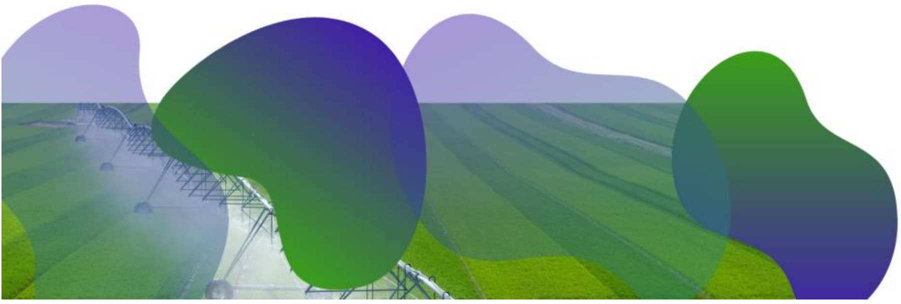

GROWTH OF CORN UNDER SUSPENSION OF WATER SUPPLY IN DIFFERENT PHENOLOGICAL PHASES

Samuel Silva[1], Carla Sabrina da Silva[2], Edmaíris Rodrigues Araújo[2], Daniele Alves de Sá[2], Francisco Ferreira Damasceno[3], Aracelle Alves Feitosa Silva[3]

ABSTRACT: The water deficit in the soil promotes physiological responses in the plant capable of significantly altering the growth and development of the crop, in which it is essential to study the behavior of the plant in the face of water stress to determine the proper management of irrigation. This work aimed to evaluate the effect of water deficit from different phenological stages on maize growth in the semiarid region. The experiment was conducted at the Instituto Federal of Alagoas/Campus Piranhas, from February to June 2019. The experimental design used in the experiment was in randomized strips with four blocks of repetitions, in which the treatments were five periods of crop submission to stress due to water deficit, which occurred from the following phases: tasseling, pollination, milky grain, pasty grain and floury grain (without stress). From the data collected during the experiment, the following steps were performed: analysis of the effect of climatic elements on the crop by measuring the degree-days between the phenological phases and evaluation of plant growth under the impact of water stress caused in each phenological phase of the crop. Temperature was not a limiting factor for maize development throughout the cycle. Plants subjected to water deficit in the tasseling and flowering phases suffered variation in the leaf area index (LAI) when compared to plants submitted to the floury grain phase.

KEYWORDS: biometry, irrigation, *Zea mays* L.

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[1] PhD, professor at the Federal Institute of Alagoas-IFAL, Campus Piranhas, samuel.silva@ifal.edu.br

[2] Agronomic engineer, researcher at the Federal Rural University of Pernambuco-UFRPE, carla.sabrina@ufrpe.br; edmairis.03@gmail.com; danielea951@gmail.com

[3] Graduating in Agronomic engineer at the IFAL-Campus Piranhas, ffd1@aluno.ifal.edu.br; aracelle.feitosa10@gmail.com

INTRODUCTION

Corn is one of the main cereals cultivated worldwide, providing several products that are widely used for human and animal food, being used by industries as raw material due to the quality of its reserves accumulated in the grains (ALVES et al., 2015). In the State of Alagoas, Brazil, the agricultural productivity of corn is impaired by the occurrence of dry spells, and the rainy season begins in April and ends in September. And even during the rainy season, in some years there are dry spells and the crop is subject to water deficit (CARVALHO et al., 2013), which limits its development and productivity (OLIVEIRA et al., 2010). In the state, 45.3% of the total area corresponds to the semi-arid region (MEDEIROS et al., 2009), which has low rainfall with prolonged periods of drought, which causes low water levels in arable soil and impairs the development of many crops plant species, including corn, directly reflecting on the family income of farmers, since corn is the main crop grown in the region (SANTOS et al., 2020).

The corn crop needs an average of 400 to 600 mm of water throughout the cycle, with insufficient or excessive rainfall being limiting factors for certain stages of development, which may compromise the final productivity (MACHADO, 2016). Water stress causes lower plant growth due to the production of abscisic acid (ABA), since this is considered a hormone that retards plant growth and, therefore, increases in plants stressed due to lack of water; when signaled by the root, ABA promotes a reduction in the plant's transpiration rate by stomatal closure, influencing the nutrient absorption rate and, consequently, the physiology and morphology of plants under water stress (TAIZ & ZEIGER, 2013).

