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IRRIGATION MANAGEMENT INFLUENCE AND FERTILIZER DOSES WITH BORON ON PRODUCTIVE PERFORMANCE OF CAULIFLOWER

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ABSTRACT: In order to provide scientific information about the irrigated cauliflower production in Northeast of Para, an experiment was installed in the Federal Rural University of Amazonia farm with the Desert hybrid under different water tensions on the ground and boron doses in the municipality of Igarapé-Açu – PA. The experimental design was a randomized block in a 4 x 4 factorial, sixteen treatments with three replications. The treatments consisted of four water tensions on the ground (15, 30, 45 and 60 kPa) as an indicative of the time to irrigate and four boron doses (0, 2, 4 and 6 kg ha^{-1}). The irrigation was performed with drippers and irrigation management with tensiometers. Each plot, 4 m^2, consisted of 8 plants located in the spacing of 1.0 m between lines and 0.5 m between plants. The hybrid is promising for cultivation in the soil and climatic conditions of the region where it was evaluated, with productivity of 17.1 t ha^{-1}, fresh mass of the inflorescence of 0.85 kg $plant^{-1}$, inflorescence diameter of 18 cm, in 38 kPa tension. The optimal dose of boron which ensured greater production of dry mass was 3 kg ha^{-1}.

KEYWORDS: *brassica oleracea* var. botrytis, drip irrigation, tensiometer.

INTRODUCTION

The cauliflower (*Brassica oleracea* var. botrytis) belongs to the Brassicaceae family and it had increased their consumption in recent years, probably due to its recognition as a functional food (ABUL-FADL, 2012). The cauliflower is 93% water, good source of potassium (256 mg in 100g), phosphorous (57 mg in 100g), it has few calories (23 kcal in 100g) and is plenty of fiber (2.4g in 100g) NEPA-UNICAMP (2011), which meets the expectations of the population concerned with health. It also has antioxidants such as vitamin A, vitamin C and several minerals SUNARISH et al. (2012); SOEGAS et al. (2011), and the Glucosinolates that work to minimize the risk of cancer and several other diseases in humans (KUMAR & ANDY, 2012).

It is a vegetable of great importance in Brazil, being among the fifteen most cultivated, especially among family farmers. Most of the production (94%) is concentrated in the South and Southeast regions, and only 1% in the Northern (IBGE, 2006).

The Northeast region of the state of Pará has a prominent position in the production of vegetables. However, the production of non-traditional vegetables, such as cauliflower, is still early. The small production of cauliflower ends up forcing the import of this food, which leads to commercial value increase in the state of Pará.

An alternative to reduce the cauliflower price in the state would be the increase in production. However, the success of its cultivation depends on several factors, especially the choice of the adapted cultivar to the climatic and soil conditions of the region, as it demands for low temperatures to form commercial inflorescences (MORAIS JÚNIOR et al., 2012). However, genetic improvement programs have produced cultivars and hybrids adapted to high temperature, allowing the cauliflower to be produced year-round in almost all Brazil (MAY et al., 2007; ZANUZO et al., 2013).

Even with the most adapted varieties to the soil and weather conditions in a region, the production and quality of brassica may be limited by the deficiency and excess of water in the soil

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(TANGUNE, 2013; TOMASSONI et al., 2013). Therefore, it is important to know when to irrigate and the amount of water to be applied.

The importance of irrigation management becomes even more evident in the state of Pará. According to SOUZA et al. (2012), the state has a concentration of irrigated areas in regions with historical problems of land use (disorderly deforestation, degraded pastures and lack of water and soil conservation techniques), and characterized by significant use of irrigation systems that have low efficiency and the unsatisfactory technical assistance for most of the producers.

According to MAROUELLI et al. (2011), the critical tension range of water in the soil in which should promote drip irrigation is between 20 and 40 kPa for sandy soils, in this range is possible to increase the efficiency of water use and to obtain maximum productivity of the cauliflower.

In addition to water management, nutrition is another important component for the production of cauliflower and exerts a great influence on productivity and quality of the inflorescence (ALVES et al., 2011; PIZETTA et al., 2005). Among the micronutrient, boron is the most important to the culture in Brazilian soils, which, although required in low quantities, 2 to 4 kg ha^{-1} in sandy soils cause characteristic and severe symptoms when they are in the range of deficiency or excess, and the limit between boron deficiency and toxicity in cauliflower plants is very narrow, which in some cases could prevent the production of marketable inflorescences by loss of product quality (MAY et al., 2007; PIZETTA et al., 2005). According to PIZETTA et al. (2005), the intensity of boron fertilization response is normally associated with the original content of this nutrient on the soil, the soil type and the cultivar.

Given the lack of technical information on the production of cauliflower in the North, and considering the hypothesis that the soil and climate conditions of the region and the critical tension are in accordance with the recommendation of MAROUELLI et al. (2011), the aim of this study was to evaluate the effect of different water tensions in the soil and boron doses in the development and production of drip irrigated cauliflower in Igarapé-Açu - PA, northeast region of the state of Pará.

MATERIAL AND METHODS

The experiment was carried out in the field from August / 2014 to February / 2015 at the Experimental Farm of the Federal Rural University of Amazonia (UFRA) with geographical coordinates of 1° 07' 48.47" S and 47° 36' 45.31" W, 54 m of elevation, in the municipality of Igarapé-Açu, Pará, Northeast of the state of Pará.

