Australian Journal of Crop Science

AJCS

AJCS 13(03): 360-366 (2019) ISSN:1835-2707
doi: 10.21475/ajcs.19.13.03.p1178

Productivity of jambu (*Acmella oleracea*) using different soil water tensions and nitrogen rates under greenhouse condition

William Lee Carrera de Aviz*[1], Joaquim Alves de Lima Junior[1], André Luiz Pereira da Silva[2], Rafaelle Fazzi Gomes[1], Rodrigo Otávio Rodrigues de Melo Souza[3], Helane Cristina Aguiar Santos[1], Pedro Daniel de Oliveira[1]

[1]Department of Plant Production, Federal Rural University of Amazonia (UFRA), Brazil
[2]Department of Plant Production, São Paulo State University (UNESP), Brazil
[3]Institute of Agricultural Sciences, Federal Rural University of Amazonia (UFRA), Brazil

***Corresponding author: william.aviz@gmail.com**

Abstract

Acmella oleracea (L.) R.K. is a native Amazon vegetable, known as jambu, which is widely used in regional cuisine and has aroused the interest of the pharmaceutical and cosmetic market. Thereby, this work aimed to study the effect of different soil water tensions and nitrogen rates on Jambu cultivation in the State of Pará. The experiment was conducted in a greenhouse for 30 days in 2016 testing Jamburana cultivar in a 10 × 10 cm spacing in the experiment. The experimental design was based on randomized blocks in a 4 × 4 factorial scheme with three replications. The treatments consisted of four soil water tensions (12, 18, 24 and 30 kPa) adjusted using drip irrigation, and four doses (0, 50, 100 and 150 kg ha^{-1}) of nitrogen. The analyzed variables were fresh mass, plant height, productivity and water use efficiency. There was no interaction between soil water tensions factors and nitrogen rates for all variables. The results showed that the best water tension in the soil and nitrogen dose that provided better development and productivity of jambu were 18 kPa and 79 kg ha^{-1}, respectively.

Keywords: *Acmella oleracea* (L.) R.K., dripping, nitrogen fertilization, protected cultivation, tensiometry.

Introduction

Jambu is a native vegetable in the Amazon region. The plant was originated in the Amazon basin and belongs to the *Asteraceae* family, which possesses extreme regional culinary importance and large medicinal purposes in the treatment of many diseases (Gusmão and Gusmão, 2013). In addition, it presents a substance called spilanthol, which has aroused the interest of the pharmaceutical and cosmetic market since it has biological activities as analgesics, antinociceptives, antioxidants, anti-inflammatories, antimutagenic, anti-wrinkle, antifungal, bacteriostatic, insecticides, anti-malarials, anti larvicides against the neonates of *Aedes aegypti* and *Helicoverpa zea* and anti-molluscicides. It can be absorbed through the skin, endothelial intestine, oral mucosa and blood-brain barrier (Barbosa et al., 2016).

At certain times of the year, due to the high temporal and spatial variability of precipitation in the North region, the production and quality of jambu can be limited by soil water deficiency as well as excess water. The efficient use of water and fertilizers is directly influenced by climatic conditions such as temperature, rainfall and light since they can interfere in beneficial or harmful ways in the development of plants. In regions with high rainfall index and high temperatures, the protected cultivation becomes a practice of extreme importance. Basically, it allows the growers to produce more yields even in periods with greater difficulties. Then, they would be able to reach a greater harvest quantity and/or produce in the off season period, in which higher prices are offered in the market (Homma et al., 2014).

Water is one of the determining factors for food production and; therefore, its lack or excess directly influences the productivity of a crop, making its rational management indispensable to maximize production (Coelho Filho et al., 2014). Regarding this, irrigation is one of the agricultural practices that have the greatest impact on increasing productivity in agriculture, including viable production in regions with low water availability. Although it is a technology incorporated in the diverse vegetable production systems, especially in regions with water limitations, irrigation management in Brazil is still performed in an inadequate way. Usually, there is a great waste of water by irrigation systems applied. These losses are unacceptable, especially when it is known that in many regions in Brazil and in the world water is a highly limiting factor (Marouelli et al., 2014).

