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Development of cover crops under different water levels in the soil

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The objective was to evaluate the effect of intervals of irrigation frequency (water deficit) in the development of cover crops. The experiment was conducted in a greenhouse at the experimental campus of the Federal University of Piauí (UFPI) in Bom Jesus-PI in the period between June to August 2011, on soil classified as Typic Dystrophic - Lad. The experimental design was randomized blocks in factorial scheme 5 x 4, with factors consisting of 5 cover crops (*Brachiaria brizantha* cv. Piata; *Mucuna aterrima*; *Pennisetum glaucum* cv. ADR-500; *P. glaucum* cv. ADR 8010; *Brachiaria brizantha* cv. Marandu), and 4 intervals of irrigation frequency (2, 4, 6 and 8 days), with 4 replications. Cover crops were significantly affected in their development, with reductions in biomass above 50% when subjected to the interval of irrigation frequency to 8 days. The *P. glaucum* cv. ADR-500 has potential to overcome the water deficit conditions during the off season in the Cerrado of Piauí.

Key words: Brachiaria, *Pennisetum glaucum* cv. ADR-500, no-tillage.

INTRODUCTION

The Southern Piauí has been occupied largely by the soybean crop, with 439 million hectares in 2011 to 2012 harvest, an increase of 14.4% compared to the previous harvest. The yield of this crop in the region for 2011 to 2012 harvest was 439 million tons, 11% above the 2010 to 2011 harvest (Conab, 2012). Thus, there have been concerns about the need for the development and adoption of techniques which can minimize impacts on the environment.

Soil management used predominantly in Southern Piauí by soybean producers have been the conventional tillage with the use of soil disturbance by plowing and harrowing before crop sowing. This practice provides loss of soil fertility and reduces the quality of the physical, chemical and biological attributes (Correia and Durigan, 2008), mainly by causing erosion (Bertol et al., 2004) and reduction in the accumulation of organic matter (Costa et al., 2004).

The no-tillage system, which recommends the untilled soils, use cover crops for biomass production and crop rotation, presents itself as a viable option to minimize the environmental impacts of inappropriate farming systems (Amabile et al., 2000; Prior et al., 2004). The presence of biomass on the soil surface reduces the kinetic energy of the drops of rain and breakdown of particles responsible for the initial process of erosion, whereas the dry weight root of these species decompression assist in the ground through the formation of tubules in the natural soil profile (Silva and Rosolem, 2001b; Gonçalves et al., 2006, Reinert et al., 2008), in addition to increasing chemical and biological fertility through increased organic matter and biodiversity of the system (Carneiro et al., 2009).

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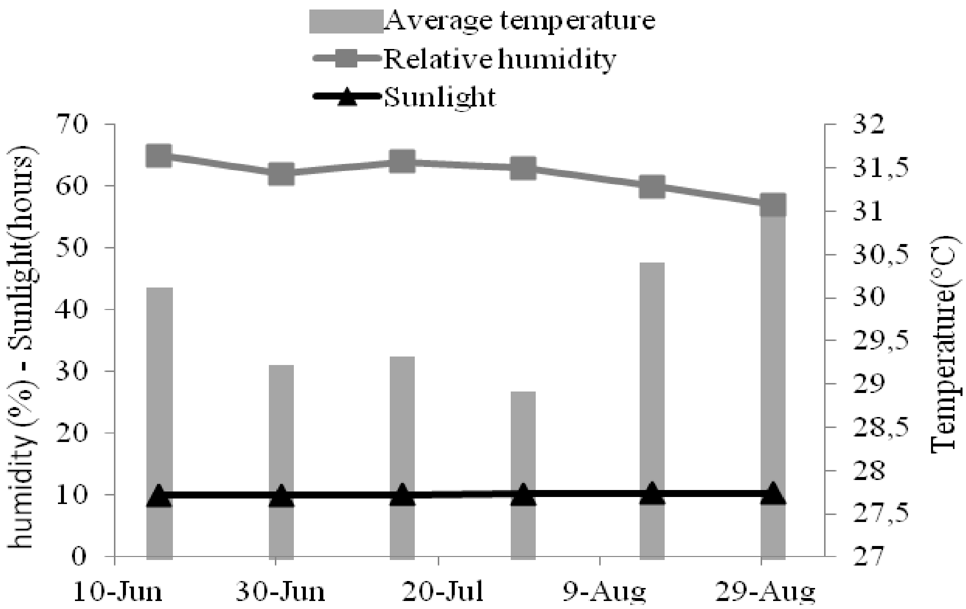