The soil of the region was classified as yellow dystrophic Acrisol, with sandy texture. The average soil density was 1.60 g cm^{-3} and the results of the fertility and particle size analysis of the experimental area obtained from sample of soil collected at the depth of 0 to 0.2 m, were: pH_{H20}= 5.2; N= 0.6 g kg^{-1}; organic matter= 13.76 g kg^{-1}; P= 21 mg dm^{-3}; Ca= 1.8 $cmol_c$ dm^{-3}; Mg= 0.5 $cmol_c$ dm^{-3}; K= 0.013 $cmol_c$ dm^{-3}; Na= 0.013 $cmol_c$ dm^{-3}; SB= 2.33 $cmol_c$ dm^{-3}; H+Al= 2.48 $cmol_c$ dm^{-3}; CEC= 4.81; V: 48 %; B= 0.52 mg dm^{-3}; Cu= 2 mg dm^{-3}; Fe= 168 mg dm^{-3}; Mn= 1.9 mg dm^{-3}; Zn= 2.9 mg dm^{-3}; and 801, 19 and 180 g kg^{-1} of Sand, Silt and Clay, respectively.

The soil of the experimental area was prepared using plowing and harrowing after liming (1.5 t ha^{-1} of limestone) held 90 days before the transplanting of the seedlings, seeking to increase the base saturation (V) to 80%. The liming, fertilization at planting and top-dressing were made manually based on the chemical analysis of the soil, following the formulation used by ZANUZO et al. (2013), but with the addition of 50 kg ha^{-1} of N and K in top-dressing fertilization. In planting fertilization (15 days before transplanting), phosphorus (600 kg ha^{-1} of P_2O_5) with superphosphate, boron (with borax according to the treatments) and chicken manure (15 t ha^{-1}) were all applied in the hole (20 cm of deep), while potassium fertilizer (410 kg ha^{-1} of K_2O) with potassium chloride and nitrogen (310 kg ha^{-1} of N) with urea were provided in installments every 15 days during the growing cycle, being one of planting and four of top-dressing.

We used in the experiment the Desert Hybrid cauliflower, summer cultivar, with a cycle varying between 80 and 90 days. The cauliflower seedlings were grown in styrofoam trays with 128 cells containing organic compound, and were transplanted 26 days after sowing on 11.04.2014, when they had four to five leaves. After transplanting, the seedlings were irrigated for 30 days before the differentiation of the treatments with 93 mm for the adaptation phase. Throughout the development of the culture, it was carried out: hand weeding for weed control; and manual cleaning of the leaves with water and liquid neutral soap, plus application of systemic insecticide with costal manual spray to control aphid. There was the staking of some plants until its stabilization on the field with bamboo stakes and piles to increase the fixing in the soil due to the observation of falling on days with strong winds.

The harvest began at 120 days after sowing, 30 days more than the recommended by the producing company of the seed, and it extended for 20 days, we observed that from the emergence of the inflorescence to the harvest there was an average of 15 days. This was done as the inflorescences presented complete development when the flower buds still united and compact and firm inflorescences.

The experimental design was randomized block in a 4 x 4 factorial with three replications. The treatments consisted of four water tensions in soil (15, 30, 45 and 60 kPa) as indicative of time to irrigate - critical tension, and four boron doses (0, 2, 4 and 6 kg ha^{-1}). Each plot had dimensions of 2m x 2m (4 m^2). We used two rows of plants spaced 0.5 m between themselves and 1 m between rows, totaling eight plants per plot.

The plants were irrigated through dripping, with a flow rate of 2 L h^{-1}, and drippers spaced 0.20 m apart. Irrigation was performed through auto compensating drip hoses of polyethylene additive, nominal diameter – ND of 16 mm, with an operating pressure of 6 mca (58.8 kPa) at the end of the hose, and emitting of in–line type. The drip hoses were positioned within the portion of the soil surface, so that each hose with 10 drippers would meet a row of plants (total of 20 transmitters / plot). These were connected in polyethylene drop lines (ND 16) and these to the PVC pipes (ND 50; PN40) under each treatment tension (15, 30, 45, 60 kPa), which were connected to the main line with sphere records used to operate the irrigation of different water tension treatments on the ground. We used for the irrigation system a water tank of 5000 L, an electric pump of ½ hp, a disc filter and a pressure regulating valve of 10 mca (98 kPa) placed on the exit of the main pipe to maintain the operating pressure on the sidelines.

After installation of the irrigation system, we carried out hydraulic evaluations for determining the performance of it through the Distribution Uniformity Coefficient (DUC). The uniformity analysis was performed in four parts, one for each treatment relating to different tensions. Collectors' containers of 50 mL were placed beneath six central drippers, collecting the water for a period of 1 min, with two repetitions. With the average of the depths collected, the DUC was calculated.

To determine the critical tension, we installed a set of four punch tensiometers in two installments of four treatments of different tensions, three to 15 cm of deep because of the highest concentration of roots on the soil surface (which indicate the time to irrigate according to treatments) and one to 30 cm of depth (to check the occurrence of percolation).

