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Production of cut sunflower under water volumes and substrates with coconut fiber

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Key words:
Helianthus annuus L.
irrigation water management
ornamental plant

ABSTRACT

This study aimed to evaluate the production of cut sunflower in response to different water volumes and substrates, composed of soil and coconut fiber. Two simultaneous experiments were conducted in greenhouse, located in the Horticulture Sector of the Federal Rural University of Rio de Janeiro (UFRRJ), Seropédica - RJ, Brazil (22º 48' S, 43º 41' W and altitude of 33 m), between April and June 2016. Water was applied by an Simplified Irrigation Controller (SIC), allowing the application of different volumes (33, 67 and 133% of retention capacity of substrate) in comparison to the control treatment (100%). The substrates used were 1/3 of coconut fiber and 2/3 of soil (v/v) (Experiment 1), and 2/3 of coconut fiber and 1/3 of soil (Experiment 2). The experimental design was completely randomized, with 5 replicates. The treatment with 100% of the volume applied by the SIC led to best growth of sunflower, increasing the potential income obtained with stems at better marketing standard according to the prices practiced.

Palavras-chave:
Helianthus annuus L.
manejo da água de irrigação
planta ornamental

Produção de girassol de corte sob volumes de água e substratos com fibra de coco

RESUMO

Objetivou-se neste trabalho avaliar a produção de girassol de corte em resposta a diferentes volumes de água e substratos, constituídos de solo e fibra de coco. Foram realizados dois experimentos simultâneos em casa de vegetação, localizada no setor de Horticultura da Universidade Federal Rural do Rio de Janeiro (UFRRJ), Seropédica - RJ, Brasil (22º 48' S, 43º 41' W e altitude de 33 m), entre abril e junho de 2016. A aplicação de água foi realizada por meio do Acionador Automático para Irrigação (AAI), possibilitando a aplicação de diferentes volumes (33, 67 e 133% da capacidade de retenção do substrato) em relação ao tratamento controle (100%). Os substratos utilizados foram 1/3 de fibra de coco e 2/3 de solo (v/v) (Experimento 1), e 2/3 de fibra de coco e 1/3 do solo (v/v) (Experimento 2). O delineamento experimental utilizado foi o inteiramente casualizado, com 5 repetições. O tratamento referente a 100% do volume aplicado pelo AAI possibilitou o melhor crescimento do girassol, proporcionando o aumento de renda potencial obtida com hastes em melhor padrão de comercialização de acordo com os preços praticados.

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Introduction

Sunflower (*Helianthus annuus* L.) is commonly used as ornamental plant in North America and Europe, and its importance in the Brazilian market has increased (Cuquel et al., 2010), due to its easy production and adaptability to different environmental conditions (Curti et al., 2012).

In the cultivation of ornamental plants, it is common to use substrates made from agro-industrial wastes, such as coconut fiber (Ludwig et al., 2010) because, besides reducing the weight of flower pots (Nazari et al., 2011), it minimizes the environmental impact of the disposal of these materials. In addition, this material stands out for the good physical properties, such as lack of reaction with nutrients from fertilization, long durability without alterations in physical characteristics, possibility of sterilization and abundance of raw material, which is renewable (Carrijo et al., 2002; Faria et al., 2010).

Regardless of how water application is performed, studies on ornamental sunflower have pointed to a positive response in agronomic variables to irrigation (Nobre et al., 2010; Viana et al., 2012). Automatic application of water in agriculture is an alternative to meet the requirements of crops (Batista et al., 2013; Gomes et al., 2014, 2017), especially with the use of devices with simple construction and low cost (Medici et al., 2010).

In this context, this study aimed to evaluate the effect of different percentages of the water volume applied by the automatic irrigation controller in the production of cut sunflower, in two substrates composed of different proportions of coconut fiber and soil.

Material and Methods

Two experiments were carried out simultaneously in a greenhouse with area of 240 m^2, built using lumber, involved with a shade screen and covered with 100-micron agricultural plastic (Leal et al., 2006), installed in the Horticulture sector of the Federal Rural University of Rio de Janeiro (UFRRJ), Seropédica - RJ, Brazil (22º 48’ S, 43º 41’ W and altitude of 33 m), between April and June 2016.

