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DEVELOPMENT OF SORGHUM PLANTS SUBMITTED UNDER DIFFERENT WATER TABLE LEVELS IN GLASSHOUSE

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ABSTRACT: This study aimed to evaluate the sorghum plants development (*Sorghum bicolor* L. Moench) submitted to different water table levels. The experiment was carried out in a glasshouse on trays with water reservoirs that allowed sub irrigation, and PVC tubes (15 cm diameter) with different heights simulating five water table levels (17 cm; 31 cm; 45 cm; 59 cm; 73 cm), treatments T1; T2; T3; T4; T5 respectively, in an entirely random design. The analyzed parameters were: fresh and dry matter, height and stem diameter of plants; fresh and dry matter and length of panicles; dry matter of roots; leaf area; crop evapotranspiration (ETc), and Kc= ETc/ETo. Water table depths between 45 and 59 cm showed significantly higher values for fresh and dry matter. The weight for fresh and dry matter and length of panicle tended to higher values for T4 and T5. There was no statistical significance among T3, T4 and T5 for stem diameter. Cultivated plants under water table closer to the surface induced plants to produce thicker stems.
Keywords: agronomic characteristics, evapotranspiration, crop coefficient.

DESENVOLVIMENTO DE PLANTAS DE SORGO SUBMETIDAS A DIFERENTES NÍVEIS DE LENÇOL FREÁTICO EM CASA DE VEGETAÇÃO

RESUMO: *O objetivo deste trabalho foi avaliar o desenvolvimento das plantas de sorgo (Sorghum bicolor L. Moench) submetidas a diferentes níveis de lençol freático. O projeto foi realizado em casa de vegetação de vidro, sobre bandejas com reservatórios de água que permitiam a subirrigação e vasos constituídos de tubos de PVC (15 cm de diâmetro) com diferentes alturas simulando diferentes níveis de lençol freático com cinco profundidades (0,17 m; 0,31 m; 0,45 m; 0,59 m; 0,73 m), tratamentos T1; T2; T3; T4; T5 e T6 respectivamente, em delineamento inteiramente casualizado. Os parâmetros analisados foram: massa da matéria fresca e seca, altura e diâmetro do colmo das plantas; massa da matéria fresca e seca e comprimento das panículas; massa da matéria seca das raízes total; área foliar; número de folhas; evapotranspiração da cultura (ETc); coeficiente da cultura (Kc). T3 e T4 foram os melhores, apresentando os maiores valores para ambas as massas, fresca e seca. Para as panículas, os maiores valores para as massas de matéria fresca e seca e comprimento foram apresentados por T4 e T5. Para o diâmetro do colmo não houve significância estatística entre T3, T4 e T5. Plantas cultivadas em níveis freáticos mais próximos da superfície induziram a produção de colmos mais grossos.*
Palavras-chave: *características agronômicas, evapotranspiração, coeficiente da cultura.*

1. INTRODUCTION

Sorghum (*Sorghum bicolor* L. Moench) is the fifth most important cereal in the world, preceded by wheat, rice, corn and barley and 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 drought (MAGALHÃES; DURÃES, 2003). Sorghum is an important alternative to help the provision of grains and, because of its nutritional characteristics, it has been studied as an alternate energetic ingredient to corn. The sorghum cultivation has great yield potential in regions with irregular rainfall due to its adaptation capacity and tolerance to high temperatures (REIS, 1992).

In Brazil, information on adaptability and stability of sorghum are scarce. The cultivars behavior analyses are extremely important to verify its performance over the cycle (SILVA et al., 2005). The forage sorghum, for example, shows growth expectation in semi-arid region due to its characteristics xerophytes and recovers after stress, ensuring production under adverse conditions (SCAPIM et al., 1998). 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, because they are crops cultivated under adverse weather and soil conditions, can reduce the impact of this factor in the provision of grains. A sorghum plant tolerates water deficit and excessive soil moisture content as well as too dry and/or too hot environmental situations, where the productivity of other cereals is not economic.

The experimental investigation on evapotranspiration to determine the water needs of crops has been exhaustively studied in recent decades, due to the need to conduct irrigation in a rational way within the reality of each region (LUNARDI, 2000). The water requirements of crop and soil conditions are the principal factors for the design of an irrigation system (FOLEGATTI, 1988; REICHARDT, 1996; PEREIRA et al., 1997). According to Silveira; Klar (2001), the problem worsens when there are not enough data that allow knowing the crop yield reduction caused by different water table levels.

The water requirement determination and crop coefficient (Kc) by lysimeters has been employed in Brazil. Water table constant lysimeters were considered accurate for studies of small crops (PAVANI, 1985). Alves et al. (1994), in order to verify the importance of the area in the lysimeter capillary rise, assembled a battery of soil columns in PVC tubes with several diameters to examine the possible influence of capillary rise in small areas and concluded that the diameter of soil columns did not interfere with the capillary rise and further this is a specific phenomenon of soil, regardless of the vessel that is confining.