Figure 1. Average temperature, relative humidity and sunlight occurred into the green house in Bom Jesus - PI during the experiment (data INMET - station Bom Jesus-PI).

The use of cover crops in the Cerrado region of Piauí presents some challenges. The low water availability, with rainfall between the months, April to October, hinders the development of species after annual crops harvest, which occurs usually in the first fortnight of March. In addition, the soil of the region presents a predominance of dystrophic Yellow Latosol sandy loam texture, which combined with high temperatures limits the ability to retain water in soil (Stone and Silveira, 1999). Thus there is need for studies that evaluate species of cover crops that have potential to develop in these weather conditions.

Some species have been described in other regions of the Cerrado, like the grasses of the genus *Brachiaria* sp. (Brachiaria grass) and *Pennisetum glaucum* (pearl millet), which stand out by presenting initial fast growth, tolerance to situations of water deficit and high accumulation of biomass (Timossi et al., 2007; Pacheco et al., 2008, 2011). However, studies to evaluate the development of cover crops under different water availability can assist producers in selecting the most appropriate species to the ecological conditions in southern Piauí.

Therefore, the aim of this study was to evaluate the development of cover crops at different water deficit levels in the Cerrado region of southern Piaui.

MATERIALS AND METHODS

Local, experimental design and treatments

The experiment was conducted in a greenhouse at the experimental campus of the Federal University of Piauí (UFPI) in Bom Jesus-PI (09º 04'28 "S and 44º 21'31" W, 277 m altitude), from June to August 2011. The climate is Aw according to Köppen classification, with two well defined seasons, with a drought that lasts from May to September and a rainy season from October to April. During the experiment there was no rainfall. Climatic data were collected at the meteorological station of the National Institute of Meteorology - INMET, located approximately 200 meters from the site of conduction of the experiment (Figure 1).

The soil used in the experiment were collected in soybean production in the Serra do Quilombo, Bom Jesus, Piauí, in the layer 0 to 20 cm, dystrophic Yellow Latosol, with the following chemical and textural analysis: 762, 57 and 181 g kg^{-1} sand, silt and clay, respectively, P - 23.7 mg dm^{-3}, K - 34.0 mg dm^{-3}, Ca - 2.0 $cmol_c$ dm^{-3}, Mg - 0.7 $cmol_c$ dm^{-3}, H - 4.5 $cmol_c$ dm^{-3}, Al - 0.3 $cmol_c$ dm^{-3}, MO - 31.25 g dm^{-3}; CTC - 7.4 $cmol_c$ dm^{-3}.

The experimental design was randomized blocks in factorial scheme 5 × 4, with factors consisting of five different species of cover crops (*Brachiaria brizantha* cv. Piata; *Mucuna aterrima*, *P. glaucum* cv. ADR 500; *P. glaucum* cv. ADR 8010; *Brachiaria brizantha* cv. Marandu) and 4 intervals of irrigation frequency (2, 4, 6 and 8 days) corresponding to 80, 60, 40 and 20% of the field capacity, a total of 20 treatments with 4 replications.

The seeding of cover crops was performed on June 11, 2011, with 10 seeds per pot (8 dm^{-3}) and 15 days after emergence plants were thinned to 2 plants per pot. Fertilization was 8 g of NPK (5-30-15) in each pot and 30 days after planting was carried out topdressing, adding 5 g of NPK formulation (5-30-15) per pot.