Tensiometers were positioned in the alignment of the culture between two plants. The tensiometers readings were done twice a day, one at 9 am and the other at 3 pm, using a digital puncture tensiometer. The irrigation management is based on the water retention in the soil characteristic curve obtained in the profile from 0 to 20 cm of soil depth (Figure 1). The irrigations were made when at least two tensiometers or the average of three reached the critical tension, and always looking to raise soil moisture until field capacity, corresponding to the tension of 10 kPa.

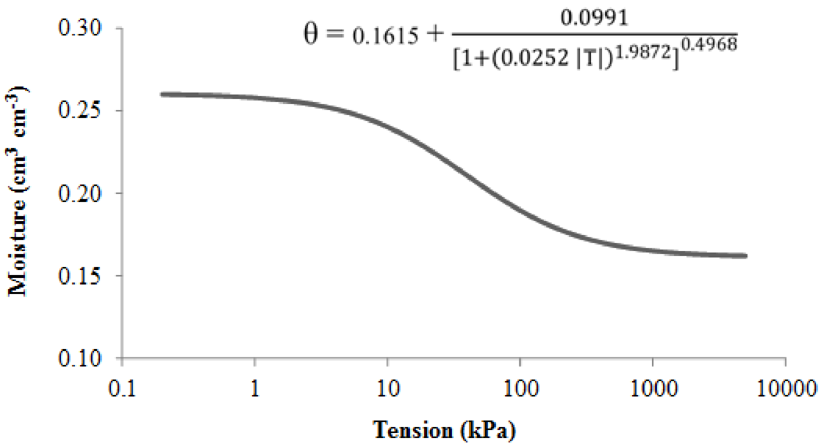

FIGURE 1. Water retention curve in the soil. In the equation, the symbols θ and T represent the moisture and tension, respectively.

The applied water levels in the differentiation of treatments and the operating time of the irrigation system were calculated according CABELLO (1996), considering the effective root depth equal to 20 cm and the water application efficiency of the drip irrigation system equal to 95%.

The meteorological data: temperature, moisture and rainfall were collected from an automatic weather station, Vantage pro2® model, installed in the experimental area.

To evaluate the effect of irrigation management and fertilization with boron, the following characteristics were analyzed: biometrics (plant height – PH, plant diameter – PD and number of leaves – NL); dry mass of the shoot without inflorescence (DMS); fresh and dry mass of the inflorescence (FMI, DMI); inflorescence diameter (ID); inflorescence height (IH); inflorescence circumference (IC); and productivity (PI).

Biometrics was carried out at 90 DAT (Days After Transplanting), during the formation of the inflorescences. The PH was determined from the plant's stem, close to the ground, up to the maximum average height of the upper leaves; the NL consisted of counting the number of leaves; the PD was determined from the average of two perpendicular diameters by measuring the distance between the plant extremities. The DMS was determined using only one plant per plot (the other plants have been preserved to maintain the experiment) at 86 DAT (beginning of the formation of inflorescences) where it was cut close to the ground and placed in paper bags and kept in an incubator with circulating air at 65 °C until constant weight. The dried material was weighed with an accuracy of 0.001 g, obtaining the average of the dry mass.

The other variables were evaluated as the inflorescences were harvested using a precision balance and greenhouse (FMI and DMI), graduated ruler in centimeters (for IH and ID) and also a tape in centimeters (for IC). The PI was estimated at t ha^{-1} with a population of plants in one hectare over the FMI.

The effects of water tension in the soil and fertilizer with boron in the characteristics of the plants and production of cauliflower were evaluated by the F test of analysis of variance with the aid of Assistat 7.7 software, and in cases in which there was significance we used regression analysis.

RESULTS AND DISCUSSION

During the experiment, the average daily air temperature was 27 °C and moisture was 80%. The lowest and highest recorded temperatures were 21 °C and 35 °C, respectively. The lowest moisture recorded was 40% and the highest was 96%. These data show a variation of more than 10 °C in temperature and over 50% of moisture throughout a day.

The water depths applied before (Inic) and after the differentiation of treatments (Irrig) and precipitation (Precip) occurred during the experiment, the total of water supplied to the crop until the harvest (Tot), the number of irrigations (NI) and the average irrigation interval (II) during the differentiation of the treatments are presented in Table 1.

We observed that the total water applied were higher in treatments with intermediate tensions (T30 and T45), probably because in these tensions there was greater demand for water by the cauliflower to meet their water needs due to higher growth, which made the tensions to reach quickly the pre-established values. The total water depths applied were lower in extreme treatments (T15 and T60), probably due to lower water demand required by the plant in T15 coming from a higher number of irrigations, and fewer irrigations in T60, which obtained the highest irrigation interval.

TABLE 1. Water tensions in soil at a depth of 0.15 m, applied water depths before the differentiation of treatments (Inic), water depths applied after differentiation of treatments (Irrig), occurred rainfall (Precip), total water depths (Tot), number of irrigation (NI) and average of the irrigation interval (II).

Treatments	Tension (kPa)	Water depth (mm)				NI (un)	II (day)
		Inic	Irrig	Precip	Tot		
T15	15	93.10	49.05	143.35	285.50	32	1.62
T30	30	93.10	101.61	143.35	338.06	21	2.22
T45	45	93.10	111.34	143.35	347.79	16	3.07
T60	60	93.10	67.53	143.35	303.98	8	5.14

These data showed a quadratic behavior in relation to water consumption per treatment (Table 1), unlike TANGUNE (2013) in an experiment with drip irrigated broccoli with different tensions, which obtained linear behavior of the results, where total water depth applied diminished with the increase of the water tension in the soil, reaching a maximum of 451.6 mm at 15 kPa.

