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SEVERAL GROUNDWATER LEVELS AFFECTING SORGHUM PLANTS IN PROTECTED ENVIRONMENT

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ABSTRACT This study aimed to evaluate the development of sorghum plants (Sorghum bicolor L. Moench) submitted to different water table treatments. The experiment was carried out in a glasshouse on trays with water reservoirs that allowed sub irrigation and pots made of PVC tubes (15 cm diameter) with different heights simulating different levels of a water table with six depths (0.17m; 0.31m; 0.45m; 0.59m; 0.73m and 0.87m) in a completely randomized design. The statistical analysis of the data was done by comparing means using Tukey's test at 5%. Treatment T6 was not considered in the analysis because of the lack of sufficient plants. Under the prevailing conditions in this experiment, it was not recommended to have water table level depths below 73 cm; water table level depths between 45 and 59 cm had significantly higher values for both fresh and dry matter of plants. These variables for the panicles, as well as the length, were thought to be higher for the water table level from 59 to 73 cm; but the plants tended to be higher at depths of 45 cm (130.55 cm) and 59 cm (133.80 cm). Regarding the stem diameter, there was no statistical significance among the treatments at 45, 59 and 73 cm. However, they were significantly differences between the plants cultivated at water table levels closer to the surface; the roots with water level at 17 cm presented the lowest statistical values when compared to the other ones; the plant evapotranspiration rates had similar values, except for treatments at 17 and 73 cm that presented the lowest values. The values of Kc (ETc/ETo) had averages around 0.50 in the first stage and 1.30 in the following one.

Keywords: Evapotranspiration, Crop coefficient, Water table.

INTRODUCTION

Sorghum (*Sorghum bicolor* L. Moench), among the food species, it is one of the most versatile and efficient of them regarding its photosynthesis and maturation speed (RIBAS, 2003)This crop demands less water to develop when compared to other cereals and, when compared to corn, sorghum produces more under water stress (the roots exploits the soil profile better), dries up less and is able to recover from longer droughts (MAGALHÃES & DURÃES, 2003). Sorghum is an important alternative to help the provision of grains and, because of its nutritional characteristics, has been studied as an alternate energetic ingredient to corn. Generally it has lower price and cultivation advantages in regions with sandy soils and dry weather because it presents better nutrient yield per area unit (SCHEUERMANN, 1998). Sorghum cultivation has great yield potential in regions with irregular rainfall due to its adaptation capacity, tolerance to high temperatures and also because of its xerophily (REIS, 1992).

The Brazilian grain production depends almost entirely on rainfall. In years when the weather conditions are unfavorable, there is generally a deficit in grain production and sorghum, as it is a crop to be cultivated under adverse weather and soil conditions, could reduce the impact of this factor in the provision of grains. A sorghum plant tolerates water deficit and excessive soil moisture better as well as too fry and/or too hot environmental situations, where the productivity of other cereals is not economic.

Over the years, man has used irrigation as a method to overcome the lack of water for plants. This method is effective for the stress reduction, but the distribution of water application is critical. Soils with excessive moisture cause reduction of oxygen content as the aeration is deficient because water occupies the soil pores making the crop yield decrease (KERBAUY, 2004). The problem worsens when there are not enough data that allow knowing the crop yield reduction caused by different water table levels.

Thus, this study aimed to evaluate the development of sorghum plants submitted to different water table treatments.

MATERIAL AND METHODS

This study was carried out in the experimental area of the Department of Rural Engineering of the School of Agronomical Sciences of UNESP - Botucatu-SP, in a 6m long, 4m wide and 3m high glasshouse, painted with 10cm wide white stripes so that the painted area could decrease the environment internal energy.

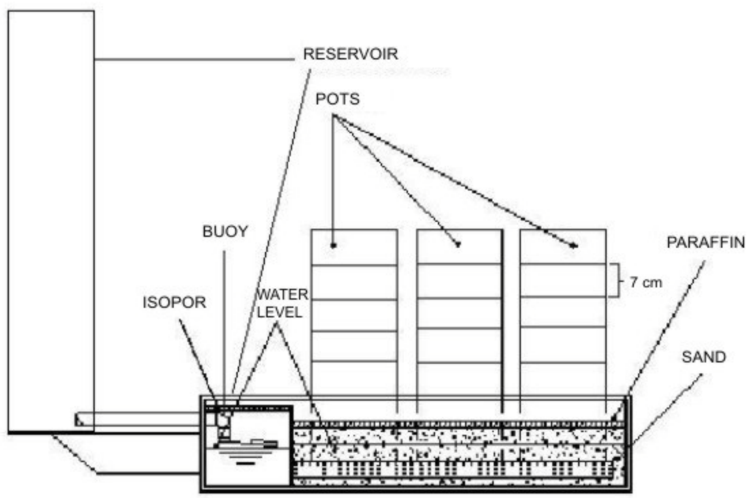
The weather of the region, according to Köeppen classification, is Cwa: hot subtropical weather (mesothermal) with rainfall in the summer and drought in the winter, and the average temperature of the hottest month is over 22ºC (CEPAGRI, 2009).