The intervals of irrigation frequency were determined as follows: a) determined the weight of the pots at field capacity (FC) by methodology adapted Bonfim-Silva et al. (2011) and Cavalcante et al. (2011), in which pots are saturated with water, leaves them to stand for 12 h to drain the excess water and determines the weight of the FC; b) then applied to the treatment with intervals drought, in which each (2, 4, 6 and 8 days) was added the amount of water to complete the FC by the calculated weight difference of the pot in the state FC current and the weight of the pot. In all treatments was

Table 1. F values for number of leaves (NL), stem length (SL), plant height (PH), dry biomass of dry leaves (DBDL), dry biomass of green leaves (DBGL), stem biomass (SB), biomass roots (BR), total biomass (TB), root volume (RV) and total chlorophyll (TC) of cover crops submitted to 4 intervals of irrigation frequency (Bom Jesus, 2011).

Fontes de variação	NL	SL	PH	DBDL	DBGL	SB	BR	TB	RV	TC
Plantas de cobertura (PC)	216.02**	225.81**	1.36^{ns}	51.34**	51.27**	49.32**	27.78**	107.85**	26.94**	1.74^{ns}
Intervalo de turno de rega (ITR)	6.87**	48.26**	4.10*	22.90**	154.75**	220.20**	84.74**	412.63**	85.60**	18.21**
PC × ITR	6.53**	1.97^{ns}	0.90^{ns}	9.66**	26.02**	10.60**	7.35**	12.29**	4.04**	2.17^{ns}

* e ** significant at 5 and 1%, respectively.

maintained the soil moisture near field capacity until 30 days after emergence (DAE), to simulate the late summer rains and promote the initial establishment of the plants and after this period were applied to different levels of deficit water.

Parameters evaluated

At 65 DAE biometric parameters were evaluated:

a) Number of leaves: by hand selecting only one plant per pot and the leaves were detached and counted subsequently;
b) Plant height: with the aid of a graduated tape (m) measured from the cervix to the apex;
c) Stem length: with distance between the neck and the insertion point of the youngest leaf with the aid of a graduated tape (m);
d) Chlorophyll content: was evaluated with the use of chlorophyll model "ClorofiLog-CFL1030", which was chosen for 2 mature leaves per plant and has been reading 3 points in different parts of the same leaf;
e) Root volume: was evaluated according to the methodology described by Cavalcante et al. (2011), in which the root has been washed and left for a period of shade drying to remove excess water. Then was placed in 1000 ml beaker, a default value of water, 300 mL, in which the roots were emerged calculating the root by the difference in volume of displaced water volume in the tube in cm^3.
f) Dry biomass of dry leaves, through the collection of dry leaves from 2 plants per pot, and then submitted to the materials for kiln drying of forced air circulation in the temperature around 70°C until constant weight display.
g) Dry biomass of green leaves: through the collection of green leaves from 2 plants per pot, and then submitted to the materials for kiln drying of forced air circulation in the temperature around 70 °C until constant weight display.
h) Stem biomass: through the collection of stems from 2 plants per pot, and then submitted to the materials for kiln drying of forced air circulation in the temperature around 70°C until constant weight display.
i) Root biomass: through the collection of roots from two plants per pot, and then submitted to the materials for kiln drying of forced air circulation in the temperature around 70°C until constant weight display.
j) Total biomass: measured by adding the dry biomass of leaves, stems and roots

Statistical analysis

The data evaluated were submitted to analysis of variance and the means of the significant variables were compared by Tukey test (5%), using the statistical program Sisvar 4.1. The regression equations were obtained using the software Sigma Plot, version 7.0.