Plant height and stem diameter may be reduced due to water stress, in addition to the reduction in photosynthesis caused by the decrease in cell expansion and damage to the photosynthetic apparatus (GUIMARÃES et al., 2019). To reverse the lack of water in the soil, it is important to resort to agronomic techniques such as irrigation, which considerably increases the agricultural productivity of agricultural enterprises and allows for other harvests in the dry season. However, it must be well planned so that stress due to deficit or excess of water does not occur throughout the phenological phases of the crop and harm its development. In the semi-arid region of Alagoas, where the irrigated areas on the banks of the São Francisco River and the progress of the construction of the irrigation channel promote the cultivation of irrigated corn, there are still few studies and insufficient access by producers to the technical assistance necessary for the proper management of the water resources in irrigated agriculture. Therefore, the objective of this work was to evaluate the effect of water deficit from different phenological stages on maize growth in the semi-arid region of Alagoas.

MATERIAL AND METHODS

The experiment was conducted at the Instituto Federal de Alagoas/Campus Piranhas (9°37'12” S; 37°46'12” W; 187 m), from February to June 2019. The climate classification of the region by the Köppen method (LIMA, 1977) it is of the Bsh type, very hot, semi-arid, steppe type climate. The rainy season starts in March and lasts until July. The average annual rainfall in the region is 492.2 mm (SANTOS et al., 2017). The soil was classified as sandy soil.

The experimental design used in the experiment was in randomized ranges with four blocks of repetitions. The treatments consisted of five periods of submission of the crop to stress due to water deficit, which occurred from the following phases: tasseling (T1), pollination (T2), milky grain (T3), pasty grain (T4) and floury grain (T5, no stress). The plots were composed of 4 internal plots of 5.0 m in length spaced at 0.80 m, resulting in a total area of 16 m^2, with the useful area consisting of 3 m in the center of the two middle rows.

The foundation fertilization was carried out according to the expected production of 10 t ha^{-1} and considering the result of the chemical analysis of the soil, according to Coelho (2007). For this, 96.2 kg ha^{-1} of P_2O_5 (in the form of simple superphosphate), plus half of 182.4 kg ha^{-1} of K_2O (as potassium chloride) and 20 kg ha^{-1} of N (in the form of ammonium sulfate). The second half of K_2O plus 180 kg ha^{-1} of N were applied in cover at 15 days after planting (DAP). Planting was done with the hybrid maize cultivar M274, sown in furrows opened manually, placing two seeds every 0.20 m, and plant thinning was performed when the plants were in the stage (V4), animated at 62,500 plants per hectare.

The control of pests and diseases was carried out through the Integrated Management of Pests and Diseases (MIPD), in which a chemical insecticide based on methomyl was used at a dose of 0.5 L ha^{-1} in the initial (V2) and growth (V9 and V15 phases) with 8, 26 and 40 DAP, respectively, to control fall armyworm (*Spodoptera frugiperda*). Spontaneous weed control was carried out through manual weeding. The irrigation system used was drip irrigation with a nominal flow of 1.5 L h^{-1}, nominal pressure of 10 mca, and spacing between drippers of 0.4 m. Irrigation management was carried out with a daily watering shift throughout the initial phase until the crop growth phase (0-50 DAP), in which, after that, irrigation was suspended according to the treatments. Monitoring was carried out using a digital tensiometer, always checked before and after irrigation up to the field capacity of the soil.

The meteorological variables evaluated were relative humidity and air temperature, rainfall and crop evapotranspiration (ETc), which were obtained by an INMET automatic data acquisition station, located close to the experimental area. Reference evapotranspiration (ETo) was calculated using the Penman-Monteith method (ALLEN et al., 1998) to estimate ETc. The thermal accumulation for the plant to reach the development phases was determined through the accumulated degree days (GDA), according to Gilmore & Rogers (1958).

Biometry was performed fortnightly from 30 DAP, in which canopy height, stem diameter and leaf area index (LAI) were measured. The analyzed variables were collected from four random plants per plot, marked throughout the experiment. The leaf area was determined according to the methodology of Hermann & Câmara (1999). The data from the biometric evaluation on each collection date were subjected to analysis of variance using the F test ($p<0.05$) and Tukey's test to verify the degree of statistical difference between treatments.