Therefore, it is important to know the right moment of irrigation and the amount of water to be applied, since water will be supplied to the plants in sufficient quantity to prevent water stress. This favors increase in productivity and quality of production and minimizes waste of water, leaching of nutrients and degradation of the environment (Marouelli et al., 2014). Additionally, an adequate irrigation allows a

vigorous growth of the plant, causing less susceptibility to the attack of pathogens. With the object of finding optimal water blade and satisfactory overall production, Geisenhoff et al. (2016) evaluated the crisphead lettuce yield subjected to different water tensions in the soil. Regarding the results, they reached maximum productivity in the tension of 12 kPa. However, they obtained higher water use efficiency on intermediate tensions (34 and 45 kPa), which led to 579.87 and 471.71 kg ha^{-1} mm^{-1} quantities of production, respectively.
Nonetheless, besides the water availability is a fundamental factor to reach high productivity. Nutrition is also another indispensable factor in the production of leafy vegetables. In leafy vegetables, the effect of nitrogen is directly reflected in yield, since the provision of adequate doses favors the vegetative development, expanding the photosynthetically active area and increasing the productive potential of the crop (Filgueira, 2008). Rodrigues et al. (2014) found a significant increase in jambu production in Pariqueira-açu, São Paulo. The treatment with a higher nitrogen dose achieved a better yield. Due to the nitrogen fertilization, this treatment provided a 90% increase in the fresh mass production in relation to the treatment with total omission of the element. Borges et al. (2013) analyzed productivity and nutrient accumulation in jambu plants, under organic and mineral fertilization and found maximum yield of 4.40 kg m². Their fertilization was based on urea. It is noteworthy that higher doses showed a decrease in productivity.
Thereby, this work aims to evaluate the effect of different water tensions in the soil and nitrogen rates on the productivity of drip irrigated jambu.

Results and discussion

Behavior of water blades, water tension in the soil and nitrogen doses

The water blades applied before (Inic) and after the treatment differentiation (Irrig) over the experiment, the total water supplied to the crop until harvest (Total), the number of irrigations (NI) and the hourly average of the irrigation applied (TR), as well as the daily water demand (DH) during the differentiation of treatments, are presented in Table 2.
Regarding the results, the total water blades applied were decreasing according to the tension increase. The treatment with 12 kPa presented the highest total water blade applied, since the control tension is practically in the field capacity adopted in this experiment (Fig 2).
These data presented a linear behavior in relation to water consumption per treatment. It is pretty similar to the experiment performed by Geisenhoff et al. (2016), in which the lettuce was irrigated by dripping irrigation under different tensions. Basically, the total water applied decreased according to the increase of water tension in the soil.
Based on the data obtained during the performance of this work, there was no interaction between the tension factors and nitrogen doses for all variables. For the variables of fresh mass of the aerial part, productivity and water use efficiency, there was a significant difference for the tension and nitrogen doses, at the level of 1% of significance. On the other hand, there was no significant difference for any of the factors considering the height variable.
It is noticeable that the water blades and the nitrogen doses influenced the development of the jambu. This evidences the need for a considerable amount of water to obtain a good development of the crop. Soil moisture, which was maintained near the field capacity, favored greater nitrogen use efficiency. Water is the fluid for nutrient transportation to the plant via soil. The management that provided a good water distribution and an intermediate irrigation shift, probably promoted the reduction of nitrogen losses by leaching and the maintenance of a great potential of water in the leaf. Thereby, the stomatal conductance and CO_2 flux could be favored. In addition, the maintenance of a good soil oxygenation, near the effective root system of the plant, presented a positive result in the accumulation of biomass and productivity.