A thermo-hygrograph (Datalogger IP-747RH, Impac), installed in the center of the greenhouse, recorded maximum, minimum and mean temperatures of 45.6, 17.1 and 25.6 ºC, respectively, and maximum, minimum and mean relative humidity values of 98.3, 22.2 and 72.1%, respectively.

Sunflower was cultivated in pots (3.1 L) filled with substrate made from a mixture of coconut fiber and soil, at two different proportions: 1/3 of coconut fiber and 2/3 of soil (v/v) (Experiment 1); and 2/3 of coconut fiber and 1/3 of soil (v/v) (Experiment 2). Each substrate was used in one independent experiment, so they did not characterize source of variation. The coconut fiber used was the commercial version Golden Mix (Amafibra, Ananindeua/PA), type 11 granulated, with electrical conductivity of 1.1 mS cm^{-1}, water retention capacity of 507 mL L^{-1}, total porosity of 95% and specific weight of 150 kg m^{-3}. The soil material used came from the A horizon of a Planosol.

Water retention capacity in the substrates was determined by the simplified evaporation method (Schindler & Müller, 2017), using the Hyprop® device. The results were used to fit equations 1 (Experiment 1) and 2 (Experiment 2) according to the model proposed by Genuchten (1980):

$$\theta = 0.1554 + \frac{0.45603}{\left[1+\left(0.059489h\right)^{1.8442}\right]^{0.4578}} \tag{1}$$

$$\theta = 0.1235 + \frac{0.6148}{\left[1+\left(0.086297h\right)^{1.7893}\right]^{0.4411}} \tag{2}$$

where:

θ - volumetric moisture, cm^3 cm^{-3}; and,

h - matric potential, hPa.

The values of soil porosity and moisture content at field capacity were respectively 0.611 and 0.255 cm^3 cm^{-3}, for the substrate of Experiment 1, and 0.738 and 0.235 cm^3 cm^{-3}, for the substrate of Experiment 2, indicating lower water retention in the substrate composed mostly by coconut fiber.

According to Portz et al. (2013), fertilizations were performed using 4.94, 2.30 and 1.52 g plant^{-1} of single superphosphate, potassium chloride and urea, respectively, based on soil analysis (Teixeira et al., 2017), which showed the following chemical characteristics: pH = 6.9; Na = 0.02; Ca = 4.0; Mg = 3.6; K = 0.21 cmol$_c$ dm^{-3}; P = 23; K = 81 mg L^{-1}.

Seeds of sunflower cv. Vicent’s Choice® (Sakata Seed Sudamerica Ltda, Bragança Paulista/SP) (98% germination) were planted on trays and after 10 days transplanted to plastic pots.

In both experiments, the design used was completely randomized and treatments were characterized by the different percentages of water volume applied by the automatic irrigation controller (SIC): T1 - 33%, T2 - 67%, T3 - 100% and T4 - 133% of retention capacity of substrate, with 5 replicates. Each experimental unit comprised 5 pots, totaling 100 pots in each experimental area. The spacing used was 0.45 m between rows and 0.30 m between pots (3.375 m^2 per treatment).

The different water volumes were obtained by the combination of iDrop PC-PCDS pressure-compensating emitters (Irritec® Brazil, Indaiatuba, SP) with flow rates of 2 and 4 L h^{-1} and flow dividers (Manifold MV4, Irritec®), which fixed to two microtubes allowed the application of half the nominal flow rate of the emitter. In addition, the micro-irrigation system was composed of 16-mm-diameter polyethylene hoses and ¾-hp motor pump set (Dancor/CP - 4C), which drew water from a 1000-L tank installed in the greenhouse.

Before the experiments began, flow rate and distribution uniformity tests were conducted and actual flow rates of 0.92 (T1), 2.08 (T2), 3.05 (T3) and 3.93 (T4) L h^{-1}, and of 0.84 (T1), 2.02 (T2), 2.88 (T3) and 3.72 (T4) L h^{-1}, respectively, were obtained for Experiments 1 and 2. The mean coefficient of distribution for both experiments was 92.6%.

