Journal of Agricultural Science and Technology B 1 (2011) 1161-1167
Earlier title: Journal of Agricultural Science and Technology, ISSN 1939-1250

Irrigation Management in Real Time for Arugula Crop in Sergipe

A. N. do Vasco[1], A. de O. Aguiar-Netto[1], R. Silva-Mann[1] and E. A. Bastos[2]

1. Department of Agronomy, University Federal of Sergipe, São Cristovão, Sergipe 49100-000, Brazil

2. Embrapa Mid-north, Teresina, Piauí 64006-220, Brazil

Received: April 14, 2011 / Published: December 20, 2011.

Abstract: The management of the irrigation is fundamental for success of leaves vegetables production. The work was carried out aiming to evaluate the production response of the arugula (*Eruca sativa* Mill.) under different irrigation levels at 25, 31, 37 and 43 days after sowing. The treatments were distributed in randomized blocks design with four replication, and evaluated in split-plot scheme of 4 × 4, with the plots constituted by four irrigation levels equivalent to reference evapotranspiration (ET0) at 50%, 75%, 100% and 125% estimated by Penman-Monteith equation; and the split-plot constituted by days after sowing. The arugula planting was established in November of 2008 with direct sowing in nursery with 0.1 m × 0.2 m per plant, using the cv. "Folha Larga". After the germination phase was carried out crop management necessary to the crop production. It was analyzed: plant height (cm), leaf number, fresh weight (g m^{-2}) and dry weight (g m^{-2}). The results showed the significant differences at level of 5% of probability for the Scott-Knott test for all variables analyzed after 37 days of planting. The results permit to infer that the irrigation levels exert influence under the studied variables with the higher efficiency of water use found for levels of 75% and 100% of the reference evapotranspiration.

Key word: Weather station, reference evapotranspiration, rational water use.

1. Introduction

In region of Itabaiana city in Sergipe State the crop predominance is leafy cultivation. The municipality is considered a commercial center of the state, and 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 must be rationally carried out. 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 [1].

Studies of water use are extremely important for Northeast region of Brazil due to presence of many semi-arid and arid regions. The consumption of water by plants (ETc) is estimated by the product between reference evapotranspiration (ET_0) and crop coefficient (Kc). There are several equations for estimating ET_0, and a comprehensive review on this topic is evaluable in the literature [2, 3]. 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 avoid inaccurate results. Another limiting aspect is the lack of climate data required by these equations.

The Kc varies according to the stage of crop development, soil and climate conditions. The use of values obtained from other regions may generate considerable errors for estimation of crop water consumption. For vegetables production these water

Corresponding author: A. N. do Vasco, M.Sc., professor, research fields: development and environment. E-mail: anderovasco@yahoo.com.br.

consumption is determined by soil water balance, which is used universally [4-6].

The arugula (*Eruca sativa* Mill.) is herbaceous annual vegetable belonging to the family Brassicaceae [7]. 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 [8].

The determination of irrigation and the definition of a rational irrigation management of crops is an important problem in agriculture, especially when water is a scarce and limiting factor for the crop production [9]. 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-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 (ET_0) on a continuous time. This method allows the development of a weather monitoring system for irrigation in real time [10-12].

To determine the irrigation of crops the system of irrigation management by real-time concerns the use of integrated components of the soil-plant-atmosphere. In this system, the levels of irrigation to be applied into the plot level are estimated taking into account the databases relatives to the soil, climate, plant, the water system evaluable and the number of irrigants [13].

In this sense it was carried out this work aiming to study the different levels of irrigation at different periods and their influence under the productive features of the development of arugula under the edaphoclimatic conditions of Itabaiana city, Sergipe State-Brazil.