RESULTS AND DISCUSSION

There was a significant interaction between cover crops and intervals of irrigation frequency for number of leaves (NL), dry biomass of dry leaves (DBDL), dry biomass of green leaves (DBGL), stem biomass (SB), dry biomass of roots (DBR), total biomass (TB), root volume (RV) and total Chlorophyll (TC) (Table 1). In general, all cover crops had negative effects on the variables analyzed, since water deficit leads to stomatal closure, limiting nutrient uptake and photosynthetic efficiency (Silva et al., 2006).

The *P. glaucum* cv. ADR500 stood out in biomass production in water deficit levels, especially the roots, which represented over 50% of total plant biomass (Table 2, and Figure 2). This feature is satisfactory for cover crops in the Cerrado, as aids in root growth and allows decompression of the soil and increase the exploration area for absorbing water and nutrients during the dry season. Moreover, the lowest proportion of air biomass in relation to root can mean greater efficiency in water use by reducing leaf area and water loss by transpiration. Gonçalves et al. (2006) found that *P. glaucum* cv. ADR500 stood out on the growth of roots and shoots under conditions of soils with compacted layers.

The presence of tillers observed in the species *P. glaucum* may have contributed to stimulate the growth of roots and shoots. By considering that under field conditions germination and seedling emergence is not uniform, the lateral growth by issuing tiller may favor the use of space, solar radiation interception and photosynthetic rate. Bonfim-Silva et al. (2011) observed that although the *P. glaucum* present reduction in both water deficit conditions can be a viable alternative for sowing in seasons with limited rainfall, due to the high speed and amount of biomass formation.

By considering that the first 30 days after emergence all treatments were maintained at field capacity, the results show that the species *P. glaucum* can leverage more effectively the end of summer rainfall for its establishment, and have a greater ability to support water stress. This can be attested to note that these species produced, with an interval of irrigation frequency of 8 days, over 40% of the total biomass produced in the treatments with interval of irrigation frequency of 2 days (Figure 2E). In addition, species *P. glaucum* presented in

Table 2. Dry biomass of dry leaves, green leaves, stem, root and total of cover crops submitted to four intervals of irrigation frequency (Bom Jesus, 2011).