Irrigation water management was carried out using the SIC (Medici et al., 2010; Batista et al., 2013; Dias et al., 2013; Gomes et al., 2014; Gonçalves et al., 2014; Santos et al., 2015), installed in the treatment T3, which turned on the irrigation system when a 4 kPa tension was reached in the hose connecting the pressure switch to the porous capsule of the device.

To monitor the number and duration of irrigation events and water tensions in the soil, pressure and tension transducers were respectively installed in the water supply network and in 2 tensiometers at 5 cm depth, per treatment. The measurements taken were sent to dataloggers, programmed to record soil water tension every hour, in the absence of irrigation, and every 10 s when the system was turned on.

Stem height and diameter were measured every week and the following parameters were evaluated at harvest: height, capitulum diameter and internal disc diameter (Travassos et al., 2011), days until harvest, fresh and dry weights of petals per inflorescence, leaf area and root volume. Plant height was measured with a tape measure, capitulum and internal disc diameters were measured with a digital caliper, and root and shoot weights with a digital scale. The dry weights of the materials were determined after drying the fresh material in a forced air ventilation oven at 45 ºC until constant weight. Leaf area was obtained using a leaf area integrator, model Li-3100C (LI-COR®, Lincoln, Nebraska - EUA) (Flumignan et al., 2008). Root volume was obtained by the difference between the water volume in a graduated cylinder before and after immersing the roots (Bosa et al., 2003).

The data were subjected to normality test and analysis of variance and, when significant by F test, subjected to regression analysis (Gomes & Garcia, 2002), at 5% significance level.

The potential income analysis relative to the stems with lengths greater than 50, 60, 70, 80 and 90 cm was carried out according to the standard established by the Brazilian Institute of Floriculture (IBRAFLOR, 2015), attributing the respective values of R$ 6.00, 7.00, 8.00, 9.00 and 10.00, which refer to the prices of commercialization of a bunch with six stems, based on the survey conducted on June 20, 2016, at the Supply Centers of Campinas - Centrais de Abastecimento de Campinas S.A. (CEASA/Campinas).

Results and Discussion

The number of actuations performed by the SIC and the total water volume applied per week in the experiments are presented in Figure 1. At the end of the experiments, 19 actuations were performed in Experiment 1 and 25 in Experiment 2 (Figure 1A), with total applied volumes of 1320 and 1020 L, respectively (Figure 1B).

The mean water volumes applied per treatment were 4.70, 10.60, 15.59, and 20.09 L plant^{-1}, in Experiment 1, and 3.46, 8.31, 11.82, and 15.28 L plant^{-1}, in Experiment 2, respectively, for the percentages corresponding to 33, 67, 100 and 133% of the water volume applied by the SIC. Despite requiring higher number of irrigations (Figure 1A), the experiment using substrate with greater quantity of coconut fiber (Experiment 2) had a shorter mean time of irrigation (7 min and 17 s) compared to Experiment 1 (14 min and 38 s)

The mean water tensions in the soil when the controller was turned on were 47.68, 19.68, 18.28 and 15.29 kPa, in Experiment 1, and 24.15, 15.80, 6.78 and 3.74 kPa, in Experiment 2, respectively, for the irrigation depths corresponding to 33,