The sorghum seeds, Catissorgo cultivar, were purchased at the Agriculture Department of Botucatu. The sowing was on December 23, 2008 and the final harvest on March 23, 2009. The seeds were treated with Captan (200 g. i. a. / 100 Kg seeds) and five seeds were sown per pot.

The set to measure the crop evapotranspiration consisted of 150mm diameter pots made of PVC with the bottoms closed with PVC covers perforated to allow sub irrigation and provided with a geotextile layer to avoid soil loss. The pot consisted of 7cm high rings, attached with adhesive tape and forming tubes that were 0.21, 0.35, 0.49, 0.63, 0.77 and 0.91m high. The pots, or tubes, were partially buried (approximately 4cm) to simulate six water tables depths (0.17; 0.31; 0.45; 0.59; 0.73 and 0.87m; treatments T1; T2; T3; T4; T5; T6, respectively), in metal trays painted white that were 40cm wide, 60cm long and 14cm high, and filled with thick washed sand.

The trays had an intermediate chamber provided with a float level ball to keep the water level constant. This chamber was filled up by a water reservoir graduated in millimeters, consisting of an 800mm-high, 150mm-diameter PVC tube. The water supply of the intermediate chamber was done by a 20mm-diameter PVC tube. In order to evaluate only the pot evapotranspiration, the interstices among them were filled up with paraffin and part of the reservoir was sealed with Styrofoam (isopor) (Figure 1)

The system, tray, pots filled with soil and water in the reservoirs were all assembled one week before planting in order to stabilize the capillarity process. (SILVEIRA, 2006).



Source: Adapted from Silveira & Klar, 2006.

Figure 01. Reservoir, tray and tubes.

The soil used to fill up the pots was obtained from an area close to the glasshouse in the Department of Rural Engineering, in the 0-0.2m layer and was corrected and fertilized following the recommendations of the Technical Bulletin 100 (RAIJ et al., 1997) according to its chemical analysis.

The analyzed responses of sorghum crop to different water table treatments were: fresh and dry matter, length and diameter of plants; fresh and dry matter, panicle length; crop real evapotranspiration, crop coefficient (Kc) and water use efficiency (WUE). The leaf area of plants was estimated by the relation of length, largest leaf width and coefficient. The crop evapotranspiration (ETc) was measured daily, at the same daytime, with a graduated tape in millimeters located in the reservoirs, and it was determined through the difference of the previous day reading to the next day reading.

The temperature and relative air humidity inside the glasshouse were measured by a thermo hygrometer. Reference evapotranspiration (ETo) was measured using a 60cm diameter and 25.5cm high tank, changed to Class A Pan by correlation method. The crop coefficient was obtained by the equation $Kc = ETc.ETo^{-1}$ (KLAR, 1988).

The evaluation of water use efficiency (WUE) was done through the production of fresh matter in grams and the required amount of water during the crop cycle (evapotranspirated water from pots).

At the end of the experiment, the plants were harvested soon after the flowering at 90 days after planting; stem length, diameter and fresh matter were determined and, this last one were dried in stove (60-70°C). The tubes were disassembled and the roots were collected to collect fresh matter and dried in stove (60-70°C) to determine dry matter.

The experiment design was completely randomized with six treatments and 10 replications in a total of 60 vases. Treatment T6 (87 cm) was discarded because there was no enough emergence of plants to be analyzed in this study. The obtained data of aerial part fresh matter, dry matter, length and diameter; root dry matter; panicle fresh matter, dry matter and length were compared to the averages by Tukey's test at 5% of significance using Sisvar software.