RESULTS AND DISCUSSION

The minimum, maximum and average relative humidity were 39 (01/03/219), 92 (18/05/2019) and 69%, while the minimum, maximum and average air temperature were 23 (28/03/219), 35 (05/18/2019) and 28°C (Figure 1). There is a decrease in air temperature and an increase in RH% on rainy days. However, it did not cause thermal restriction for the development of corn, whose ideal range for its growth and development is between 24 and 30°C (CARON et al., 2017). The air temperature regulates the development of the corn crop, which can accelerate due to the occurrence of high temperatures, or delay, under the effect of lower temperatures (MAGALHÃES, 2017). The increase in air temperature increases the amount of water vapor that the atmosphere can store, thus, with an increase in temperature, there is a decrease in the water potential of the atmosphere, increasing the gradient between the potential of the leaf and the air, which can have a significant effect on the growth and development of plants (SILVA et al., 2016). It is noticed that the place of study did not present extremes of air temperature equivalent to the basal temperatures (lower and higher) inferring that the culture was in its full development with regard to air temperature, not suffering thermal stress, as temperatures below the lower basal and above the upper basal negatively interfere with the plant's photosynthesis rate. Similar data were obtained by Cordeiro (2019) in his research on soil water balance for corn in the semi-arid region of Alagoas during nine years of study, confirming that the average temperature was approximately 27.19ºC at all planting times.

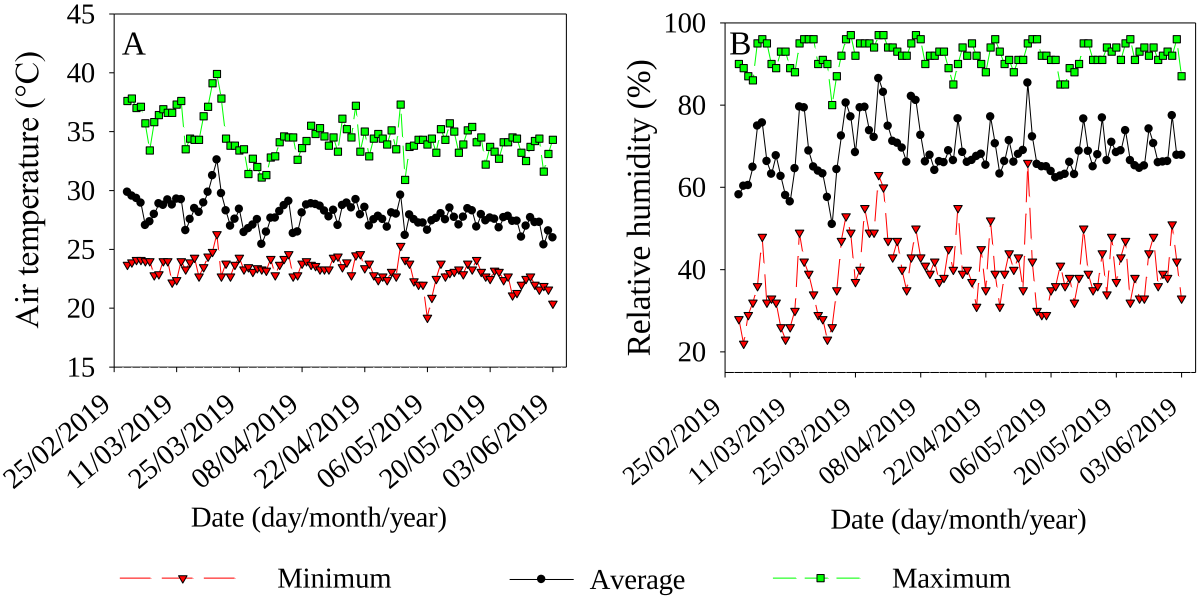

Figure 1. Daily average values of air temperature and humidity from February to June 2019 during the corn crop cycle cultivated under water deficit in different phenological stages in Piranhas - AL.

Derived from temperature, the plant's thermal requirement to reach the phenological stages, which is represented by degree-days (GD), ranged from 15 to 23°C during the cycle (Figure 2). This information is important for crop planning and for choosing the appropriate genetic material for the climate region.