We observed in Table 1 that the frequency of irrigation, similar to TANGUNE (2013), was higher in the low tension treatment, but the operating time of the irrigation system was lower when compared to other treatments where the system had to work longer to apply the water depth necessary to raise soil moisture to its field capacity.

In the evaluation of the irrigation system, we obtained a Distribution Uniformity Coefficient (DUC) of 98%, which favors higher efficiency in the application of drip irrigation.

The total amount of water supplied during the cauliflower crop cycle of all treatments, even with the precipitations, was below the range needed for the production of 380-500 mm mentioned by MAY et al. (2007), demonstrating in this study a possible saving of water and therefore energy. Differently from ZANUZO et al. (2013) that using a micro-sprinkler irrigation system applied a 450 mm of water depth from transplanting to the harvest of the “Piracicaba Precoce” cultivar, about 5 mm day $^{-1}$, however for the hybrids, they applied an average water depth of 327 mm. MORAIS JÚNIOR et al. (2012) using drip irrigation system only reported that irrigations were made throughout the crop cycle in three-day intervals, complementing the rains. The same happened with MONTEIRO et al. (2010), but they used a sprinkler system to irrigate. As can be seen, there is a lack of irrigation techniques information for the cauliflower.

According to MAY et al. (2007), the cauliflower under favorable conditions such as adequate temperature and moisture, which depends on the cultivar to be planted, may have growth and development divided into four stages: the first, from 0 to 30 days (early growth), second from 30 to 60 days (leaf expansion) third from 60 to 90 days (differentiation and the development of early flower and outer leaves) and fourth from 90 to 120 days (inflorescence development). However the length of these phenological stages can vary according to the own characteristics of the cultivar, can also to the plant response to cultivation environmental conditions.

The harvest of the experiment took place 120 days after sowing, 30 days after the recommendation of the seed producer, probably because the soil and climate conditions of the

Northeast of the state of Pará are different from the origin region of the seed. The seeds are from the south of the Brazil, and are considered from summer. The summer in the South region has an average of 14h of light, while in the north the average is 12h (SILVA et al., 2010). This photoperiod difference may also explain the delay in cauliflower harvest in Igarapé-Açu / PA. According to SCHUSTER et al. (2012), the photoperiod influences the flowering, even if it is little for the cauliflower culture (FILGUEIRA, 2008).

Prolonged periods of temperature above 25 °C may also delay the formation of the cauliflower plants inflorescence (MONTEIRO et al., 2010). These authors also observed, so this study, precocity difference in a summer hybrid, where it has reached the point of harvest at 119 days after sowing, differently from MORAIS JÚNIOR et al. (2012) and ZANUZO et al. (2013), for the same hybrid they obtained a short period between sowing and harvesting - 112 days and 105 days, respectively. This shows that the precocity is influenced by the environment, varying considerably between regions.

The results obtained with the use of different tensions and boron dose in cauliflower culture can be seen in Figures 2, 3 and 4.

We observed that there was no interaction between the water supply in the soil and boron factors, but water tension depths had a significant effect on the soil of 1% and 5% of probability by the F test for the variables: productivity (PI) ($p \leq 0.01$), fresh and dry mass of the inflorescence (FMI, DMI) ($p \leq 0.01$), inflorescence diameter (ID) ($p \leq 0.01$), inflorescence circumference (IC) ($p \leq 0.01$), inflorescence height (IH) ($p \leq 0.01$), dry mass of shoot (DMS) ($p \leq 0.01$), number of leaves (NL) ($p \leq 0, 05$), plant diameter (PD) ($p \leq 0.01$), plant height (PH) ($p \leq 0.05$); and significant effect of boron doses, only on the variables: dry mass of the shoot (DMS) ($p \leq 0.05$), dry mass of the inflorescence (DMI) ($p \leq 0.05$) and inflorescence height (IH) ($p \leq 0.05$).

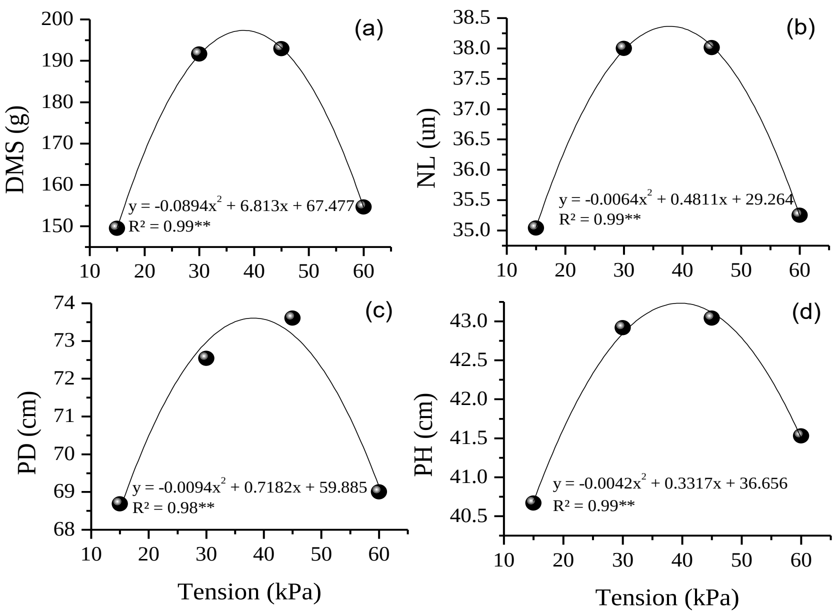

FIGURE 2. Effect of different values of water tension in soil on the dry mass of shoot (a), number of leaves (b), plant diameter (c) and plant height (d) (average values).