2. Methodology

2.1 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 km far from Aracaju capital, with climate transition between semi-arid and semi humid, with annual average temperatures of 24.7 ºC and average rainfall of 858.5 mm. The city has an average altitude of 180 m above the sea level, and is surrounded by Itabaiana Saw. The experiment was installed in Vida Verde Farm in November of 2008, with an irrigation system of microaspersion. The treatments were distributed in randomized blocks design with four replications, and evaluated in split-plot scheme of 4 × 4, with the plots constituted by four irrigation levels of the reference evapotranspiration (ET_0) equivalent to 50%, 75%, 100% and 125% estimated by Penman-Monteith equation; and the split-plot constituted by days after sowing.

The climatic monitoring was obtained collecting daily data of humidity, temperature, speed and direction of wind, solar radiation and net radiation necessary to estimate the reference evapotranspiration (ET_0) according to Penman-Monteith, fundamental to the irrigation of crops in these areas, using the following equation [14]:

$$ETo = \frac{0.408\Delta(R_n - G) + \gamma \frac{900}{T+273} U_2 (e_s - e_a)}{\Delta + \gamma(1 + 0.34U_2)} \quad (1)$$

where:

ET_0 = reference evapotranspiration (mm day^{-1})

Δ = slope of the vapor pressure of saturation (kPa $^oC^{-1}$)

R_n = net of radiation on surface (MJ m^{-2} day^{-1})

G = soil heat (MJ m^{-2} day^{-1})

y = psicrometric constant (kPa $^oC^{-1}$)

T = air temperature measure at 2 meters height (^oC)

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 levels of irrigation were defined with aiming of the automatic agro meteorological station equipped with a data transmission system via world net computer [15]. The climatic data feeds software and sheet of estimative of the ET_0 (Table 1) for posterior irrigation management of the crops by methods of water balance in the soil [16].

2.2 Management of the Planting of Arugula

The planting was executed on December 16th, 2008 in nursery of 0.1 m × 0.2 m using the arugula seeds cv. “folha larga”, in an area with soil previously prepared. The fertilization was based on chemical analysis (Table 2), 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 to the crop leaving three seedlings per planting hole. The soil was keep under the soil capacity with irrigation of micro aspersion during the period of 6:30 am to 7:30 am with emitters spaced every 4.65 m × 4.65 m until the 15^{th} days after sowing. After this period was initiated the differentiation of the irrigation with levels referents to ET_0 (50%, 75%, 100% and 125%) the day before. The cover fertilization with nitrogen was supplied with 40 g m^{-2} of urea as source of N.

The beginning of the evaluation occurred the 25^{th} day after sowing (DAS) followed by evaluations at 31^{st}, 37^{th} and 43^{th} day harvesting the entire plants. The evaluation included analysis of plant height (cm), number of leaves, fresh matter (g m^{-2}) and dry matter (g m^{-2}). The variance analysis for statistical design was carried out in randomized blocks in split plot scheme and the data were analyzed by SISVAR software [17]. The joint analysis of the variables was estimated, and the mean values were compared by the Scott-Knott test at 5% probability.

3. Results and Discussion

Data of reference evapotranspiration obtained from the automatic weather station collected during the period of application of irrigation levels are shown in Fig. 1A. The maximum observed evapotranspiration was with 5.90 mm day^{-1}, the minimum with 0.50 mm day^{-1}, and the average of all measurements performed was with 4.62 mm day^{-1}.

The accumulated values of levels of irrigation applied are found in Fig. 1B. There was a lower differentiation among the irrigation at beginning of the

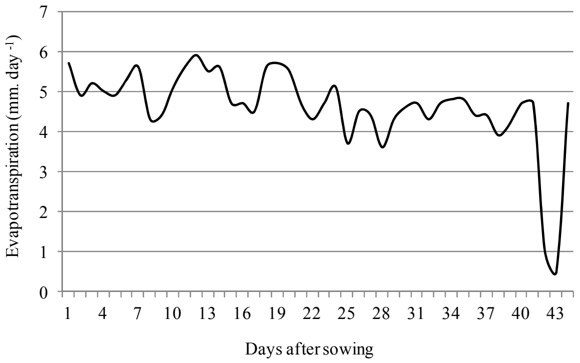
Table 1 Weekly average values of maximum, medium, minimum temperature; relative humidity and reference evapotranspiration (ET_0) obtained from December 16^{th}, 2008 to February 10^{th}, 2009. Data collected by agro-meteorological station. Itabaiana-SE, 2009.