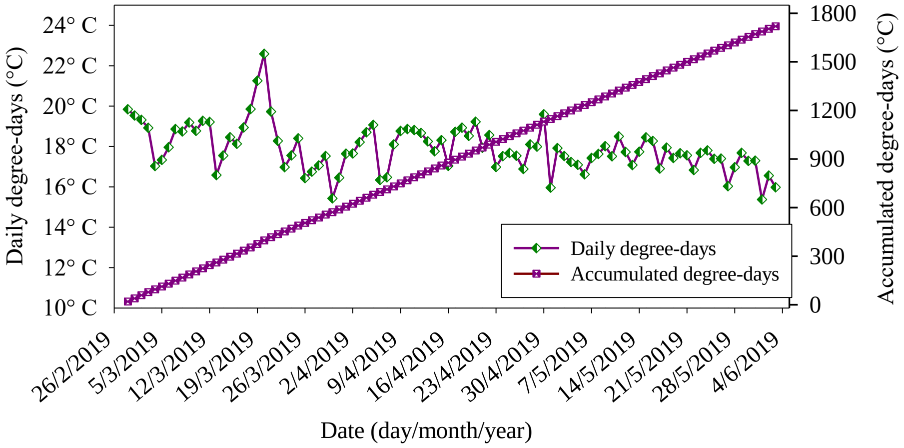

Figure 2. Daily degree-days (GD) and accumulated degree-days (GDA) values during corn cultivation under water deficit in different phenological stages from February to June 2019 in Piranhas - AL.

The cumulative thermal sum for crop emergence was 112 GDA in 5 days (Table 1). The energy availability for the crop, from planting to pollination, was 1,022 GDA, in which the cultivar is classified as late, according to the classification by Fancelli & Dourado Neto (2000), which divides it into super-early (780 to 830 GDA), early (831 to 890 GDA) and late (891 to 1,200 GDA). The total 1720°C (GDA) during the cycle was reached in 95 days.

Table 1. Duration (days) and accumulated degree-days-GDA (°C) between the stages of hybrid corn M274 cultivated under water deficit in different phenological stages during the period from February to June 2019 in Piranhas - AL.

Phenological phase	GDA in the phase / Duration (days)	DAP	GDA °C
Planting – Emergency (VE)	112/5	5	112
VE – Tasseling (VT)	729/40	45	841
VT – Pollination (R1)	182 / 10	55	1,023
R1 – Milky grain (R3)	176 / 10	65	1,199
R3 – Pasty grain (R4)	175 / 10	75	1,374
R4 – Floury grain (R5)	176 / 10	85	1,550
R5 – Physiological maturation (R6)	167/ 10	95	1,717
Planting - Physiological maturation	1,720 /95		

Rainfall during the corn production cycle, which lasted from 02/28/2019 to 06/03/2019 (95 days), totaled 156 mm, with 75% (118 mm) of this rainfall occurring during the month of March (03/04/2019 to 03/31/2019), characterizing irregular distribution of rainfall during the cultivation period (Figure 3). This period of the year corresponds to the rainy season in the region, but this water availability is insufficient to meet the water demand of the crop, which, according to Machado (2016), for good production requires 400 to 600 mm of water during the cycle. It is considered that the corn crop has a high demand for water, but it is also one of the most efficient in its use, that is, it produces a large amount of dry matter per unit of absorbed water (CAVALCANTE et al., 2018).

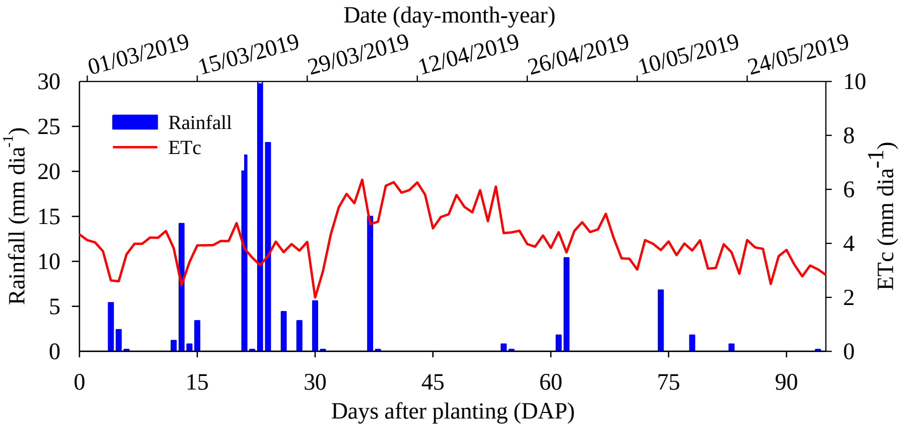

Figure 3. Daily rainfall and ETc values from February to June 2019 during corn cultivation subjected to water deficit at different phenological stages in Piranhas - AL.