Cover crops	**Intervals of irrigation frequency (Days)**				
	2	**4**	**6**	**8**	**Média**
Dry biomass of dry leaves (g 2 plants^{-1})					
B. brizantha cv. Piatã	3.47^{A}	7.87^{B}	9.07^{B}	10.77^{A}	7.79^{B}
M. aterrima	3.87^{A}	2.33^{C}	1.03^{C}	0.50^{B}	1.93^{C}
P. glaucum cv. ADR 500	6.97^{A}	12.70^{A}	10.97^{B}	10.97^{A}	10.40^{A}
P. glaucum cv. ADR 8010	5.70^{A}	12.37^{A}	9.13^{B}	10.63^{A}	9.46^{AB}
B. brizantha cv. Marandu	4.03^{A}	6.70^{BC}	16.20^{A}	11.33^{A}	9.42^{AB}
C.V (%)			21.14		
MSD			1.92		
Dry biomass of green leaves (g 2 plants^{-1})					
B. brizantha cv. Piatã	33.50^{A}	18.93^{B}	9.73^{A}	3.13^{B}	16.33^{A}
M. aterrima	11.33^{BC}	13.53^{C}	7.43^{A}	7.23^{A}	9.88^{B}
P. glaucum cv. ADR 500	7.33^{C}	9.13^{C}	5.27^{A}	5.67^{A}	6.85^{C}
P. glaucum cv. ADR 8010	12.53^{B}	11.77^{C}	7.30^{A}	4.77^{A}	9.10^{BC}
B. brizantha cv. Marandu	31.13^{A}	24.63^{A}	5.73^{B}	3.77^{B}	16.32^{A}
C.V (%)			18.47		
MSD			2.46		
Stem biomass (g 2 plants^{-1})					
B. brizantha cv. Piatã	43.93^{AB}	18.67^{C}	10.57^{AB}	5.23^{A}	19.60^{B}
M. aterrima	8.77^{C}	9.57^{D}	4.70^{B}	3.40^{A}	6.61^{C}
P. glaucum cv. ADR 500	49.17^{A}	27.90^{AB}	15.27^{A}	8.20^{A}	25.13^{A}
P. glaucum cv. ADR 8010	49.83^{A}	30.63^{A}	12.30^{AB}	783^{A}	25.15^{A}
B. brizantha cv. Marandu	39.17^{B}	21.60^{BC}	8.60^{AB}	6.37^{A}	18.93^{B}
C.V (%)			19.57		
MSD			4.35		
Root biomass (g 2 plants^{-1})					
B. brizantha cv. Piatã	48.90^{A}	23.57^{BC}	12.93^{B}	5.73^{A}	22.78^{B}
M. aterrima	23.07^{B}	10.70^{C}	6.93^{B}	6.27^{A}	11.74^{C}
P. glaucum cv. ADR 500	40.00^{A}	62.27^{A}	28.80^{A}	17.97^{A}	37.26^{A}
P. glaucum cv. ADR 8010	38.30^{A}	35.83^{B}	11.93^{B}	10.87^{A}	24.23^{B}
B. brizantha cv. Marandu	48.27^{A}	22.37^{BC}	9.37^{B}	5.87^{A}	21.47^{B}
C.V (%)			25.51		
MSD			6.99		
Total biomass (g 2 plants^{-1})					
B. brizantha cv. Piatã	129.80^{A}	69.04^{B}	42.30^{B}	24.86^{B}	66.5^{B}
M. aterrima	47.04^{C}	36.13^{C}	20.09^{C}	17.40^{B}	30.16^{C}
P. glaucum cv. ADR 500	103.47^{B}	112.17^{A}	60.31^{A}	42.81^{A}	79.69^{A}
P. glaucum cv. ADR 8010	106.36^{B}	90.60^{A}	40.66^{B}	34.00^{AB}	67.90^{B}
B. brizantha cv. Marandu	122.60^{A}	75.30^{B}	39.90^{B}	27.34^{B}	66.28^{B}
C.V (%)			22.20		
MSD			13.80		

Distinct letters in the row indicate significant differences according to Tukey test at 5%. MSD: minimum significant difference.

visual form, the lower leaf rolling when subjected to drought, favoring the efficiency of interception of photosynthetic active radiation, as described by Kunz et al. (2007).