Fresh mass and productivity

The production of fresh mass and productivity behaved in a quadratic way according to the nitrogen doses. The first one achieved maximum result with the dose of 79 kg ha^{-1} of nitrogen, in which 32.4 g $plant^{-1}$ (Fig 3a) could be reached. Similarly, the productivity (Fig 3b) reached maximum under the nitrogen dose of 80 kg ha^{-1}. Its computed balance achieved 3268.94 g m². It is noticeable that the dose close to 80 kg ha^{-1} promoted greater efficiency in the use of nitrogen for the increase of fresh mass and productivity. It is noteworthy that the reduction of fresh matter occurred according to the increase of the nitrogen doses. This effect may be due to the higher doses found in this work to be above the absorption range of the nutrient by the plant.
Borges et al. (2013) worked on cultivation of jambu under organic and mineral fertilization, and Borges et al. (2014) evaluated morphological and physiological indices and productivity of different jambu varieties influenced by organic and mineral fertilization. They also reported high fresh mass of the aerial part upon application of fertilizers. The results of these studies were 87.11 g and 210.13 g, respectively. However, the productivity found in this work was superior to those found by Borges et al. (2013) and Borges et al. (2014). They recorded totals of 4.4 kg m^{-2} and 2.98 kg m^{-2}, respectively. These values found by the authors were achieved using mineral fertilization. The same behaving performance occurred in this work. Likewise, a similar response of the plants in this work could be noticed. Through the nitrogen fertilization, which is directly responsible for growth, development and cell differentiation, with a dose of 120 g m², resulted in an increase in fresh matter production and productivity. The difference between the works previously referred and this one may be related to the planting density and spacing adopted in those experiments. Since the fresh mass obtained by them was superior to that found in this work.
Regarding the water tensions in the soil, the fresh mass of the aerial part and productivity variables behaved in a quadratic form. The fresh mass of the aerial part reached a maximum production of 30.53 g / plant under 18kPa tension (Fig 4a).

Table 1. Physical and chemical properties of the soil before experiment.

Granulometry			Soil chemical analysis							
Sand	Silt	Clay	pH H2O	M.O	N	P	K	Na	Ca	Mg
g kg-1				g kg-1	%	mg dm-3			cmolc dm-3	
801	19	180	6.5	13.76	0.08	192	263	44	2.4	1.3

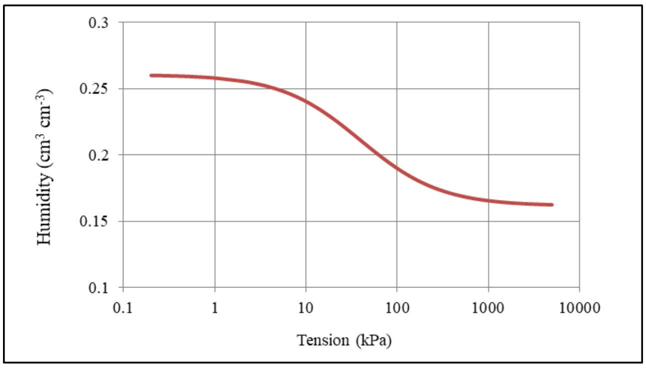

Fig 1. Water retention curve in soil.

Table 2. Water tension in the soil at a depth of 0.15 m, blades applied before the differentiation of treatments (Initial) applied blades after differentiation of treatments (Irrigation), total water blades (Total), the number of irrigations (NI), irrigation interval (II), and daily water demand (DWD).

	blades (mm)					
Tension	Initial	Irrigation	Total	NI	II (day)	DWD (mm/day)
12 kPa	31.9	13.74	45.64	11	1.8	1.52
18 kPa	31.9	11.43	43.33	5	4	1.44
24 kPa	31.9	10.43	42.33	3	6.7	1.41
30 kPa	31.9	8.84	40.74	2	10	1.36

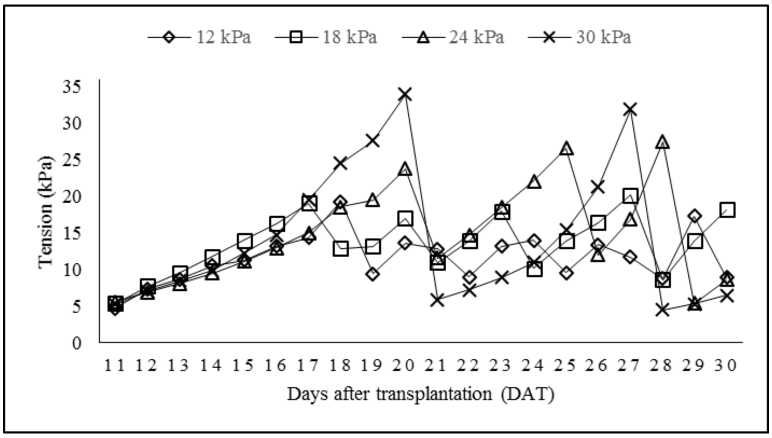

Fig 2. Daily values of soil water tension of treatments 12, 18, 24 and 30 kPa.