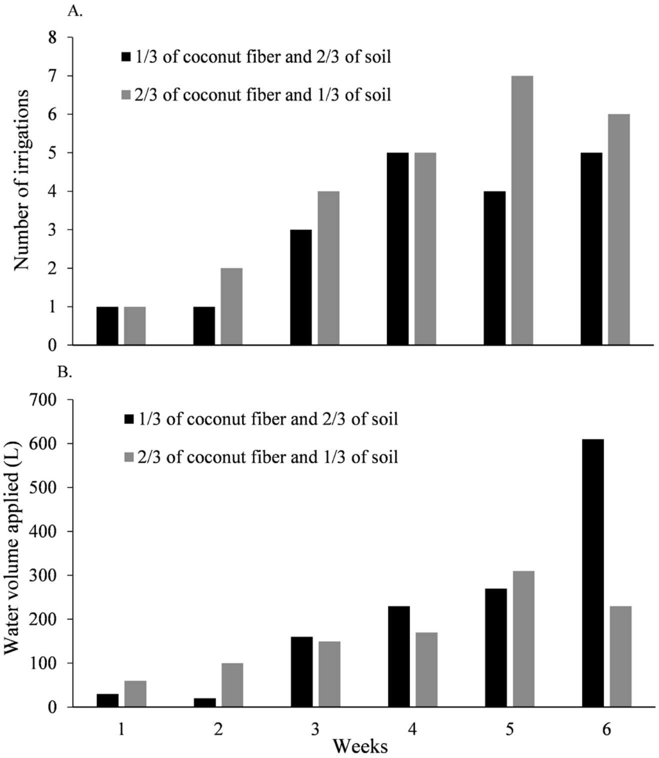

Figure 1. Number of irrigations (A) and water volume applied (B) for cut sunflower in the Experiments 1 (1/3 of coconut fiber and 2/3 of soil) and 2 (2/3 of coconut fiber and 1/3 of soil)

67, 100 and 133% of the water volume applied by the SIC. As expected, the intensity of the tensions decreased as the water volumes of the treatments increased.

In the experiment which used the substrate composed of 1/3 of coconut fiber and 2/3 of soil (Experiment 1), the different water volumes applied significantly affected the final height (Figure 2A), in an progressive distancing from the fourth week, height at harvest, capitulum diameter, internal disc diameter and final stem diameter in the sixth week (Figure 2C), fresh and dry weights of shoots and roots, leaf area and root volume (Table 1). Most variables showed an increasing effect up to values close to 100% of the water volume applied by the Simplified Irrigation Contoller (SIC) (T3), decreasing up to 133% of the water volume applied by the SIC (T4), except for root dry weight, which exhibited a linear behavior. The variables days until harvest and numbers of leaves and petals were not significantly affected by the different water volumes applied.

The ratio between shoot and root dry weights in Experiment 1 showed a cubic behavior in its regression, which was highly significant and with technically absolute fit (100%). Such cubic response may have been influenced by water and nutritional deficits. The reduction of water supply from the treatment T3 (100%) to T2 (67%) caused a decline in the shoots and slight increase in root weight, reducing the shoot/root ratio from 11.32 to 8.14. The decrease from T2 (67%) to T1 (33%), characterizing higher level of water stress, compromised the roots more intensely than the shoots, causing an increase in the ratio to 13.66. A mild drought can make the plant to exhibit such adaptive response, which allows reduction in transpiration and increase in water absorption, whereas a severe drought usually reduces the growth of both