Thus, this study aimed to evaluate the development of sorghum plants submitted to different water table levels in glasshouse, in Botucatu – São Paulo state.

2. MATERIAL AND METHODS

This study was carried out in the experimental area of the Department of Rural Engineering of the College of Agronomical Sciences of UNESP – Botucatu, São Paulo State, Brazil, in latitude of 22º51’ S, longitude of 48º26’ W and altitude of 786 meters. The glasshouse was 6 m long, 4 m wide and 3 m high, painted with 10 cm white stripes in order to decrease the environment internal energy.

The weather of the region, according to Köeppen classification is Cwa characterized: 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 (CENTRO DE PESQUISAS METEOROLÓGICAS E CLIMÁTICAS APLICADAS À AGRICULTURA – CEPAGRI, 2009). We used sorghum seeds of Catissorgo cultivar with sowing 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 Catissorgo cultivar has double purpose, it can be used as forage and grain production, and has the following characteristics: cycle of 115 days for grain, 90 days for silage; planting occurs from January to March; flowering period from 70 to 75 days after planting (DAP), height is about 1.40 m and stand of 120,000 plants per hectare (COORDENADORIA DE ASSISTÊNCIA TÉCNICA INTEGRAL – CATI, 2009).

The equipment to measure the crop evapotranspiration consisted: the pots were 150 mm diameter PVC tubes with PVC covers on the bottom perforated to allow capillary irrigation. Each pot consisted rings of 7cm height, attached with adhesive tape and forming tubes with 21, 35, 49, 63 and 77 cm high. Tubes were partially buried (approximately 4 cm, discounted on total height) in sand, to simulate five water tables depths (17; 31; 45; 59 and 73 cm; treatments T1; T2; T3; T4; T5, respectively), on white metal trays measuring 40 cm wide, 60 cm long and 14 cm high, and filled with thick washed sand.

The trays had an intermediate chamber provided with a float level controller ball to keep constant water level. This chamber was filled up by a water reservoir graduated in millimeters, consisting of an 80 cm high, 15 cm diameter PVC tube. The water supply of the intermediate chamber was done by a 2 cm perforated PVC tube diameter. 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 (Figure 1).

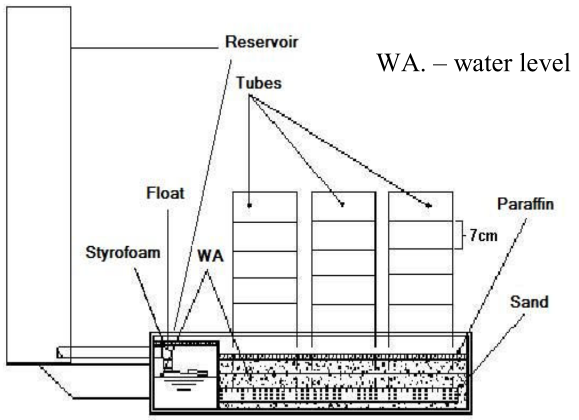

Figure 1. Reservoir, tray and tubes. (Source: Adapted from SILVEIRA; KLAR, 2001).

The pots were filled with soil and reservoirs received water one week before planting in order to stabilize the capillarity process (SILVEIRA; KLAR, 2001). The soil used to fill up the pots was obtained from an area close to the glasshouse in the Department of Rural Engineering (0-20 cm layer) and it was corrected and fertilized following the recommendations of the Technical Bulletin 100 (RAIJ et al., 1997).

The temperature and relative air humidity inside the glasshouse were measured by psycrometer with forced ventilation. The evapotranspiration data were obtained by evaporimetric pan of 60 cm diameter and 25.5 cm height. The analyzed responses of sorghum plants to different treatments were: fresh and dry matter, and height and stem diameter of plants; fresh and dry matter and length of panicles; crop evapotranspiration (ETc), Kc (=ETc/ETo).

The leaf area of plants was estimated by the relation of length, the largest leaf width and an adjustment factor equal 0.747 (STICKLER et al., 1961).

The crop evapotranspiration was measured daily with a graduated scale tape located in the reservoirs. The pots were disassembled and roots were collected to get dry matter.

The experiment design was completely randomized with five treatments and 10 replications. The data were compared by Tukey's test at 5% of probability using Sisvar (2003) software.

3. RESULTS AND DISCUSSION

The emergence of plants started on December 27th, 2008 (4 DAP) and extended until January 4th, 2009 as shown in Table 1. The thinning was done on January 12th, 2009, leaving 2 plants per pot. In order to allow seed germination of deeper treatments (T3, T4, T5 and T6), was added 100 ml of water every day until there were four expanded leaves. The treatments with more available water emerged before the other ones.