Data	T. maximum (ºC)	T. average (ºC)	T. minimum (ºC)	Humidity (%)	Evapotraspiration (ET_0) (mm)
December 16-22 of 2008	32.58	26.80	21.03	73.89	5.22
December 23-29 of 2008	32.52	27.35	22.19	74.07	5.20
January 30-05 of 2009	32.49	26.84	21.19	70.75	5.05
January 06-12 of 2009	31.30	26.88	22.46	76.18	4.32
January 13-19 of 2009	33.15	28.13	23.12	75.17	4.56
January 20-26 of 2009	32.65	27.64	22.64	75.33	3.90

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

Profundity (cm)	pH ($CaCl_2$)	O. M (%)	P_{resin} (mg dm^{-3})	Al^{+3}	H + Al	K	Ca	Mg	SB	CEC	BSI (%)
					..................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

O.M: Organic matter, CEC: Cation exchange capacity, SB: Sum of bases, BSI: Basis saturation index.



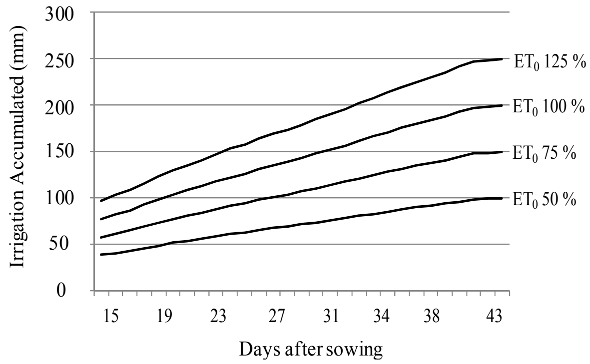


Fig. 1 Daily values of evaporation (A) and cumulative irrigation applied (B).

application. This difference was further accentuated in the course of the experiment, reaching expressive values at harvesting period (43 days after transplanting date) with levels of 100, 150, 200 and 250 mm for evapotranspiration at 50%, 75%, 100% and 125%, respectively. The levels applied at ET_0 125% was 2.5 times superior to the level applied at ET_0 50%, which have been evidencing a wide variation in the water content in the soil for the development of arugula.

The mean values for the height of plants (HP), number of leaves (NL), fresh weight (FW) and dry matter (DM) of arugula growing under different irrigation levels, assessed for different periods is displayed on Table 3. There are significant differences among the treatments ($P \leq 0.05$) at 37 and 43 days after sowing.

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 (ET_0) presented the best results, followed by treatment at 75% ET_0. Both irrigation levels of irrigation, at 50% and at 125% of Et_0, showed 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 [18].

One of the first effects of water stress is reflected on plant growing [19]. 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.

In according to results presented in Table 3 the development of the 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 of 100% ET_0, which led to decrease for the variables indicated 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% of ET_0 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

Table 3 Mean values of leaves or plant height (PH), number of leaves (NL), fresh matter (FM) and dry matter (DM) of arugula cv "folha larga" in different periods under different levels of irrigation in Itabaiana city, Sergipe State, 2009.