RESULTS AND DISCUSSION

The emergence of seedlings started on December 27th, 2008 (4 days after planting) and extended until January 4th, 2009 (12 days after planting) as shown in Table 01. On January 12th, 2009, only two plants were leaved per pot. In order to allow seed germination of deeper treatments (T3, T4, T5 and T6), 100 ml of water was added every day until there were four expanded leaves. In Table 01, it can be observed that there was differentiation among the treatments in seed germination. The treatments with more water available for the seeds emerged before the others.

Table 01. Emergence percentage of sorghum seedlings

Treat.	Emergence of seedlings (%)									%
	4 DAP	**5 DAP**	**6 DAP**	**7 DAP**	**8 DAP**	**9 DAP**	**10 DAP**	**11 DAP**	**12 DAP**	**Total**
T1	16	4	18	8	4	6	0	0	34	90
T2	18	4	34	10	6	4	0	2	18	96
T3	20	24	32	14	4	0	2	0	2	98
T4	0	12	2	28	14	8	8	8	18	98
T5	0	0	0	0	0	0	36	20	32	88
T6	0	0	0	0	0	0	0	4	2	6

Peters et al. (1982) report that sorghum crop presents some problems related to the physiological quality of seeds that affect the initial emergence due to its germination no uniformity. However, this is not the case in this experiment because, except for T6, all other treatments had good germination according to the preliminary tests of seeds. Treatment T6 (87 cm) could not be considered in the analyses because there was not enough plant emergence. Consequently, the daily water application of 100 ml was insufficient for this treatment; this did not happen in the other treatments because there was the necessary ascending by capillarity. Treatment T5 (73 cm) at first had the same problem and started emergence at 10 days after planting, and than developed as the other treatments. Alves et al. (1994) observed that the diameter of soil columns (PVC tubes ranging from 5 to 25 cm) does not influence capillary ascending.

The flowering duration of sorghum plants, regarding the ten replications, is represented in Table 02. Treatments T1, T2 and T5 were the last ones, starting their flowering at 68, 69 and 74 days after planting. The flowering of treatment T3 lasted 8 days and treatment T1, 22 days. Treatment T4 was the most precocious, beginning its flowering at 62 days after planting and lasting 16 days. According to Magalhães & Durães (2003), flowering duration ranges from 6 to 15 days and occurs at 60 to 82 days after planting; the results found in this study were: flowering duration was from 8 to 22 days and occurred at 74 days after planting.

The averages of fresh and dry matter of sorghum plant aerial parts were statistically analyzed using Tukey's test at 5%, and it is observed in Table 03 that there were differences among the treatments. Treatments T4 (137.3g) and T5 (131.5 g) significantly had the greater fresh matter while treatments T1 (89,4g) and T2 (31g) had

Table 02. Flowering period of sorghum plants (*Sorghum bicolor* L. Moench) submitted to different water table treatments in glasshouse.

Treatment	Flowering (DAP)		Duration (days)
	Start	End	
T1	68	89	22
T2	69	83	14
T3	64	72	8
T4	62	78	16
T5	74	89	15

the smallest one, which is a result of the lower volume of available plant roots. Treatment T3 did not differs statistically from the other ones, considering its fresh and dry plant matter. Treatment T4 (64.01g) statistically presented the greatest aerial dry matter when compared to treatments T5 (41.07g), T1 (37.52g) and T2 (36.25g) that had the lowest ones.

These results corroborate the ones found by Barreto et al. (2008) who work with forage sorghum and observed a decrease in the production of fresh and dry matter when submitted to flooding and compared to T1 and T2. In T5, the plants started developing like in the other treatments even if there germination was late due to the delay to receive water from the water table (Table 01). This treatment also had some discrepancies in height (Table 04) that influenced the plant dry matter (Table 03) with significant lower data than T4 but with larger stem diameter (Table 04) when compared to T1 and T2.

Table 03. Aerial part fresh and dry matter in grams of sorghum plants (*Sorghum bicolor* L. Moench) submitted to different water table treatments using Tukey's test at 5%

Treatments	Fresh matter		Dry matter	
T1	89.40	B	37.52	B
T2	88.00	B	36.25	B
T3	109.90	AB	50.74	AB
T4	137.30	A	64.01	A
T5	131.50	A	41.07	B

*CV – 26.58; 33.41 – Fresh and dry matter respectively

** F – 0.53; 1.91 – Fresh and dry matter respectively.

There was no significant difference as to the aerial part length, in cm, of sorghum plants as shown in Table 04. The highest averages were found in treatments T4 (133.80 cm) and T3 (130.55 cm). Plant height was inferior to the characteristics described for the Catissorgo cultivar that was 140cm (CATI, 2004), probably because the plants were collected before maturation.