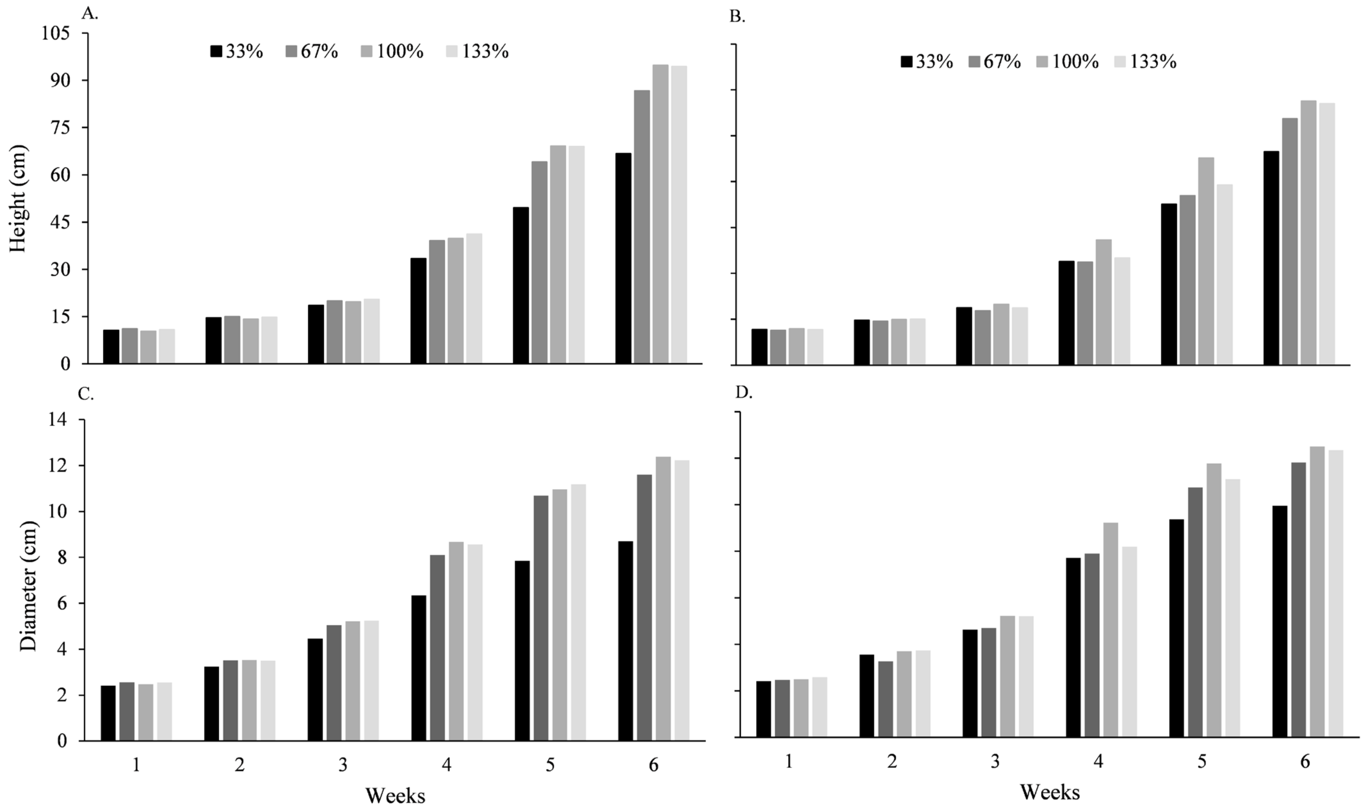

Figure 2. Height and diameter of cut sunflower stem for different percentages of water volume applied by the Simplified Irrigation Controller (SIC), in the Experiments 1 (A and C - 1/3 of coconut fiber and 2/3 of soil) and 2 (B and D - 2/3 of coconut fiber and 1/3 of soil), along 6 weeks of cultivation

Table 1. Production variables of cut sunflower for different percentages of the water volume applied by the Simplified Irrigation Controller (SIC), in the Experiment 1 (1/3 of coconut fiber and 2/3 of soil, v/v)

Variable		Pr > Pf	CV (%)	% of the volume applied by the SIC				R^2 (%)	Equation
				33	67	100	133		
Final height	(cm)	0.002	6.46	66.73	86.70	94.73	94.36	100	$y = -0.17x^2 + 6.00x + 42.24$
Height at harvest	(cm)	0.002	6.39	73.86	95.32	104.70	102.85	100	$y = -0.20x^2 + 6.74x + 46.30$
Capitulum diameter	(cm)	0.023	3.94	12.70	13.74	14.32	14.00	98	$y = -0.01x^2 + 0.37x + 11.17$
Internal disc diameter	(cm)	0.015	5.16	5.17	5.80	6.21	6.01	98	$y = -0.01x^2 + 0.23x + 4.22$
Final diameter	(cm)	<0.001	3.91	8.70	11.61	12.39	12.23	100	$y = -0.03x^2 + 0.88x + 5.17$
Days until harvest		ns	1.40	55.61	55.36	55.57	55.08	-	-
Root fresh weight	(g)	0.018	18.37	14.27	33.35	36.48	40.44	98	$y = -0.13x^2 + 4.78x + 4.84$
Shoot fresh weight	(g)	<0.001	7.16	107.99	188.83	209.85	203.26	100	$y = -0.76x^2 + 24.86x + 8.43$
Root dry weight	(g)	<0.001	25.61	1.53	3.72	3.62	4.26	80	$y = -0.16x + 1.21$
Shoot dry weight	(g)	0.033	23.48	18.18	30.53	38.36	33.95	97	$y = -0.14x^2 + 4.59x + 0.71$
Number of leaves		ns	4.46	22.15	22.44	23.38	23.14	-	-
Number of petals		ns	5.28	28.80	31.00	31.36	30.56	-	-
Shoot/root ratio		0.006	20.46	13.66	8.14	11.32	8.93	100	$y = -0.02x^3 + 0.68\,x2 + 8.16x + 38.76$
Leaf area	(cm^2)	<0.001	7.11	1540.29	2289.89	2474.44	2389.35	100	$y = -7.27x^2 + 234.62x + 602.92$
Root volume	(cm^3)	0.007	18.53	18.00	43.00	48.50	50.75	99	$y = -0.19x^2 + 6.85x + 9.49$

