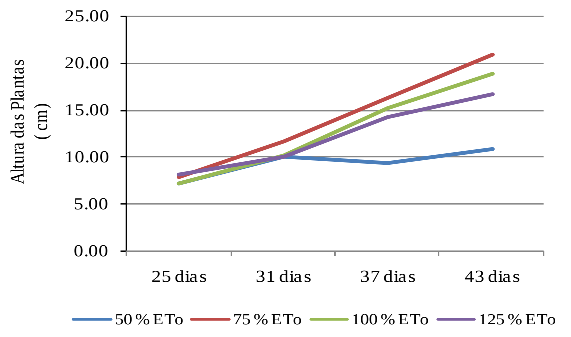
(C)



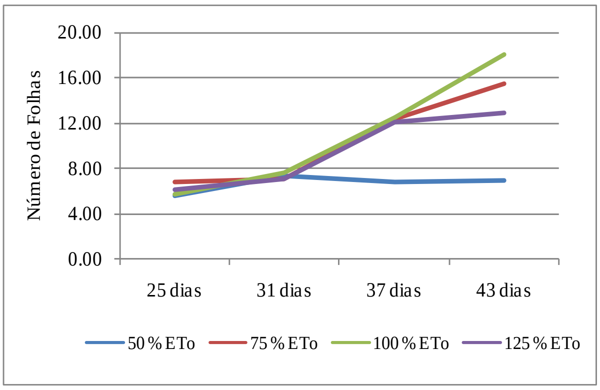
(D)

Figure 4 - Quadratic regression curve related to water depth (ETo) at 50%, 75%, 100% and 125% for 42 days after sowing (DAS) for variables: PH - plant height (A), NF - number of leaves (B), FM - fresh matter (C) and DM - dry matter (D), 2009.

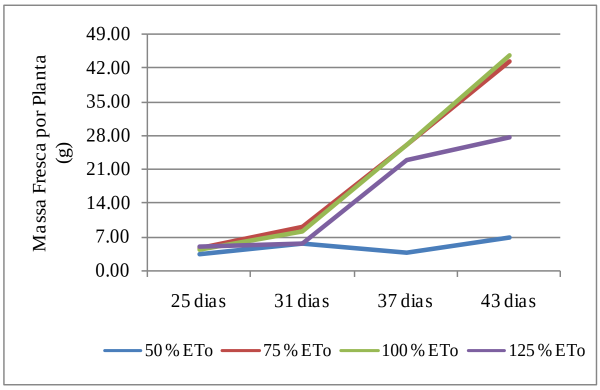
By polynomial adjusts for fresh and dry matter was determined a quadratic curve, expressed by the model: MF = -3.206x2 + 599.8x – 20836 (r^2 = 0.985) and MS = - 0.288x2 + 54.37x – 1828 (r^2 = 0.998) (Figure 4C and 4D). By deriving the models, it is possible to find the maximum point with values of 7.218.0 and 738.1 gm^{-2} for 93.54 and 94.39% of ETo, respectively. This estimative indicates a perfect application between the levels of irrigation at 75% and 100% of ETo. Similar results were obtained by Andrade Jr. et al. (1997) for lettuce, which observed adjust to quadratic equation with maximum value of 0.75 of evaporation from the Class A.



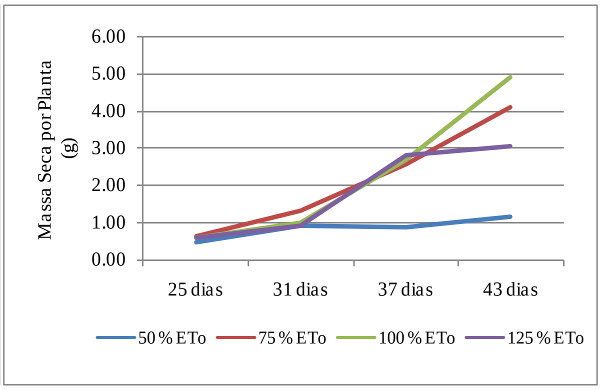
(A)



(B)



(C)



(D)

Figure 5 – Evaluation of the arugula development, cv. folha larga per days after sowing (DAS), in according to water depth for the variables plant height (A), number of leaves (B), fresh matter (C) and dry matter (D), 2009.

In according to results presented in Figure 5 the development of arugula was affected by the management of irrigation water, and affected all variables studied, where the results for development at the early stage of the crop was unaffected by different irrigation, which is explained by lower demand for water needed by the crop. But 37 days after sowing (DAS) the arugula showed the best differentiated results for irrigation at 75% and 100% of reference evapotranspiration.

Values above 100% ETo, which led to decreased for the variables indicating that the excess of water, excessive irrigation, reduces plant growth. It was possible to observe in field the presence of yellowing leaves early and late growth, which can implicate in a low commercial value of the arugula.

The decreasing performance on development caused by irrigation levels below of 75% ETo can be explained by leafy vegetables at lower soil water response negatively on their development, indicating a probable closure of the stomata in order to avoid water loss, reducing respiration and therefore less photosynthesis, contributing to the reduction of cell expansion and consequently a reduction of photosynthetic translocation of liquids and nutrients. This implicates on another survival strategy. Dry matter accumulated by plants is related to photosynthetic activity and nutrients absorption (Benincasa, 2003) that in those water restriction treatments is reduced.

CONCLUSIONS The adequate irrigation levels for arugula can be analyzed monitoring the plant height, fresh and dry matter 43 days after sowing (DAS), which varies significantly according to irrigation.

In the conditions of this experiment, it can be state that the management of irrigation at 100% of reference evapotranspiration provides the best development and productivity for arugula crop.

Water depths above 100% ETo promote a reduction in productivity (height of leaves, leaf number, fresh and dry mass). The water deficit caused by irrigation levels below at 75% ETo are impractical for the production of leafy vegetables as arugula.

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