Table 3. Analysis of variance for plant height (PH), fresh mass of aerial part (FMAP) Productivity (PRODUCT) and water use efficiency (WUE) according to the soil water tension and nitrogen.

FV	GL	F			
		PH	FMAP	PRODUCT	WUE
Tension	3	0.6235ns	28.7366**	28.7366**	20.8328**
Nitrogen	3	1.7289ns	61.0821**	61.0821**	64.0419**
Tension × Nitrogen	9	1.7572ns	1.2222ns	1.2222ns	1.0193ns
Treatments	15	1.5249ns	18.6971**	18.6971**	17.5865**
Block	2	1.9229ns	0.2191ns	0.2191ns	0.2128ns
Residue	30				
CV%		12.61	8.94	8.94	8.68

** significant at p<0,01; * significant at p>0,05; ns: not significant.

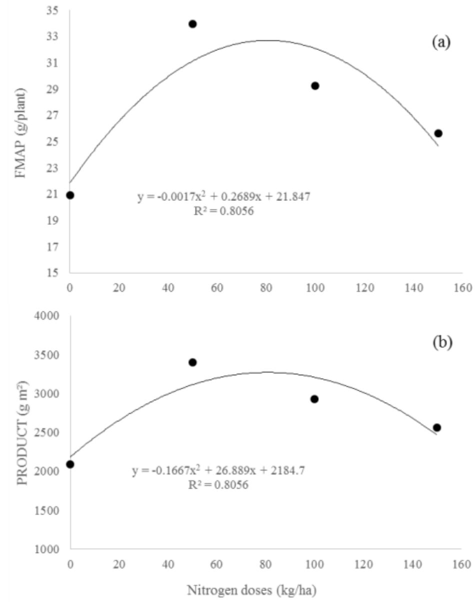

Fig 3. Fresh mass of aerial part (FMAP) (a) and Productivity (PRODUCT) (b) according to the different nitrogen doses (0, 50, 100 and 150 kg ha¹).

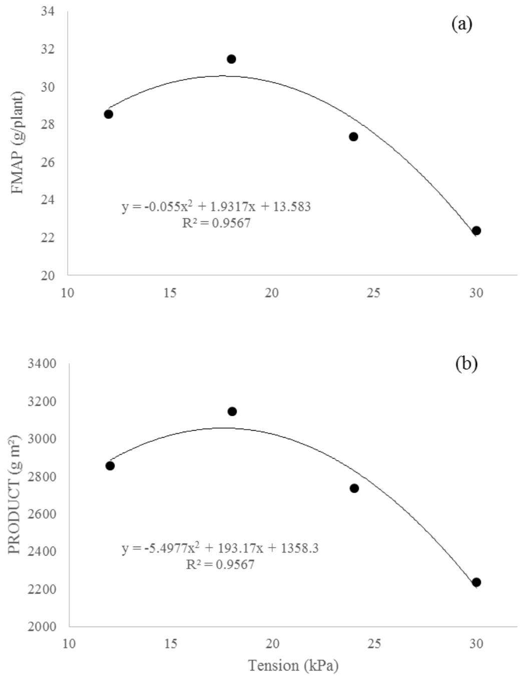

Fig 4. Fresh mass of aerial part (FMAP) (a) and productivity (PRODUCT) (b) depending on the different soil water tensions (12, 18, 24 and 30 kPa).

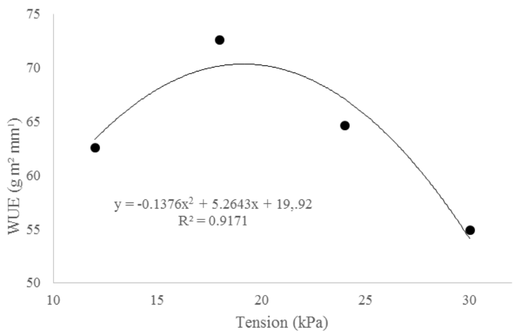

Fig 5. Water use efficiency (WUE) depending on the different soil water tensions (12, 18, 24 and 30 kPa).

The productivity variable, similarly to the fresh mass of the aerial part variable, was significantly affected by soil water tension. It presented a quadratic behavior (Fig 4B), reaching maximum productivity of 3054.11 g m^2 with a tension of 18 kPa.