By the regression analysis of the tension factor, we found a quadratic behavior of the results for all variables, that is, there was an increase of the variables up to 38 kPa, from which there was a decrease in that values. We noted that lower and higher voltages than 38 kPa negatively affected the variables analyzed.

The maximum values estimated from the adjustment equations of the dry mass of cauliflower shoots at the beginning of the formation of the inflorescences were 197.3 g (Figure 2a), the leaves number was 38.3 (Figure 2b), the diameter of the plants was 73.6 cm (Figure 2c) and plant height was 43.2 cm (Figure 2d). The DMS was greater than 87g of the total dry mass (leaves, stems, inflorescences and roots) of the Verona hybrid found by GONDIM et al. (2011) in Jaboticabal - SP, Brazil, as well as the number of leaves (24.2 un plant $^{-1}$) and plant height (37.1 cm). But for the same hybrid, MONTEIRO et al. (2010) found an average plant diameter of 97.1 cm, higher than the one in this study. This difference may be due to different hybrids associated with soil and weather conditions of the cultivation region.

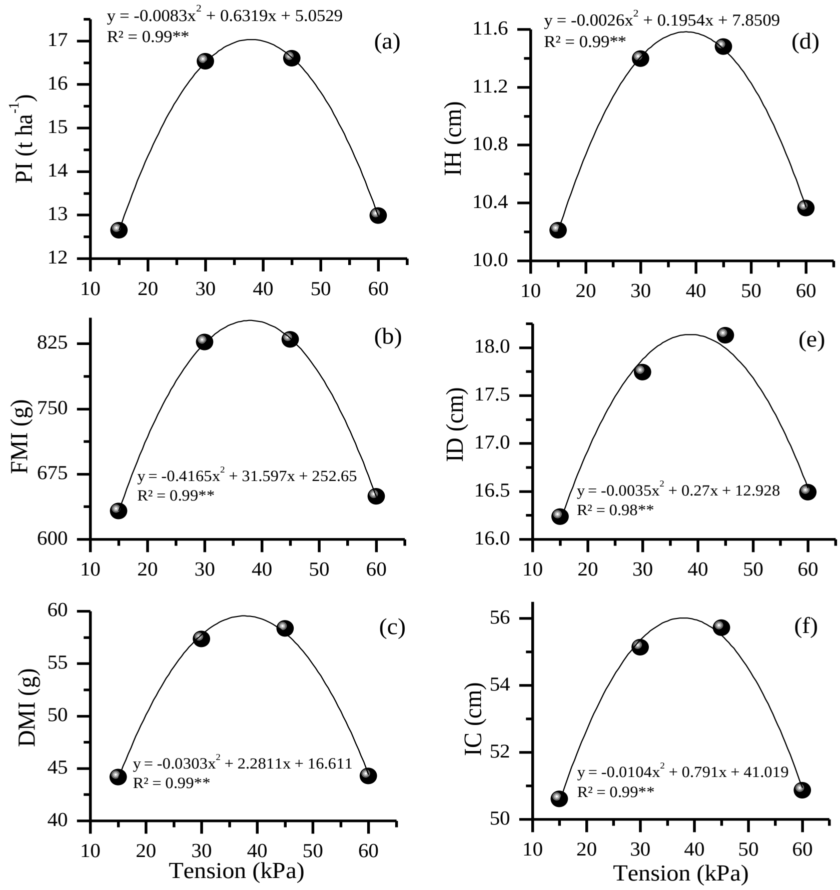

FIGURE 3. Effect of different values of water tension in soil in productivity (a) fresh mass of the inflorescence (b) dry mass of the inflorescence (c) inflorescence height (d), inflorescence diameter (e) and inflorescence circumference (f) (average values).

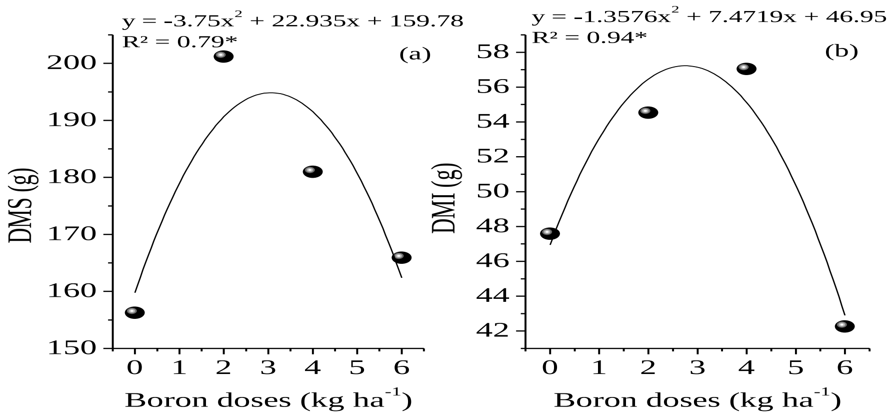

FIGURE 4. Effect of boron doses in the dry mass of the shoot (a) and dry mass of the inflorescence (b) (average values).