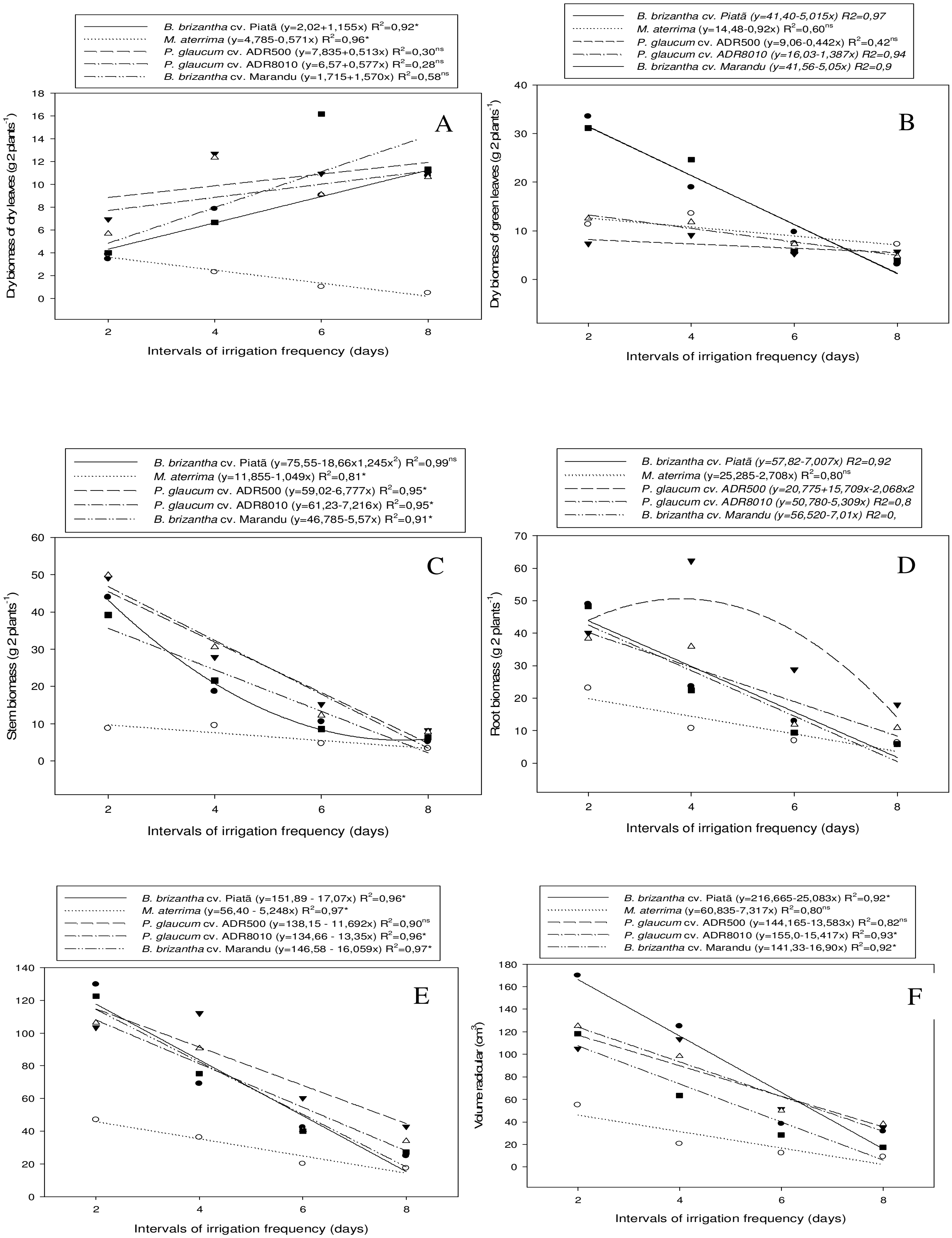

Figure 2. Dry biomass of dry leaves (A), green leaves (B), stem (C), root (D) e total (E) and root volume (F) of cover crops submitted to four intervals of irrigation frequency (Bom Jesus-PI, 2011). * e **: significant by Tukey test at 5 and 1%. ns: not significant at P < 0.05