ns - Not significant

roots and shoots (Chen et al., 2015). On the other hand, the behavior of this ratio between T3 (100%) and T4 (133%) appears to result from losses of nutrients by leaching with the excess water in T4, which may have collaborated to the limitation of shoot growth and stimulus to root growth in order to increase the absorption of nutrients, also leading to the reduction in shoot/root ratio. In general, the excess of nutrients in the soil relatively reduces the investment of the plant in roots, optimizing the use of resources, since the absorption of nutrient is facilitated (Ågren & Franklin, 2003). The image of the plant from the T4 treatment (Figure 3) corroborates the hypothesis of leaching of nutrients, because there is a visual symptom of N deficiency in comparison with T3, that is, older leaves with chlorosis in T4.

The cubic behavior exhibited by the shoot/root ratio has practical implications for the crop because it indicates the plasticity of the plant to adapt and better explore different availabilities of water and nutrients, although this adaptive capacity has limits to be expressed. These results also indicate that the water depth applied in T3 is the one that allows better use of plant plasticity to optimize the production of sunflowers.

In the experiment which used substrate composed of 2/3 of coconut fiber and 1/3 of soil (Experiment 2), the different water volumes applied significantly affected the final height, which became evident from the fourth week (Figure 2B), height at harvest (Figure 3), capitulum diameter and final stem diameter (Figure 2D), fresh and dry weights of shoots, number of petals, shoot/root ratio, leaf area and root volume (Table 2). Except for capitulum diameter and root volume, the increment of water led to increase in the values of the other variables up to

Figure 3. Plant height at harvest of cut sunflower for the different percentages of water volume applied by the Simplified Irrigation Controller (SIC), in Experiment 2 (2/3 of coconut fiber and 1/3 of soil, v/v)

100% of the water volume applied by the Simplified Irrigation Controller (SIC) (T3), with subsequent decrease up to 133% of the water volume applied by the SIC (T4), demonstrating that the excess of water hampered the development of cut sunflower (Table 2). This result can be explained, at least partially, by the expulsion of air from the soil and its oxygen caused by the excess of water, which compromised the physiology of roots in their respiration (Mattos et al., 2005).

The ratio between shoot dry weight and root dry weight increased with the increment in the water volume applied. This behavior is possibly due to a greater investment of the plant in organs of extraction in response to the deficit as a way to compensate it by exploring new areas where water can be found (Santos & Carlesso, 1998). The variables capitulum internal disc diameter, days until harvest, fresh and dry weights of roots and number of leaves were not influenced by the different percentages of water volume applied by the SIC (Table 2).

The water deficit caused deleterious effect on most production variables for both substrates. The treatment where the controller was installed (100% of the water volume applied by the SIC) had the best performance in vertical and radial growth, especially in the substrate with 2/3 of coconut fiber and 1/3 of soil, in which the effect was more evident (Figure 2). Viana et al. (2012) observed similar influence of the water depth applied in sunflower, with linear fit for parameters such as height and stem diameter.