The diameter average of aerial part, in mm, obtained at the plant base, was significantly different as it can be observed in Table 4. Treatment T5 diameter (15.15 mm) was the largest and did not significantly differ from T4 (14.65 mm) and T3 (13.20 mm), but it was different from the others. Treatments T4, T3 and T1 (12.50 mm) did not differ among themselves and the treatments T3, T1 and T2 (12.20 mm) did not either, but still treatments T4 and T5 tend to present higher values than the others.

Table 04. Aerial part length, in centimeters, of sorghum plants (*Sorghum bicolor* L. Moench) submitted to different water table treatments using Tukey's test at 5%

Treatments	Length		Diameter	
T1	115.75	A	12.50	BC
T2	119.35	A	12.20	C
T3	130.55	A	13.20	ABC
T4	133.80	A	14.65	AB
T5	115.70	A	15.15	A
	*CV – 16.35 ** F – 0.19		*CV – 14.22 ** F – 1.65	

Treatment T1 (11.46 g) was the only one that differed in the comparison of total dry matter of plant roots in Tukey's test at 5%; the others did not differ as shown in Table 5 because treatment T1 had only 17 cm, which is little space for development.

Table 05. Total dry mass of sorghum plant roots (*Sorghum bicolor* L. Moench) in grams submitted to different water table treatments using Tukey's test at 5%

Treatments	Averages	Tukey 5%
T1	11.46	B
T2	24.52	A
T3	27.15	A
T4	26.17	A
T5	24.43	A

*CV – 37.12 ** F – 2.74

The treatment T1 (8.17 g) was significantly different from treatments T4 (19.71 g) and T5 (17.95 g) in the average comparison of panicle fresh matter by Tukey's (Table 06) and had the lowest average because it was under unfavorable conditions to its development, as already mentioned before. Treatments T3 (13.28 g) and T2 (12.77 g) did not differ from other treatments. T4 (19.71 g) and T5 (17.95 g) had the highest averages. Panicle dry matter is similar to the fresh matter, except for T5, which lost more water than treatment T3, but still did not differ from T4 that had the highest average for fresh and dry matter.

Table 06. Fresh and dry matter of panicles in grams and length (cm) of sorghum plants (*Sorghum bicolor* L. Moench) submitted to different water table treatments using Tukey's test at 5%

Treatments	Fresh matter		Dry matter		Length (cm)	
T1	8.17	B	3.16	B	17.85	B
T2	12.77	AB	4.77	AB	18.97	B
T3	13.28	AB	5.82	AB	21.45	AB
T4	19.71	A	7.46	A	23.97	A
T5	17.95	A	5.54	AB	25.57	A

There was difference among the treatments for panicle length (Table 06); T5 (25.57g) and T4 (23.97g) had the highest averages and T1 (17.85g) and T2 (18.97g) the lowest ones. T3 did not differ statistically in any treatment. According to Magalhães & Durães (2003), the panicle length ranges from 4 to 25 cm. In this stage of the crop development, T5 plants had water availability favorable to the development of panicles.

Crop evapotranspiration (ETc), reference evapotranspiration (ETo), and Kc were daily measured for all water table treatments and they are shown in decreasing values in Tables 07, 08, 09, 10 and 11 of all treatments. The values of crop evapotranspiration were similar, from 81 to 87 mm, except for T1 (64 mm) and T5 (76 mm).

Table 07. Descending reference evapotranspiration (mm) and descending crop evapotranspiration (mm) average descending Kc of sorghum crop (*Sorghum bicolor* L. Moench) submitted to different water table treatments