The percentage of water found in the inflorescence was the same in all treatments, 93%, similar to that described by NEPA-UNICAMP (2011).

The maximum values estimated from the cauliflower adjustment equations were 17.1 t ha^{-1} for productivity (Figure 3a), 852 g for the fresh mass of the inflorescence (Figure 3b), 59.5 g of dry mass of the inflorescence (Figure 3c), 11.5 cm of inflorescence height (Figure 3d), 18.1 cm of inflorescence diameter (Figure 3e) and 56.1 cm for the inflorescence circumference (Figure 3f) consistent with the diameter, demonstrating a circular shape of the inflorescences.

The maximum yield of cauliflower obtained in this experiment is within the range cited by MAY et al. (2007) of 15 to 25 t ha^{-1} as well as the tension responsible for the maximum productivity is within the range of 20 to 40 kPa for sandy soils mentioned by MAROUELLI et al. (2011).

The greatest productivity obtained is related to the maximum values of: fresh and dry mass of the inflorescence, shoot dry mass, inflorescence height, inflorescence diameter, inflorescence circumference, plant height, canopy diameter and number of leaves. These variables demonstrate greater morphological growth, resulting in greater accumulation of biomass, which is strictly dependent on the photosynthetic process, when compared to tension values below and above of 38 kPa.

The low cauliflower productivity, as well as low FMI, DMI, ID, IH, IC, DMS, PH, PD and NL values related to the values near to field capacity, probably due to the characteristic of the own cauliflower to respond negatively to a prolonged exposure to the condition of soil low aeration porosity in these conditions. The low aeration porosity may be involved in the reducing of the oxygen-absorbed rate by plant roots, limiting root breathing, causing crop yields to be reduced. It is noteworthy that the irrigation did not exceeded field capacity, as it was not observed water percolation into the soil through tensiometers installed at 30 cm depth.

Since the decrease in productivity from 38 kPa, and the low FMI, DMI, ID, IH, IC, DMS, PH, PD and NL values probably occurred because water becomes more strongly retained in the soil, and it reduces the availability of water to plants, which requires a greater amount of energy expended by them to absorb the water needed to their metabolic needs (VILAS BOAS et al., 2012; TEIXEIRA et al., 2013).

With the increased tension in the soil, there is also an improvement of drought, and the upper ground layers are the first to be dried, causing the loss of surface roots and proliferation of deep roots, which can be considered as a defense strategy of the plant against drought (RAMOS JUNIOR et al., 2013). However this strategy requires allocation of assimilates of photosynthesis, which is also limited by water deficit due to the reduced CO_2 supply caused by stomata closure (ALBUQUERQUE et al. 2013), for the growing roots ends, which probably generated in this study assimilated competition between roots and shoots (vegetative phase) and between roots and inflorescences (reproductive stage), making both productivity and the other variables mentioned above were decreasing with the tension increase. TANGUNE (2013) in an experiment with broccoli also noted that higher tension values negatively affect productivity, fresh mass, diameter and circumference of the inflorescence.

ZANUZO et al. (2013), working with different genotypes of summer cauliflower in a tropical region with a dry season - Aw, observed better agronomic performance of hybrids compared to the ‘Piracicaba Precoce’ cultivar. The hybrids (Verona, Veneza, Sarah and First Snow) had an average yield of 17 t ha^{-1}, similar to this study; Piracicaba already showed low productivity of only 6.67 t ha^{-1}.The diameter also was higher for hybrids with an average of 18 cm, also similar to this study; and Piracicaba with only 13.7 cm. The fresh mass of the inflorescence hybrid also showed average values of 0.85 kg plant^{-1}, similar to this study, and above ‘Piracicaba Precoce’, 0.32 kg plant^{-1}.

Higher values than those obtained in this study of fresh mass (average of 1.07 kg plant^{-1}), inflorescence diameter (average of 24.33 cm), inflorescence height (average of 12.20 cm) and productivity (average of 21.5 t ha^{-1}) were reported by MONTEIRO et al. (2010) in Jaboticabal-SP working with the same hybrids of ZANUZO et al. (2013). These results demonstrate that there is a positive correlation with the temperature factor, where milder temperatures tend to favor the better development of the inflorescence. MORAIS JÚNIOR et al. (2012) confirm this statement, because working with an average temperature of 21.9 °C they found average mass for the same hybrid of the above authors of 1.71 kg plant^{-1}, inflorescence diameter of 21.49 cm, inflorescence height of 14,10 cm and productivity of 34,17 t ha^{-1}; also noted that 'Piracicaba Precoce' showed 1.37 kg plant^{-1} of fresh mass of the inflorescence, 21.29 cm in diameter, 11.99 cm of height and 27.45 t ha^{-1} of productivity.

By the regression analysis of boron, there was a quadratic behavior of the results for the following variables: dry mass of the shoot – DMS (Figure 4a) and dry mass of the inflorescence – DMI (Figure 4b). The inflorescence height variable - IH despite having significance in the analysis of variance did not show a defined behavior in function of the applied boron doses ($p \geq 0.05$). We observed that the optimum dose of boron to ensure increased production of DMS (195 g) and DMI (57 g) was 3 kg ha^{-1}.