Days after sowing	Lamina of irrigation (mm)	Evaluated characteristics			
		PH (cm)	NL (nº)	FM ($g\ m^{-2}$)	DM ($g\ m^{-2}$)
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	1,315.5 a	199.5 a
	100% ETo	10.25 a	7.69 a	1,204.5 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	3,904.5 a	385.5 a
	100% ETo	15.25 a	12.50 a	3,912.0 a	403.5 a
	125% ETo	14.25 a	12.10 a	3,424.5 a	421.5 a
43	50% ETo	10.89 d	7.08 c	1,012.5 c	172.5 d
	75% ETo	20.90 a	15.50 a	6,487.5 a	616.5 b
	100% ETo	18.85 b	18.00 a	6,702.0 a	733.5 a
	125% ETo	16.65 c	12.93 b	4,158.0 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 at 5% of probability.
ET_0: reference evapotranspiration.

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 that in those water restriction treatments is reduced [20].

In general the vegetables cultivated under the field conditions have the development intensively influenced by soil humidity conditions. The water deficiency is a factor limiting for to obtaining the elevated productivity and products of good quality, but the excess also can be prejudicial [18].

One of the first effects of water deficiency is the low growth of the plants [19]. The growth of plants is result of the innumerous physiological integrated process, however there is an accentuated individuality in the environmental interactions. The hydric stress induces the turgescence redution that reduce the cell expansion, which in turn reduces the leaf area and agricultural productivity [21-25]. This effect is particularly damaging in green leafy vegetables.

The response functions of variables subjected to different irrigation levels follows quadratic models with high significance, according to Fig. 2.

In Figs. 2A and 2B, it is possible to confirm the performance of plant height and number of leaves of arugula in function of applied irrigation. It is verified that both deficit and excess of the irrigation promoted lower mean value for the corresponding variables. According to the regression equations, the maximum yields (maximum point of the equation) for the variables HP, NF were 20.9 (cm) and 18 leaves on average by the applied irrigation levels of 93.8% and 94.9% of the ET_0. For the production of fresh matter and dry matter most physical productivity was found with irrigation level at 75% and 100% of ET_0. Similar results were observed with lettuce [26].