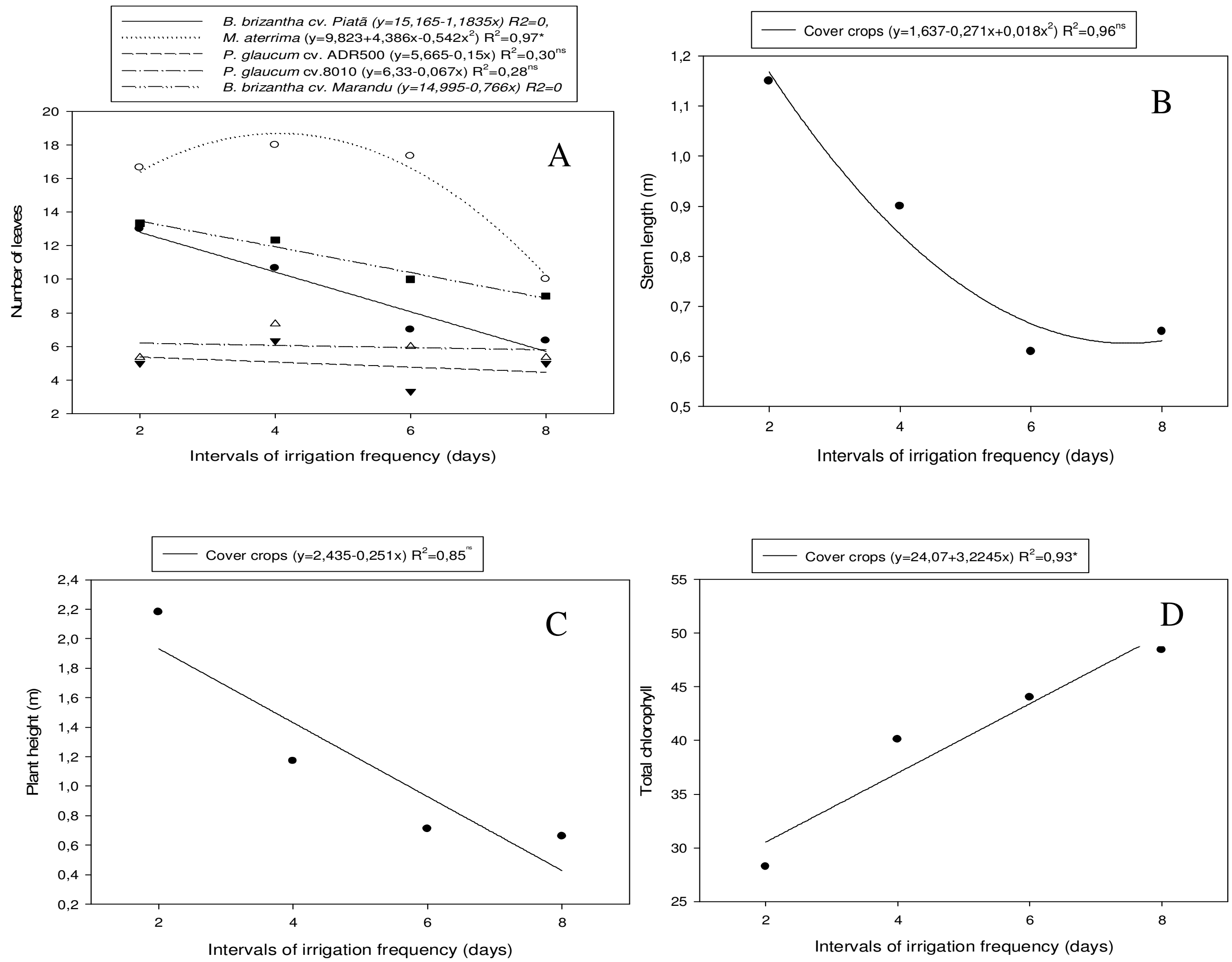

Figure 3. Number of leaves (A), steam lenght (B), plant height (C) e total chlorophyll (D) of the cover crops submitted to four intervals of irrigation frequency (Bom Jesus-PI, 2011). * e **: significant by Tukey test at 5 and 1%. ns: not significant at $P < 0.05$.

The high amount of dry weight of dry leaves (Figure 2A) in the species P. glaucum is associated with early maturity, which can be attested by the presence of panicles to 65 days after emergence, with translocation of assimilates to the grains. Suzuki and Alves (2006) and Pacheco et al. (2011) observed that *P. glaucum* presented early cycle compared to other cover crops used in the Cerrado. On the other hand, *Brachiaria* spp. and *M. aterrima* were still in full vegetative growth, which resulted in a significant quantity of green leaves.

By observing the dry weight of the stem (Figure 2C) composed of more lignified tissues (Boer et al., 2007), species *P. glaucum* showed high accumulations, which may represent higher C/N ratio of crop residues and lowest rate of decomposition during the off-season, contributing to greater amount of biomass on the ground until the beginning of the sowing of the next harvest.