The treatment with soil water tension of 18 kPa kept the soil near the moisture of field capacity (10 kPa). It demonstrates that the water availability is an essential factor for the increase of fresh mass and productivity in the jambu crop, which is very sensitive to water variation.

Vegetable production is benefited by the tension that maintains soil moisture close to field capacity. This favors the production of photo-assimilates and aeration in the soil, and, consequently reflects a better vegetative development and productivity. The behavior of the variables was similar to the results found by Geisenhoff et al. (2016) working with lettuce. Vilas Boas et al. (2012) evaluated productivity in onion and Lima Junior et al. (2012) on carrot and obtained maximum tensions near to the field capacity.

Water use efficiency

Water use efficiency is the variable that shows the relationship between crop production and water consumption. The total water blade tensions applied in this work presented a variation of less than 5 mm^{-1} between the tension of 12 kPa (the highest blade tension), while the tension 30 kPa, caused the lowest blade tension (Table 2). It evidences the sensitivity of the jambu culture on small variations of water content. Therefore, the efficiency followed the same productivity behavior, since the blades were very close, and the maximum was found in the tension of 18 kPa, corresponding to 70.34 g m^{-2} mm^{-1} (Fig 5).

The other tensions, with bigger and smaller total water blades, showed smaller efficiencies in the use of water. This result is in agreement with those found by Geisenhoff et al. (2016), who evaluated the water use efficiency in crisphead lettuce crop under different water tensions in the soil, which presented a quadratic behavior. Therefore there was a need of reducing the water use efficiency as tension increased. Nevertheless, the water use efficiency found in this work is in a water tension in the intermediate soil, close to the field capacity, demonstrating that the jambu crop responds positively to the water availability.

Materials and methods

Plant materials

The cultivar Jamburana, with a life cycle of approximately 70 to 80 days, was used in the experiment. The seedlings were produced on styrofoam trays with 128 places. All of them contained organic composting. The transplanting was carried out 32 days after sowing and the seedling were placed over a 10 cm x 10 cm spacing scheme, in which each plot had dimensions of 0.4 m x 0.5 m (0.2 m^2). Thereby, they counted twenty plants. Central plants were considered useful (useful area with 10 plants).

After transplanting, the seedlings were irrigated for 10 days prior to the differentiation of the treatments to adapt the seedlings. The total water blade applied was 31.9 mm (3.19 mm dia^{-1}). Throughout the crop development, manual weeding was performed inside and between the beds to control weeds. There was no significant incidence of pests and diseases during the conduction of the experiment. The harvest started at 62 days after sowing.

Climatic aspects

Over the experiment period, the mean diurnal air temperature was 27.5 °C and the humidity was 74.8%. The lowest and highest temperature and humidity recorded were 21.9 ºC, 32.6 ºC, 53% and 94%, respectively. This information show a variation of more than 10 °C in temperature and more than 40% in humidity over a day. Mean diurnal temperatures around of 25.9 °C, as well as annual rainfalls of 2,761 mm per year, potential evapotranspiration of 1,455 mm, relative air humidity 86% and 2,389 hours of sunlight per year assured optimum conditions for the well development of a Jambu crop (Villachica et al., 1996). Thereby, the experiment was carried out under ideal conditions for the good development of the culture.

Experimental site

The experiment was carried out in a protected cultivation area, over an arch arrangement, from May/2016 to July/2016 at the Experimental Farm of Igarapé-açu (FEIGA), which belongs to the Federal Rural University of Amazon (UFRA). The farm is located under the geographic coordinates of 1º07'48.47''S and 47°36'45.31''W, with an elevation of 54 m over the city of Igarapé-Açu, in the northeast part of Pará State.

Type and characteristics of the soil

The soil of the region was classified as dystrophic Yellow Argisoil, with sandy texture. The mean soil density was 1.60 $g.cm^{-3}$. The analysis of fertility and granulometry in the experimental site were obtained from a composite sample of soils, collected from depths of 0 to 0.2 m (Table 1).