Total crop evapotranspiration (ETc) in the cropping cycle was 399 mm, with total values of 32.9; 212.4; 51.1; 48.6; 53.5; 56;1; 57.9 mm for the stages of development shown in Table 1. Lower values of ETc are observed in the period when there is rainfall, when there is high cloud cover and a decrease in the intensity of solar radiation, the heating of the atmosphere and, consequently, the atmospheric water demand. Throughout the entire crop cycle, mean, minimum and maximum ETc values of 4.2 were observed; 2 and 6.4 mm day^{-1}, respectively (Figure 3). A similar result was found by Soares (2019) working with irrigated corn and nitrogen fertilization in Rio Largo-AL, where the total ETc was 460.0 mm, with an average of 4.0 mm day^{-1} and a daily maximum of 6.3 mm.

Anjos (2016) working with irrigated corn at different times, the first time being conducted between the months of April and August in Pão de Açúcar, Alagoas semi-arid region, similar to the growing season of the research under study, obtained an average result of evapotranspiration of reference equal to 514.48 mm throughout the cycle.

The irrigation applied in the cultivation from planting until the end of the growth phase of the culture (0-45 DAP), made all treatments have moisture close to field capacity (CC), equivalent to -8.0 kPa (Figure 4). From the bolting stage onwards, the water tension in the soil at T1 was below the critical moisture point (-50 kPa) due to the suspension of irrigation. In treatments T2, T3, T4 and T5 the water tension in the soil remained close to the CC until 55, 65, 75 and 85 DAP, which correspond, respectively, to the pollination stages, milky grain, pasty grain and farinaceous grain reached by the culture. From these periods of suspension of irrigation in all treatments (tasseling to floury grain), the tension decreased drastically, surpassing the critical humidity point for the crop. This reflected negatively on the crop growth and productivity variables, except for T5, which had the suspension of water supply when there was no longer any effect of soil moisture on grain filling.

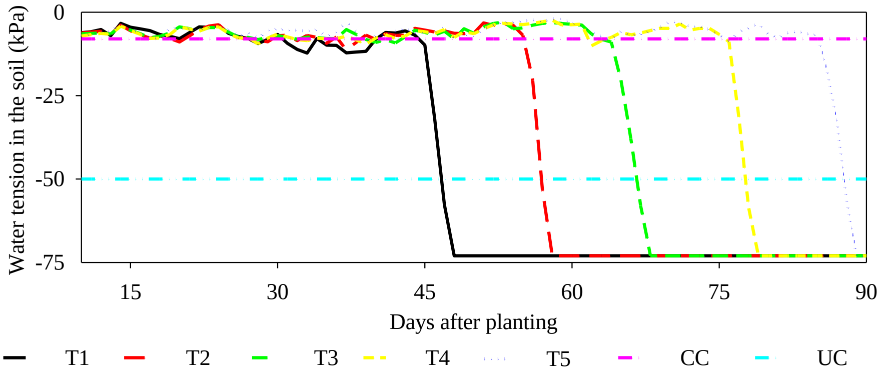

Figure 4. Soil water tension during corn cultivation subjected to water deficit in different phenological stages from February to June 2019 in Piranhas - AL.

The biometric variables were obtained throughout the maize cultivation cycle, in samplings carried out at 20, 34, 48, 63 and 77 DAP. It is observed that there was no significant difference in canopy height and stem diameter between treatments in any of the samples (Figure 5) due to stress being caused after the growth phase. However, for the variable Leaf Area Index (LAI), there was a difference in the samplings at 63 and 77 days after planting. At 63 DAP, the LAI presented minimum, maximum and average values of 2.8 (T1); 5.1 (T5) and 4.3. At 77

DAP, the values were 1.5 (T1); 3.7 (T5) and 2.7, referring to the minimum, maximum and average. At 48 DAP, the plants reached the maximum LAI, which indicates a greater degree of translocation of photoassimilates to the ear, decreasing afterwards due to the senescence of older leaves.