The boron content found in the soil of the experiment (0.57 mg dm^{-3}) is within the range considered average for the soils of the state of Pará (CRAVO et al., 2007). This fact probably did not influence most of the variables evaluated, primarily on productivity. CAMARGO et al. (2009) working with 'Sharon' cauliflower in yellow red Acrisols with B content of 0.54 mg dm^{-3} on the APTA Centro Sul-UPD farm from Tietê – SP, Brazil, also noted that the supply of 3 kg of B ha^{-1} did not affect the total productivity, the mass and the diameter of the inflorescences. However PIZETTA et al. (2005) with 0.15 mg dm^{-3} of B in 20 cm of soil, also working with different doses of boron in the culture of cauliflower in Santa Rita do Passa Quatro (SP), found quadratic effect on the productivity, requiring 5.1 kg ha^{-1} of B to achieve maximum productivity of 30 t ha^{-1}.

In the present study, boron doses only influenced DMS and DMI possibly due to the higher accumulation of solids with an optimal dose of 3 kg ha^{-1}, which was probably required to translocate the maximum leaves carbohydrates to other organs, making the division and cell elongation, and acting in the formation of the cell wall. MONTEIRO et al. (2010) found the same dose of 74.9 g plant^{-1} (average of the evaluated hybrids) dry mass of the inflorescence (considering the fresh mass with 93% of water), higher than the one in this study that obtained maximum value of 57.2 g plant^{-1}. ZANUZO et al. (2013) found with the dose of 4 kg ha^{-1} for the same hybrids, dry mass of the inflorescence, also considering the 7% of solids, average equal to the one of this study 57.2 g plant^{-1}. This difference may be due to the different soil and weather conditions of the cultivation region.

CONCLUSIONS

We found that to ensure greater development and production of cauliflower irrigated by dripping, we should irrigate when the tension reaches 38 kPa in the Northeast region of Pará.

The optimal dose of boron to ensure greater dry mass production is 3 kg ha^{-1}.

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REFERENCES

ABUL-FADL, M.M. Nutritional and chemical evaluation of white cauliflower by-products flour and the effect of its addition on beef sausage quality. **Journal of Applied Sciences Research**, Punjab, Jordan, v.8, n.2, p.693-704, 2012.

ALBUQUERQUE, M.P.F.; MORAES, F.K.C.; SANTOS, R.I.N.; CASTRO, G.L.S.; RAMOS, E.M.L.S.; PINHEIRO, H.A. Ecofisiologia de plantas jovens de mogno-africano submetidas a deficit hídrico e reidratação. **Pesquisa Agropecuária Brasileira**, Brasília, v.48, n.1, p.9-16, 2013. doi: 10.1590/S0100-204X2013000100002

ALVES, A.U.; PRADO, R.M.; CORREIA, M.A.R.; GONDIM, A.R.O.; CECÍLIO FILHO, A.B.; POLITI, L.S. Couve-flor cultivada em substrato: marcha de absorção de macronutrientes e micronutrientes. **Ciência e Agrotecnologia**, Lavras, v. 35, n. 1, p. 45-55, 2011.

CABELLO, F.P. **Riegos localizados de alta frecuencia (RLAF) goteo, microaspersión, exudasión**. 3 ed. Madrid: Mundi-Prensa, 1996. 511 p.

CAMARGO, M.S.; MELLO, S.C.; FOLTRAN, D.E.; CARMELLO, Q.A.C. Produtividade e podridão parda em couve-flor ‘Sharon’ influenciadas pela aplicação de nitrogênio e boro. **Horticultura Brasileira**, Brasília, v. 27, n. 1, p. 30-34, 2009.

CRAVO, M.S.; VIÉGAS, I, de J.M.; BRASIL, E.C. **Recomendações de adubação e calagem para o Estado do Pará**. Belém: Embrapa Amazônia Oriental, 2007. 262p.

FILGUEIRA, F.A.R. **Novo manual de olericultura:** agrotecnologia moderna na produção e comercialização de hortaliças. 3. ed. Viçosa: UFV, 2008. 242 p.

GONDIM, A.R.O.; PRADO, R.M.; CORREIA, M.A.R.; ALVES, A.U.; CECÍLIO FILHO, A.B.; POLITI, L.S. Curva de crescimento e acúmulo de matéria seca em couve-flor cultivada em substrato. **Bioscience Journal**, Uberlândia, v. 27, n. 1, p. 88-94, 2011.

IBGE – Instituto Brasileiro de Geografia e Estatística. **Censo Agropecuária** 2006. Disponível em: http://www.sidra.ibge.gov.br/bda/tabela/listabl1.asp?c=819&n=0&u=0&z=p&o=2&i=P. Acesso 12 fev. 2014.

KUMAR, S.; ANDY, A. MiniReview Health promoting bioactive phytochemicals from Brassica. **International Food Research Journal**, v. 19, n.1, p. 141-152, 2012.

MAROUELLI, W.A.; OLIVEIRA, Á.S. DE; COELHO, E.F.; NOGUEIRA, L.C.; SOUSA, V.F.. Manejo da água de irrigação. In: SOUSA, V.F.; MAROUELLI, W. A.; COELHO, E.F.; PINTO, J.M.; COELHO FILHO, M.A (Ed.). **Irrigação e fertirrigação em fruteiras e hortaliças**. Brasília: Embrapa Informação Tecnológica, 2011. p. 157-232.