	Days after planting									
T1	1-10	11-20	21 -30	31 - 40	41 - 50	51 - 60	61 - 70	71 - 80	81 -90	Total of cycle
ETo (mm)	6.83	7.16	5.56	7.93	8.78	7.92	8.79	7.79	8.54	69.30
ETc (mm)	2.45	3.81	3.53	5.71	10.12	9.07	9.84	9.76	9.85	64.14
Kc	0.36	0.53	0.64	0.72	1.15	1.15	1.12	1.25	1.15	
T2	1-10	11-20	21 -30	31 - 40	41 - 50	51 - 60	61 - 70	71 - 80	81 -90	Total of cycle
ETo (mm)	6.83	7.16	5.56	7.93	8.78	7.92	8.79	7.79	8.54	69.30
ETc (mm)	3.90	3.16	4.52	10.52	10.49	12.16	12.63	10.44	13.34	81.16
Kc	0.57	0.44	0.81	1.33	1.19	1.54	1.44	1.34	1.56	
T3	1-10	11-20	21 -30	31 - 40	41 - 50	51 - 60	61 - 70	71 - 80	81 -90	Total of cycle
ETo (mm)	6.83	7.16	5.56	7.93	8.78	7.92	8.79	7.79	8.54	69.30
ETc (mm)	2.03	4.14	7.26	8.11	11.86	12.31	15.08	12.77	14.00	87.57
Kc	0.30	0.58	1.31	1.02	1.35	1.56	1.72	1.64	1.64	
T4	1-10	11-20	21 -30	31 - 40	41 - 50	51 - 60	61 - 70	71 - 80	81 -90	Total of cycle
ETo (mm)	6.83	7.16	5.56	7.93	8.78	7.92	8.79	7.79	8.54	69.30
ETc (mm)	3.05	3.51	3.82	6.22	11.28	12.55	13.17	13.53	15.35	82.48
Kc	0.45	0.49	0.69	0.78	1.28	1.59	1.50	1.74	1.80	
T5	1-10	11-20	21 -30	31 - 40	41 - 50	51 - 60	61 - 70	71 - 80	81 -90	Total of cycle
ETo (mm)	6.83	7.16	5.56	7.93	8.78	7.92	8.79	7.79	8.54	69.30
ETc (mm)	2.12	2.53	3.71	4.99	12.31	12.03	12.11	12.36	14.30	76.45
Kc	0.31	0.35	0.67	0.63	1.40	1.52	1.38	1.59	1.67	

The crop coefficient (Kc) reports specific water consume of plants and its development stadium (Table 7). Kc values increase with crop development until maximum development and then decreases with plant senescence. This last stadium was not reached in this study. In the tables above, this tendency can be observed because the plants were picked soon after the emission of the last panicle of the plants in the experiment. Initial Kc of the treatments was around 0.50 and the average Kc was 1.30;

these values were higher than the recommended ones by FAO, which are 0.3 and 1.15, respectively (DOORENBOS et al, 1979). The climate conditions in the glasshouse and the plant confinement certainly must be the cause for the discrepancy among the results and data indicated by those authors.

The water efficiency use is represented in Table 8. Sorghum plants submitted to the deepest treatments, (73 cm), produced more fresh matter per mm of utilized water ($1.74 g.mm^{-1}$), followed by T4 ($1.67 g.mm^{-1}$). The less efficient plants were the ones in treatments T2 ($1.11 g.mm^{-1}$), T3 ($1.36 g.mm^{-1}$) and T1 ($1.42 g.mm^{-1}$). Kanemasu et al (1976) cite data from several authors, showing that the water consume by sorghum crop ranges from 350 to 720 mm, with water use efficiency from 231 to 433 $g.mm^{-1}$. Consequently, there is great elasticity in this consume, that varies according to conditions of soil, cultivar and climate. Considering that the evapotranspiration of treatments T1 (17 cm) and T5 (73 cm) were lower the others, their efficiencies were not too different from the others.

Table 8. Water use efficiency by sorghum plants (*Sorghum bicolor* L. Moench).

TREATMENTS	USA
T1	1.42
T2	1.11
T3	1.36
T4	1.70
T5	1.79

CONCLUSIONS

The results under this experiment conditions allowed the following conclusions:

- there were differences in the development of the plants submitted to different water table treatments; - water table treatments below 73 cm would not be recommended; - water table treatments from 45 to 59cm had significantly higher values for both fresh and dry matter. These variables for panicles, as well as the length, tend to have higher values for water table treatments from 59 to 73 cm; - plants tended to be taller in treatments with 45cm (130.55 cm) and 59 cm (133.80 cm); - as to stem diameter, there was no significant statistics among the treatments with 45, 59 and 73 cm. However, they were significantly different from the ones cultivated in water tables closer to the surface; - roots with water table treatments with 17 cm presented values statistically lower than the other treatments; - plant evapotranspiration presented similar values, except for treatments with 17 and 73 cm that had lower values; -Kc (ETc/Eto) values had an average of 0.50 in the first stage and 1.30 in the following one.

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