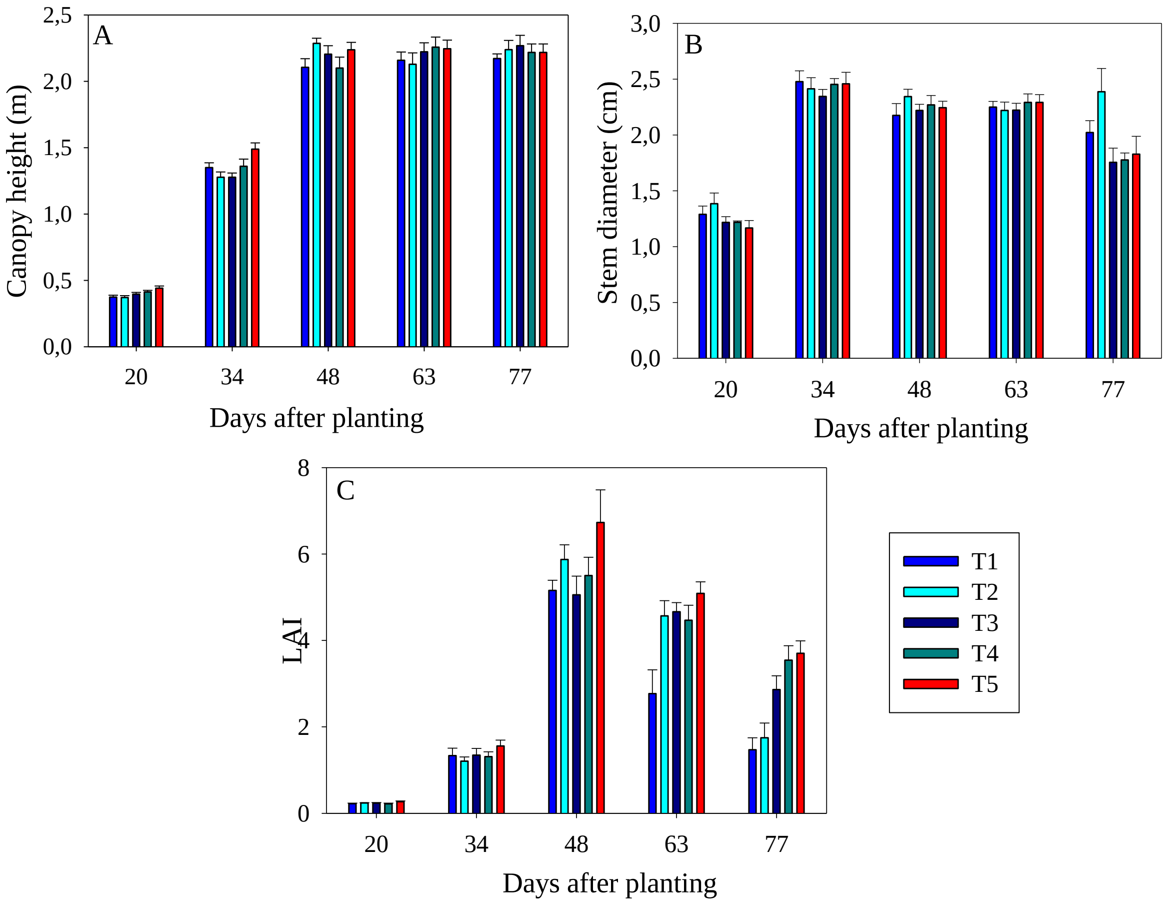

Figure 5. Biometric variables (with mean standard error) of corn grown under water deficit at different phenological stages during the period from February to June 2019 in the region of Piranhas - AL.

Treatment T1, in both final samplings (63 and 77 DAP), showed lower LAI values than treatment 5, due to submission to water deficit, while treatment 5, which started shortly before 90 DAP, still was being irrigated, with no development interference. With the submission to the water deficit for more than 10 days, the plants of the first treatment had an increase in the senescence of the leaves due to the lack of water in the soil, causing the unavailability of enough nitrogen to supply the needs of the culture's development, with that the nitrogen of the The interior of the plant is retranslocated from the older leaves to the growth points (VALENTINUZ & TOLLENAAR, 2004) and there is also a decrease in the interception of solar radiation.

According to Taiz & Zeiger (2013), under conditions of water stress, most plants seek alternatives to reduce water consumption, mainly reducing transpiration and within the most known adaptations, there is a reduction in leaf area through the reduction of leaf area. number of leaves and the size of individual leaves (cell expansion), since it decreases the growth rate of the branches. Corroborating the results of Jamieson et al. (1995), who verified in research carried out with the barley crop that the leaf area index is related to transpiration and that it varies with the time of occurrence of the water deficit.

CONCLUSIONS

- High levels of air temperature do not have much influence on maize development when it is already grown under severe water stress;
- The occurrence of water stress from the tasseling stage of maize drastically reduces the photosynthetic leaf area.

ACKNOWLEDGEMENT

To the Federal Institute of Alagoas-IFAL, the National Council for Scientific and Technological Development-CNPq and the National Institute of Meteorology-INMET.

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