MAY, A; TIVELLI, S.W.; VARGAS, P.F.; SAMRA, A.G.; SACCONI, L.V.; PINHEIRO, M.Q. **A cultura da couve-flor**. Campinas: IAC, 2007. (Boletim Técnico, 200). Disponível em: http://www.iac.sp.gov.br/publicacoes/publicacoes_online/pdf/Tecnico200.pdf. Acesso 21 jan. 2014.

MONTEIRO, B.C.B.A.; CHARLO, H.C.O.; BRAZ, L.T. Desempenho de híbridos de couve-flor de verão em Jaboticabal. **Horticultura Brasileira**, Brasília, v. 28, n. 1, p. 115-119, 2010.

MORAIS JÚNIOR, O.P.; CARDOSO, A.F.; LEÃO, E.F.; PEIXOTO, N. Desempenho de cultivares de couve-flor de verão em Ipameri. **Ciência Rural**, Santa Maria, v.42, n.11, p.1923-1928, 2012.

NEPA-UNICAMP. **Tabela brasileira de composição de alimentos – TACO**. 4 ed. rev. ampl. Campinas, 2011. 161 p.

PIZETTA, L.C.; FERREIRA, M.E.; CRUZ, M.C.P.; BARBOSA, J.C. Resposta de brócolis, couve-flor e repolho à adubação com boro em solo arenoso. **Horticultura Brasileira**, Brasília, v.23, n.1, p.51-56, 2005.

RAMOS JUNIOR, E.U.; MACHADO, R.A.F.; OLIBONE, D.; CASTOLDI, G.; RAMOS, B.M. Crescimento de plantas de cobertura sob déficit hídrico. **Semina**: **Ciências Agrárias**, Londrina, v. 34, n. 1, p. 47-56, 2013. doi: 10.5433/1679-0359.2013v34n1p47

SCHUSTER, M.Z.; KAWAKAMI, J.; BROETTO, D.; SZYMCZAK, L.S.; RAMALHO, K.R.O. Influência do fotoperíodo e da intensidade de radiação solar no crescimento e produção de tubérculos de rabanete. **Revista Brasileira de Tecnologia Aplicada nas Ciências Agrárias**, Guarapuava, v.5, n.2, p. 73-86, 2012. doi: 10.5777/PAeT.V5.N2.06

SILVA, F. S.; CATELLI, F.; GIOVANNINI, O. Um modelo para o movimento anual aparente do sol a partir de uma perspectiva geocêntrica. **Caderno Brasileiro de Ensino de Física**, Florianópolis, v. 27, n. 1: p. 7-25, abr. 2010.

SOEGAS, P.; SOTELO, T.; VELASCO, P.; CARTEA, M.E. Antioxidant properties of Brassica vegetable. **Functional Plant Science and Biotechnology**, Miki-Cho, v. 5, n. 2, p. 43-45, 2011.

SOUZA, R.O.R.M; PANTOJA, A.V.; AMARAL, M.A.C.M.; PEREIRA NETO, J.A. Cenário da agricultura irrigada no estado do Pará. **Irriga,** Botucatu, v. 17, n. 2, p. 177 - 188, 2012.

SUNARISH, E.S.; HAKIM, L.; SUGIYANTO, S.; SUMANTRI, S. Protective effect of Brassica oleracea var. botrytis L. against theophylline-induced hepatocellular abnormalities in rats. **Universa Medicina**, Jakarta, v.31, n.1, p. 12-19, 2012.

TEIXEIRA, R.P.; PEREIRA, G.M.; SOUZA, R.J.; GARCIA, H.H.; GAMA, G.B.N. Análise das tensões de água no solo cultivado com morangueiro sob poda. **Irriga**, Botucatu, v. 18, n. 1, p. 25-42, 2013.

TANGUNE, B.F. **Produção de brócolis irrigado por gotejamento, sob diferentes tensões de água no solo**. 2013. 73 f. Dissertação (Mestrado em Recursos Hídricos em Sistemas Agrícolas) – Universidade Federal de Lavras, Lavras, 2013.

TOMASSONI, F.; SANTOS, R.F.; ROCHA, A.A.; GALDINO, T.S.; NADALETI, W.C.; ROSSI, E.; CARPINSKI, M. Sensibilidade da couve-flor ao excesso de água no solo. **Acta Iguazu**, Cascavel, v.2, n.4, p. 1-6, 2013.

VILAS BOAS, R.C.; PEREIRA, G.M.; SOUZA, R.J.; GEISENHOFF, L.O.; LIMA JÚNIOR, J.A. Desenvolvimento e produção de duas cultivares de cebola irrigadas por gotejamento. **Revista Brasileira de Engenharia Agrícola e Ambiental,** Campina Grande, v.16, n.7, p.706–713, 2012.

ZANUZO, M.R.; RIBEIRO, L.M.; LANGE, A; MACHADO, R.A.F.; MASSAROTO, J.A. Desempenho agronômico de genótipos de couve-flor nas condições edafoclimáticas de Sinop. **Horticultura brasileira**, Brasília, v. 31, n. 2, p. 332-337, 2013.