The *M. aterrima* stood out as the species with greater tolerance between the levels of water deficit, however, the quantities of biomass of aerial parts and roots did not stand out (Figures 2 and 3). The featured for this species was observed for the variable number of leaves (Figure 3A). This species showed high apical growth, with leaf appearance on main stems and side. However, the accumulated biomass was low and water loss by transpiration increased, which compromised the root biomass and aerial parts. Suzuki and Alves (2006) found that *P. glaucum* surpassed *M. aterrima* of biomass production, pre-planted crop in the Cerrado of São Paulo. Furthermore, it was observed that the initial growth of *M. aterrima* during the first 30 days, during which all treatments were maintained at field capacity, was lower than the other species, which compromised their ability to withstand the water deficit until 65 days after emergence. The species of *Brachiaria* sp. under conditions of adequate water availability showed similar behavior as the variables, with emphasis on dry biomass production of green leaves (Table 2, Figure 2B) and root volume

(Table 2, Figure 2F). However, these species had significant reduction in biomass formation with prolonged drought, which partly explains the seasonal production of Brachiaria biomass during the off season (Figure 2). Mattos et al. (2005) found a significant reduction in net photosynthesis in some species of *Brachiaria* sp. As a result of reduced water potential and leaf tissue dehydration and lower enzymatic activity in vital biochemical reactions to plants, such as photosynthesis. Timossi et al. (2007) and Pacheco et al. (2008, 2011) observed that *Brachiaria ruziziensis* showed low accumulation of biomass during the dry season (April to September), and only after rains early summer the plants presented a high accumulation of biomass. Portes et al. (2000) pointed out that the highest rates of growth of *B. brizantha* cv. Marandu occurs after 45 days, a period normally where water availability is low in regions of the Cerrado Piauí. Thus, it is characterized that the Brachiaria require initial summer rains to sprout biomass and accumulate in significant quantities to the no-tillage system.

The significant values of the root volume of *B. brizantha* cv. Piata, *P. glaucum* cv. ADR500 and *P. glaucum* cv. ADR8010 characterize these species as promising species for use in water deficit conditions (Figure 2F). Under field conditions, these species can promote high root growth in soil depth, which would contribute to their development in conditions of low water availability during the off season.

It was found that there was a marked decrease in plant height (Figure 3C) with the increase of the intervals of irrigation frequency. According to Silva et al. (2001) the reduction in growth is one of the most remarkable effects of water stress on plants, mainly caused by an inhibition of leaf and stem elongation when the water potential decreases, differing among species. Similar results were found by Bonfim-Silva et al. (2011), who observed a significant reduction in the height of cover crops (*P. glaucum* and *Sorghum bicolor*) under conditions of water deficit.

The chlorophyll levels among the studied species showed no statistical differences (Figure 3D). However, this variable showed linear fit between the increasing intervals of irrigation frequency, demonstrating that the levels of water deficit caused increased levels of chlorophyll. These results might partly be explained by the fact that chlorophyll portable meters determine the relative rather than absolute levels of chlorophyll, in the other words, the radiation transmitted through 3 wavelengths of light, it is estimated relative chlorophyll content. It turns out that this index is determined by unit area, thus, in conditions of water deficit is reduced in swelling (water potential) of the cells, increasing the number of cells and chloroplasts per unit area and hence the absorbed radiation. Taiz and Zaiger (2004) reported that water deficit reduces photosynthesis and consumption of assimilates in leaf expansion, indirectly decreasing the amount of exported assimilates in the leaves, increasing the concentration of chlorophyll.

Conclusions

1) The variables concerning the accumulation of biomass of the cover crops were reduced significantly (greater than 50%) when submitted to water deficit conditions.
2) The *P. glaucum* cv. ADR500 presented the greatest growth potential among the levels of water deficit evaluated, with emphasis on roots and total biomass.
3) The chlorophyll content cannot be used with a parameter for assessing the tolerance of plants to water deficit.
4) The cultivars of *Brachiaria brizantha*, especially *B. brizantha* cv. Piata presented significant reductions in the growth of the aerial parts and root under water deficit conditions during early vegetative growth (30 to 65 days after emergence);
5) The species *M. aterrima* had the highest tolerance for water deficit, however, the growth of the aerial parts and root are less than the remaining species.

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