Preparation of the area and fertilization

In the area, there was no need for liming. Fertilization was carried out based on soil chemical analysis and according to the recommendation of the analysis made by Cravo et al. (2007). The planting fertilization was done with triple superphosphate (100 kg ha^{-1} of P2O5), while the cover fertilization was done in three plots, with 10, 17 and 24 days after transplantation, using potassium chloride (60 kg ha^{-1} of K2O) and urea (0, 50, 100 and 150 kg ha^{-1} of N).

Treatments and experimental design

The experimental design adopted was based on randomized blocks in a 4 x 4 factorial scheme with three replications. The treatments consisted of four soil water tensions (12, 18, 24 and 30 kPa) and four nitrogen doses (0, 50, 100 and 150 kg ha^{-1}).

The plants were irrigated by drip irrigation, with a flow rate of 1.2 L h^{-1} and emitters spaced 20 cm apart. Irrigation was performed through self-compensating polyethylene drip hoses with a nominal diameter of 16 mm, with a service pressure of 6 mwc at the end of the hose, and with in-line emitters type. The drip hoses were positioned within the plot. Each hose watered two rows of plants (4 plants/ dripper). These latter ones were connected to the polyethylene bypass lines (DN 16), where these to the PVC pipes (DN 50; PN40), which were connected to the main line through solenoid valves of electrical control via a controller installed in the control head. The irrigation system contained a water tank of 5,000 L with an electric pump of 1.5 cv, which was driven by a controller; a disc filter and a pressure regulating valve, both configured to work with 6 mwc in the secondary line inserted in the irrigation system.

After the installation of the irrigation system, hydraulic analyzes were performed to determine the performance by the Uniform Distribution Coefficient (UDC) (Calgaro and Braga, 2008).

In order to determine the critical stress, two tensiometers of puncture were installed in two plots of four treatments under different tensions to 15 cm of depth. Thus the right moment of irrigation could be indicated.

Tensiometers were placed in the planting line between two plants. Soil water stress measurements were performed once a day at 09:00 a.m., using a digital tensiometer. Irrigation was carried out when the average of the respective tensiometers treatments reached the critical tension and performed to raise the moisture field capacity, corresponding to 10 kPa (0.240 cm^3 cm^3). Irrigation management was based on the soil water characteristic curve obtained in the depth profile of 0 to 20 cm of the soil (Fig 1). The daily values of water stresses in the soil of the treatments are presented in Fig 2.

The tension in all the treatments increases every day. The irrigations are performed, when it reached the critical tension. After irrigation, the voltage was reduced to the field capacity (10 kPa). Different from the others, the treatment 12 kPa in several days remained above the critical tension established after the irrigations. This can be explained because the critical stress of this treatment is very close to the field capacity and the water blades applied for the replacement of moisture were not sufficient for the plant needs.

The water blades applied in the differentiation of the treatments and the operation time of the irrigation system were calculated according to Cabello (1996). This author considers the effective depth of the root system equal to 20 cm. Besides that, according to Gusmão and Gusmão (2013), water application efficiency of the drip irrigation system was considered to be equal to 95%.

The meteorological data: temperature, air humidity and precipitation were collected from an automatic meteorological station – Vantage pro2 model – installed in the experimental area inside the greenhouse.

Characteristics evaluated

In order to evaluate the effect of different soil water tensions and nitrogen rates, the following parameters were analyzed: plant height (PH), fresh mass of aerial part (FMAP), productivity (PRODUCT) and water use efficiency (WUE). The plant height was measured at the time of harvest. This one was determined according to the measure between the lap and the highest point of the plant. The fresh aerial mass part was determined through the use of a precision scaled weighing machine. It is noteworthy that it was carried out right after harvesting. The productivity was estimated in g m^{-2} by the product of the fresh mass of the aerial part and the population of plants in a square meter. Water use efficiency was measured through the productivity with the total water blade applied by the treatments.

Statistical analysis

The effects of tension and nitrogen fertilization on the evaluated variables were deferred through the analysis of variance achieved by the Tukey's test. The program used to perform the calculus was the assistat 7.7. In addition, for those cases that a statistical significance was noticed, a regression analysis was carried out.