Table 2. Production variables of cut sunflower for the different percentages of water volume applied by the Simplified Irrigation Controller (SIC), in Experiment 2 (2/3 of coconut fiber and 1/3 of soil, v/v)

Variable		Pr > Pf	CV (%)	% of the volume applied by the SIC 33	67	100	133	R^2 (%)	Equation
Final height	(cm)	0.028	5.5	69.8	80.6	86.3	85.5	78	y = -0.15x+ 4.20x + 56.85
Height at harvest	(cm)	0.034	4.9	76.6	90.4	96.6	98.5	100	$y = -0.15x^2 + 4.62x + 62.31$
Capitulum diameter	(cm)	0.010	5.9	12.0	12.7	13.7	13.1	65	y = 0.11x + 11.78
Internal disc diameter	(cm)	ns	12.9	5.2	5.0	5.7	5.2	-	-
Final diameter	(cm)	0.021	6.4	10.0	11.8	12.5	12.4	100	$y = -0.03x^2 + 0.71x + 7.81$
Days until harvest		ns	3.3	55.7	56.3	55.2	56.6	-	-
Root fresh weight	(g)	ns	42.7	22.1	38.8	38.5	35.8	-	-
Shoot fresh weight	(g)	0.006	16.5	109.9	169.7	210.8	182.8	93	$y = -1.24x^2 + 29.99x + 18.15$
Root dry weight	(g)	ns	27.4	3.0	3.9	4.4	3.8	-	-
Shoot dry weight	(g)	0.023	20.8	17.4	27.0	34.7	29.3	92	$y = -0.20x^2 + 4.90x + 2.31$
Number of leaves		ns	6.0	22.2	21.7	22.6	22.7	-	-
Number of petals		0.022	5.1	27.1	28.0	30.4	27.7	100	$y = -0.02x^3 + 0.58x^2 - 4.22x + 35.70$
Shoot/root ratio		0.009	24.1	6.03	6.8	8.8	9.0	92	y = 0.28x + 4.96
Leaf area	(cm^2)	0.040	16.9	1504.1	2006.4	2369.5	2090.4	93	$y = -10.68x^2 + 255.53x + 722.63$
Root volume	(cm^3)	0.006	26.26	33.7	52.2	62.5	58.0	78	y = 2.21x + 30.11

ns - Not significant

Table 3. Number of cut sunflower stems in each Ibraflor classification standard, potential income and virtual economic losses of the bunches with six stems, according to the prices on June 20, 2016, at CEASA/Campinas, for different percentages of the water volume applied by the Simplified Irrigation Controller (SIC), in the Experiments 1 (1/3 of coconut fiber and 2/3 of soil) and 2 (2/3 of coconut fiber and 1/3 of soil)

% of the water volume applied by the SIC	Stem length (cm) 90	80	70	60	50	Total of stems	Potential income R$	R$ ha^{-1}	Variation in relation to 100% of the water volume applied by the SIC
						Experiment 2			
33	1	10	8	5	1	25	34.16	101,214.71	-16%
67	15	5	2	1	-	23	36.38	107,792.48	-11%
100	20	4	1	-	-	25	40.73	120,681.36	-
133	21	3	-	-	-	24	39.57	117,244.33	-3%
						Experiment 1			
33	-	5	10	8	-	23	30.16	89,362.87	-27%
67	16	8	-	1	-	25	39.89	118,192.47	-4%
100	24	1	-	-	-	25	41.58	123,199.88	-
133	22	3	-	-	-	25	41.24	122,192.47	-1%

In economic terms, the performances obtained by the treatment where the controller was installed (100% of the water volume applied by the SIC) were the most profitable ones, in both experiments. Deficit (33 and 67% of the water volume applied by the SIC) and excess (133% of the water volume applied by the SIC) of irrigation water caused financial losses, although the excess did not compromise expressively the potential income obtained (Table 3).

In both experiments, the greater potential income of the treatment corresponding to 100% of the water volume applied by the SIC is associated with higher occurrence of individuals with stems classified in the standard of higher financial value (the most profitable).

Although the financial superiority is evident in the present study, more specific works are necessary to understand the development of production costs in response to this higher yield and to determine the water volume which would lead to highest net profit to the producer.

Conclusions

1. Water deficit and excess hampered the development of cut sunflower.

2. Water management performed using the simplified irrigation controller (SIC) (100% of the water volume applied by the SIC) led to the best performance in the various growth parameters and in potential income obtained with the crop.

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