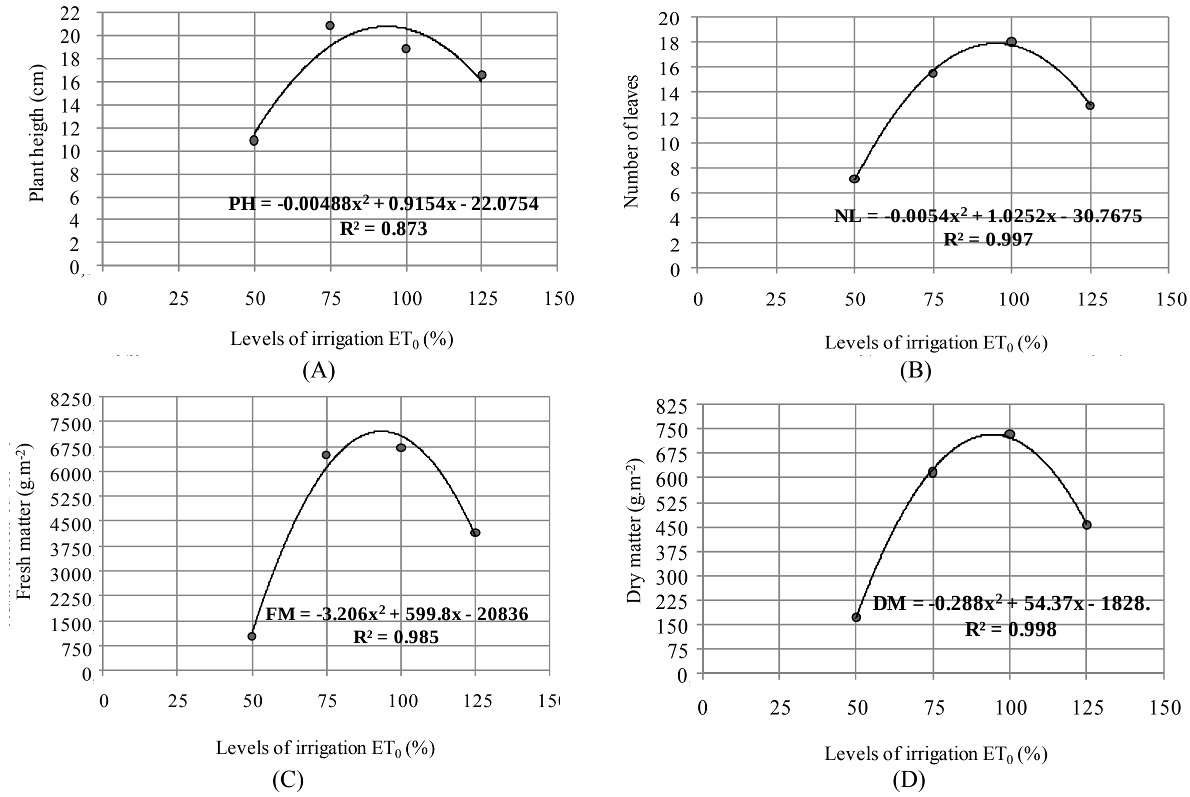


Fig. 2 Quadratic regression curve related to water depth (ET_0) at 50%, 75%, 100% and 125% for 42 days after sowing (DAS) for variables: plant height (A), number of leaves (B), fresh matter (C) and dry matter (D), 2009.

By polynomial adjusts for fresh and dry matter was determined a quadratic curve (Figs. 2C and 2D). By deriving the models, it is possible to find the maximum point with values of 7,218.0 and 738.1 gm^{-2} for at 93.54% and 94.39% of ET_0, respectively. This estimative indicates a perfect application between the levels of irrigation at 75% and 100% of ET_0. Similar results were obtained for lettuce, which adjust to quadratic equation with maximum value of 0.75 of evaporation from a Class A [21].

4. Conclusions

The adequate irrigation levels for arugula can be analyzed monitoring the plant height, fresh and dry matter at 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 between 75% and 100% reference evapotranspiration provides the best development and productivity for arugula crop.

Water depths above 100% ET_0 promote a reduction in productivity (height of leaves, leaf number, fresh and dry mass). The water deficit caused by irrigation levels below to 75% ET_0 is impractical for the production of leafy vegetables as arugula.

References

[1] A.J.S. Silva, A.S. Andrade-Junior, F.R. Marin, Arquitetura para plataforma de coleta e disseminação de dados climáticos no estado do Piauí, Revista Tecnologia Fortaleza 29 (2008) 134-140.

[2] G. Rana, N. Katerji, Measurement and estimation of actual evapotranspiration in the field under mediterranean climate: a review, European Journal of Agronomy 13 (2000) 125-153.

[3] A.P. Camargo, M.B.P. Camargo, Uma revisão analítica da evapotranspiração potencial, Bragantia 59 (2000) 125-137.

[4] A.E. Klar, M.A. Fernandes, Water needs for winter bean crop, Scientia Agricola 54 (1997) 133-138.

[5] W. Trambouze, P. Bertuzzi, M. Voltz, Comparison of methods for estimating actual evapotranspiration in a row-cropped vineyard, Agricultural and Forest Meteorology 91 (1998) 193-208.

[6] V. Sousa, L.S. Pereira, Regional analysis of irrigation water requirements using kriging: application to potato crop (*Solanum tuberosum* L.) at Trás-os-Montes, Agricultural Water Management 40 (1999) 221-233.

[7] F.A.R. Filgueira, *Novo manual de olericultura*: agrotecnologia moderna na produção e comercialização de hortaliças (2005) ISBN 978-85-726-9313-4.

[8] L.F.V. Purquerio, Crescimento, produção e qualidade de rúcula (*Eruca sativa* Miller) em função do nitrogênio e da densidade de plantio, 2005, available at: http://www.biblioteca.unesp.br/bibliotecadigital/document/listeses.php?tid=213&stat=a (Accessed 5 May 2010).