Conclusion

For the best development and production of jambu, the 18 kPa tension was the best treatment for fresh mass of the aerial part and yield, which produced 30.53 g $plant^{-1}$ and 3,054.11 g m^{-2}, respectively. For the best development and production of jambu, the nitrogen dose of 80 kg ha^{-1} was the treatment that obtained the best result for the fresh mass of the aerial part and productivity variables. They were 32.44 g $plant^{-1}$ and 3,268.94 g m^{-2}, respectively. The water use efficiency obtained maximum efficiency with the combination of 19 kPa reaching 70.34 g m^2 mm^{-1}.

Acknowledgments

The authors are grateful to CNPq - National Council for Scientific and Technological Development, for financial assistance in the accomplishment of this work and for the scholarship, the Federal Rural University of Amazonia - UFRA and the Basic and applied research center in irrigated agriculture- NPBAAI.

References

Barbosa AF, Carvalho MG, Smith RE, Sabaa-srur AUO (2016) Spilanthol: occurrence, extraction, chemistry and biological activities. Rev Bras Farmacogn. 26: 128–133. Borges LS, Guerrero AC, Goto R, Lima GPP (2013) Produtividade e acúmulo de nutrientes em plantas de jambu, sob adubação orgânica e mineral. Semin-Cienc Agrar. 34: 83-94.

Borges LS, Goto R, Lima GPP (2014) Índices morfo-fisiológicos e produtividade de cultivares de jambu influenciadas pela adubação orgânica e mineral. Biosci J. 30: 1768-1778.

Cabello FP (1996) Riegos localizados de alta frecuencia, goteo, microaspersión, exudasión. 3ª ed. Mundi-Prensa, Madrid.

Calgaro M, Braga MB (2008) Determinação da Uniformidade de Distribuição de Água em Sistema de Irrigação Localizada. Embrapa semi-árido, Petrolina.

Coelho filho MA, Bassoi LH, Angelocci LR, Coelho EF, Pereira FAC (2014) Relação solo-planta-atmosfera. In: Sousa VF, Marouelli WA, Coelho EF, Pinto JM, Coelho filho MA (ed) Irrigação e fertirrigação em fruteiras e hortaliças, Embrapa Informação Tecnológica, Brasília.

Cravo MS, Viégas IJM, Brasil EC (2007) Recomendações de adubação e calagem para o Estado do Pará. Embrapa Amazônia Oriental, Belém.

Filgueira FAR (2008) Novo manual de olericultura: agrotecnologia moderna na produção e comercialização de hortaliças. (3 ed) UFV, Viçosa.

Geisenhoff LO, Pereira GM, Lima junior JA, Silva ALP, Aviz WLC (2016) Greenhouse crisphead lettuce grown with mulching and under different soil water tensions. Eng Agr-Jaboticabal. 36: 46-54.

Gusmão MTA, Gusmão SAL (2013) Jambu da amazônia (acmella oleraceae [(L.) R.K. Jansen] Características gerais, cultivo convencional, orgânico e hidropônico. (1 ed) UFRA, Belém.

Homma AKO, Sanches RS, Menezes AJEA, Gusmão SAL (2011) Etnocultivo do jambu para abastecimento da cidade de belém, estado do pará. Amazôn Ciênc Desenv. 6(10): 125-141.

Lima junior JA, Pereira GM, Geisenhoff LO, Vilas boas RC, Silva WG, Silva ALP (2012) Desempenho de cultivares de cenoura em função da água no solo. Rev Bras Eng Agr Amb.16: 514-520.

Marouelli WA, Oliveira AS, Coelho EF, Nogueira LC, Sousa VF (2014) Manejo da água de irrigação. In: Sousa VF, Marouelli WA, Coelho EF, Pinto JM, Coelho filho MA (ed) Irrigação e fertirrigação em fruteiras e hortaliças, Embrapa informação tecnológica, Brasília.

Rodrigues DS, Camargo MS, Nomura ES, Garcia VA, Correa JN, Vidal TCM (2014) Influencia da adubação com nitrogênio e fósforo na produção de jambu, *Acmella oleracea (L) R.K. Jansen.* Rev Bras Plan Med. 16: 71-76.

Vilas boas RC, Pereira GM, Souza RJ, Geisenhoff LO, Lima junior JA (2012) Desenvolvimento e produção de duas cultivares de cebola irrigadas por gotejamento. Rev Bras Eng Agr Amb. 16: 706–713.

Villachica H (1996) Frutales y hortalizas promissórios de la Amazônia. Secretaria Protempore, Lima.