Table 1. Emergence percentage of sorghum plants.

Depth (cm)	Emergence of plants (%)				
	4 DAP	5 DAP	6 DAP	7 DAP	8 DAP
17	16	4	18	8	4
31	18	4	34	10	6
45	20	24	32	14	4
59	0	12	2	28	14
73	0	0	0	0	0
Depth (cm)	**Emergence of plants (%)**				
	9 DAP	**10DAP**	**11DAP**	**12DAP**	**Total**
17	6	0	0	34	90
31	4	0	2	18	96
45	0	2	0	2	98
59	8	8	8	18	98
73	0	36	20	32	88

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 was not uniform. Treatment T5 (73 cm) had a problem at first and started emergence at 10 days after planting. Alves et al. (1994) observed that the diameter of soil columns (ranging from 5 to 25 cm), does not influence capillary ascension to tubes up to 1.5 meters height.

The flowering duration of sorghum plants, regarding the 10 replications, is represented in Table 2. Treatments T1, T2 and T5 were the last ones, starting their flowering at 68, 69 and 74 DAP. The T3 flowering duration was 8 days and T1, 22 days. The T4 was the most precocious, beginning its flowering at 62 DAP and lasting 16 days. According to Magalhães; Durães (2003), the flowering duration ranged from 6 to 15 days and occurred at 60 to 82 DAP; corroborating with the results found in this study where: flowering duration was from 8 to 22 days and at 74 DAP.

The averages of fresh and dry matter weight of sorghum plant aerial parts were statistically analyzed by Tukey's test at 5%, and it is observed in Table 3 that there were differences among treatments. Treatments T4 (137.3 g) and T5 (131.5 g) significantly had the greatest fresh matter weights while compared to T1 (89.4 g) and T2 (31 g), which is probably a result of the lower volume of available plant roots. Treatment T3 did not differs statistically from the other ones, considering their fresh and dry matter aerial part weights. Treatment T4 (64.01 g) statistically presented the greatest aerial part dry matter weight, when compared to treatments T5 (41.07 g), T1 (37.52 g) and T2 (36.25 g) that had the lowest ones.

Table 2. Flowering period of sorghum plants (*Sorghum bicolor* L. Moench*)* submitted to different water table treatments in glasshouse.

Depth (cm)	Flowering (DAP)		Duration (days)
	Start	End	
17	68	89	22
31	69	83	14
45	64	82	8
59	62	72	16
73	74	89	15

These results corroborated with the ones found by Barreto et al. (2008) who worked with forage sorghum and observed a decrease in the production of fresh and dry matter when submitted to flooding and compared to levels of T1 and T2. In T5, plants started developing like in the other treatments even germination was late due to the delay to receive water from the water table (Table 1). This treatment also had some discrepancies in height (Table 4) that influenced dry matter values (Table 3) with significant lower data than T4, but with larger stem diameter (Table 4) when compared to T1 and T2.

Table 3. Fresh and dry matter of aerial part of sorghum plants (*Sorghum bicolor* L. Moench) submitted to different water table levels in glasshouse, in Botucatu, SP.

Depth (cm)	Fresh matter (g)	Dry matter (g)
17	89.40 b	37.52 b
31	88.00 b	36.25 b
45	109.90 ab	50.74 ab
59	137.30 a	64.01 a
73	131.50 a	41.07 b

Fresh matter: CV – 26.58, F – 0.53; Dry matter: CV – 33.41, F – 1.91.
* Means with the same letter in the column does not have significant difference by Tukey's test at 5% of probability.

Table 4. Length and diameter of sorghum plants (*Sorghum bicolor* L. Moench) aerial part submitted to different water table levels in glasshouse, in Botucatu, SP.

Depth (cm)	Length (cm)	Diameter (mm)
17	115.75 a	12.50 bc
31	119.35 a	12.20 c
45	130.55 a	13.20 abc
59	133.80 a	14.65 ab
73	115.70 a	15.15 a

Length: CV – 16.35, F – 0.19; Diameter: CV – 14.22, F – 1.65.
* Means with the same letter in the column does not have significant difference by Tukey's test at 5% of probability.

There was no significant difference for aerial part length of plants as shown in Table 4 but there was a tendency for higher averages in treatments T4 (133.80 cm) and T3 (130.55 cm). The plant height was inferior to the characteristics described for the Catissorgo cultivar by CATI, 2009 was 140 cm, because the plants were collected before maturation.

The diameter average of stem, in mm, obtained at the plant base, was significantly different (Table 4). For T5, the diameter (15.15 mm) was the largest one and did not significantly differ from T4 (14.65 mm) and T3 (13.20 mm), but it was different from the other ones. 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 other ones.