[9] G. D'urso, A. Santini, A remote sensing and modeling integrated approach for the management of irrigation distribution system, in: C.R. Camp, E.J. Sadler, R.E. Yoder (Eds.), Evapotranspiration and Irrigation Scheduling, ASAE, St. Joseph, 1996, pp. 435-441.

[10] Campbell Scientific Inc., On-line Measurement of Potential Evapotranspiration with the Campbell Scientific Automated Weather Station, Campbell Scientific Inc., Logan, 1993, p. 23.

[11] R.L. Elliot, F.V. Brock, M.L. Stone, S.L. Harp, Configuration decision for an automated weather station network, Applied Engineering in Agriculture 10 (1994) 45-51.

[12] A. Muhammad, J.C. Loftis, K.G. Hubbard, Application of geostatistics to evaluate partial weather station networks, Agricultural and Forest Meteorology 84 (1997) 255-271.

[13] P.H. Quiñones, H. Unland, W. Ojeda, E. Sifuentes, Transfer of irrigation scheduling technology in Mexico, Agricultural Water Management 40 (1999) 333-339.

[14] R.G. Allen, L.S. Pereira, D. Raes, M. Smith, Guidelines for computinh crop water requiriments, FAO Irrigation and Drainage 56, Rome, 1996.

[15] C.L. Munster, J.E. Parsons, R.W. Skaggs, Using the personal computer for water table management data acquisition, Applied Engineering in Agriculture 13 (1997) 227-234.

[16] J.J. Teixeira, L.S. Pereira, ISAREG: an irrigation scheduling simulation model, ICID Bulletin 41 (1992) 29-48.

[17] D.S. Ferreira, SISVAR Versão 4.3 (Build 45), DEX/UFLA, Lavras, 2003.

[18] W.L.C. Silva, W.A. Marouelli, Manejo da irrigação em hortaliças no campo e em ambientes protegidos, in: M.A. Faria, (Coord.), Manejo de irrigação, UFLA, SBEA, Lavras, 1998, pp. 311-351.

[19] P.J. Kramer, Walter Relations of Plants, Academic Press, New York, 1983, p. 489.

[20] M.M.P. Benincasa, Análise de Crescimento de Plantas (noções básicas), Jaboticabal: FUNEP, 2003, ISBN: 978-85-885-0572-8.

[21] A.S. Andrade Júnior, A.E. Klar, Manejo da irrigação da cultura da alface (*Lactuca sativa* L.) através do tanque Classe A, Scientia Agrícola 54 (1997) 31-38.

[22] G. Houle, L. Morel, C.E. Reynolds, J. Siégel, The effect of salinity on different developmental stages of an endemic annual plant, *Aster laurentianus* (Asteraceae), American Journal of Botany 88 (2001) 62-67.

[23] L.N. Rodrigues, P.D. Fernandes, H.R. Gheyi, S.B.A. Viana, Germination and formation of rice seedlings under saline stress, Revista Brasileira de Engenharia Agrícola e Ambiental 6 (2002) 397-403.

[24] A.K.S. Lobato et al. Morphological, physiologicaland biochemical responses during germination of cowpea (*Vigna unguiculata* Cv. Pitiuba) seeds under salt stress, World Journal of Agricultural Sciences 5 (2009) 590-596.

[25] B.F. Dantas, L.S. Ribeira, C.A. Aragão, Germination, initial growth and cotyledon protein contento of bean cultivars under salinity stress, Revista Brasileira de Sementes 29 (2007) 106-110.

[26] M.J. Santana, J.A. Carvalho, T.M. Queiroz, C.A.S. Ledo, D.C. Nannetti, Resposta do pimentão (*Capsicum annuum* L.) a diferentes níveis de déficit hídrico e de adubação nitrogenada, in: 41° Congresso brasileiro de olericultura. Anais do 41° CBO, CD-ROM, Brasília, DF, 2001.