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

Table 5. Total dry matter of sorghum plant roots (*Sorghum bicolor* L. Moench), submitted to different water table levels in glasshouse, in Botucatu, SP.

Depth (cm)	Weight (g)
17	11.46 b
31	24.52 a
45	27.15 a
59	26.17 a
73	24.43 a

Weight: CV – 37.12, F – 2.74. * Means with the same letter in the column does not have significant difference by Tukey's test at 5% of probability.

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 it 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.

Table 6. Fresh and dry matter and length of sorghum panicles (*Sorghum bicolor* L. Moench) submitted to different water table levels in glasshouse, in Botucatu, SP.

Depth (cm)	Fresh matter (g)	Dry matter (g)	Length (cm)
17	8.17 b	3.16 b	17.85 b
31	12.77 ab	4.77 ab	18.97 b
45	13.28 ab	5.82 ab	21.45 ab
59	19.71 a	7.46 a	23.97 a
73	17.95 a	5.54 ab	25.57 a

Fresh matter: CV – 45.07, F – 3.31; Dry matter: CV – 44.53, F – 2.46.
* Means with the same letter in the column does not have significant difference by Tukey's test at 5% of probability.

There were differences among the treatments for panicle length (Table 6); T5 (25.57 cm) and T4 (23.97 cm) had the highest averages and T1 (17.85 cm) and T2 (18.97 cm) the lowest ones. T3 did not differ statistically to the others in these variables (fresh, dry and length). 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 panicles development. Crop evapotranspiration (ETc), reference evapotranspiration (ETo), and Kc are shown in Table 7. The values of crop evapotranspiration shown closed values from 81 to 87 mm, except for T1 (64 mm) and T5 (76 mm) with larger differences.

Table 7. Crop evapotranspiration (ETc), reference evpotranspiration (ETo) and crop coefficient (Kc) averages, submitted to water table treatments, in glasshouse, in Botucatu, SP.

Depth (cm)	Days after planting									Total of cycle
	1 to 10	11 to 20	21 to 30	31 to 40	41 to 50	51 to 60	61 to 70	71 to 80	81 to 90	
T1 (17 cm)										
ETc	7.95	9.22	8.05	8.40	21.73	24.09	26.11	26.58	20.68	152.82
ETo	10.25	11.47	9.40	12.39	14.38	13.03	14.14	13.41	13.79	112.26
Kc		0.56					1.41			
T2 (31 cm)										
ETc	4.57	6.02	6.52	7.34	19.37	16.85	20.67	17.91	15.75	115.00
ETo	10.25	11.47	9.40	12.39	14.38	13.03	14.14	13.41	13.79	112.26
Kc		0.56					1.52			
T3 (45 cm)										
ETc	8.61	7.79	11.14	10.06	30.19	25.82	37.88	36.94	16.15	184.56
ETo	10.25	11.47	09.40	12.39	14.38	13.03	14.14	13.41	13.79	112.26
Kc		0.55					1.52			
T4 (59 cm)										
ETc	2.83	2.99	5.01	5.35	22.28	29.43	38.73	41.35	22.42	170.38
ETo	10.25	11.47	9.40	12.39	14.38	13.03	14.14	13.41	13.79	112.26
Kc		0.46					1.48			
T5 (73 cm)										
ETc	3.12	1.65	2.14	2.71	10.22	14.17	24.90	33.22	29.77	121.91
ETo	10.25	11.47	9.40	12.39	14.38	13.03	14.14	13.41	13.79	112.26
Kc		0.38					1.51			

The crop coefficient (Kc) values increased with crop development until maximum development and then decreased with plant senescence (DOORENBOS, 1979). This was not completed in this study. In the tables above, this tendency can be observed, because the plants were harvested after the emission of the last panicles of the plants in the experiment. Initial Kc average (until flowering) of the treatments was around 0.50 and after that phase, the average Kc was 1.30; these values were higher than those recommended by FAO, 0.3 and 1.15, respectively (DOORENBOS, 1979). The climate conditions in the glasshouse and the plant confinement may be the cause for the discrepancy among the result differences.

4. 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: - below 73 cm would not be recommended; from 45 to 59 cm had significantly higher values for fresh and dry matter. These variables for panicles, as well as the length, tend to have higher values for treatments from 59 to 73 cm;

The plants tended to be higher in treatments with 45 cm (130.55 cm) and 59 cm (133.80 cm). To stem diameter, there were no significant statistic values 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; The 17 cm water table presented fresh and dry matter values statistically lower than the other treatments; The crop evapotranspiration presented similar values, except for treatments with 17 and 73 cm that had lower values; Kc values (ETc/ETo) had an average of 0.50 in the first stage (until flowering) and 1.30 in the following one.

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