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USE OF FERROUS WATER FOR DRIP IRRIGATION OF ORNAMENTAL SUNFLOWER IN POTS

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1 ABSTRACT

The objective of the present study was to determine the critical concentration of iron in irrigation water that interferes with the performance of the ornamental sunflower, ‘Sunflower F1 Sunbright Supreme’ cultivar produced in pots and subject to drip irrigation. A 4 x 2 completely randomized factorial design was adapted with four replications, testing four iron concentrations in water (0.0, 0.5, 1.5, and 3.0 mg L^{-1}) and two types of emitters (self-compensating and conventional). The experiment was conducted in a greenhouse and the following characteristics were evaluated: shoot height, stem and root system length, stem diameter, number of leaves, leaf area, shoot dry weight, root dry weight, flower dry weight, total dry weight and flower diameter. The use of water with the presence of iron did not produce satisfactory results compared to the commercial standards of ornamental sunflower production, precluding its use under irrigation conditions.

Keywords: *Helianthus annuus* L., iron sulfate, production quality.

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ÁGUA FERROSA NO CULTIVO DE GIRASSOL ORNAMENTAL EM VASOS IRRIGADOS POR GOTEJAMENTO

2 RESUMO

Neste trabalho, teve-se por objetivo determinar a concentração crítica de ferro na água de irrigação que interfere no desempenho da cultura do girassol ornamental, cultivar ‘Sunflower F1 Sunbright Supreme’ produzido em vasos e irrigado por gotejamento. Adotou-se o delineamento experimental inteiramente casualizado, no esquema fatorial 4 x 2, com quatro repetições, testando-se quatro concentrações de ferro na água (0,0; 0,5; 1,5; e 3,0 mg L^{-1}) e dois tipos de gotejadores (autocompensante e convencional). O experimento foi conduzido em casa de vegetação sendo avaliados: altura da parte aérea, comprimento da haste e sistema radicular, diâmetro da haste, número de folhas, área foliar, massa seca da parte aérea, massa seca do sistema radicular, massa seca das inflorescências, massa seca total e diâmetro de

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inflorescências. A utilização de água com presença de ferro não apresentou resultados satisfatórios aos padrões comerciais de produção de girassol ornamental, sendo inviável a sua utilização em condições de cultivo irrigado.

Palavra-chave: *Helianthus annuus* L., sulfato de ferro, qualidade de produção.

3 INTRODUCTION

Sunflower culture (*Helianthus annuus* L.) is ranked fourth in oilseed grain production and fifth in cultivated area worldwide. In addition to grain production, the sunflower is also widely cultivated for cut and pot flower production (SCHOELLHORN et al., 2003). The three most important characteristics for the commercialization of ornamental sunflowers flower diameter as well as stem diameter and length (SLOAN & HARKNESS 2006).

Potted flowers are one of the most interesting and promising forms of ornamental production and new products and/or species are often selected for the market. Sunflowers exhibit desirable characteristics from an agronomic viewpoint, including a short cycle, which makes them a good choice for flower producers in Brazil (CARVALHO et al. 2009).

Sunflower water consumption varies as a function of weather conditions, cycle duration, soil type, as well as soil and crop management. Water demand, according to SILVA et al. (2011), is roughly 533.70 mm, which is well distributed throughout the cycle, resulting in near-maximum yields.

Drip irrigation is one of the most efficient methods currently in use. However, emitter obstruction caused by the presence of solid particles in irrigation water is one of the factors that increases the operating and maintenance costs of irrigation systems, in some cases even precluding its use (RIBEIRO et al., 2004).

Iron, the micronutrient most absorbed by sunflower, accumulates large amounts in flowers and seeds (ZOBIOLE et al. 2011). According to BARBOSA FILHO (1991), the Fe concentration of 50 to 1,680 mg L^{-1} is toxic to plants. Iron applications should not exceed the amount required for plant development, since high concentrations of this element reduce growth and cause undesirable tissue accumulations; excess applications can also result in crop failure (AYERS & WESTCOT, 1991).

Iron is one of the main problems of irrigation water, due to its tendency to obstruct pipes and drip irrigation system emitters. In Fe^{+2} to Fe^{+3} oxidation, iron precipitates and is retained at emitter outlets and pipe walls (RIBEIRO & PATERNIANI, 2008), resulting in increased pressure drop, thereby compromising the irrigation system. Concentrations higher than 0.2 mg L^{-1} pose a significant risk of clogging (GILBERT & FORD, 1986). Once precipitated, iron forms a red slime, which may adhere to pipes and clog emitters.

The objective of the present study was to determine the critical iron concentration in irrigation water that interferes with the performance of ornamental sunflowers, the 'Sunflower F1 Sunbright Supreme' cultivar, produced in pots and subjected to drip irrigation.

4 MATERIAL AND METHODS

The experiment was conducted at the Department of Rural Engineering, School of Agricultural Sciences, niversidade Estadual Paulista - UNESP, Botucatu Campus, São Paulo

State, whose geographic coordinates are 21°51'03'' south 48°26'37'' west and elevation of 786m.

The experiment was performed in two parts, one in a greenhouse measuring 37.50 m long, 5.00 m wide, 1.50 m high walls and 3.00 m at the center. The pots were spaced 20 cm apart and placed on top of bricks set on the greenhouse floor to avoid direct contact with the soil.

The other portion was performed in the laboratory to evaluate emitters in bench-top assays with 4 lateral lines and water recirculation, as well as a 300- liter reservoir , pressure pump , 200- mesh metal filter, 2 air outlet valves and 2 gauges calibrated and tested prior to testing to maintain working pressure at 1.0 kPa. Metal carts were also constructed on rails to facilitate removal of sample containers.

For the greenhouse experiment a completely randomized 4 X 2 design with four repetitions was adapted. Each plot consisted of 20 plants (one per pot). Four concentrations of iron in the irrigation water were assessed (0.0, 0.5, 1.5, and 3.0 mg L^{-1}), along with two types of emitters (one self-compensating and the other conventional), both with flow rates of 4.0 L h^{-1}. In the laboratory a completely randomized design was also used with three concentrations of iron in the water (0.5, 1.5, and 3.0 mg L^{-1}) and two types of emitters (one self-compensating and the other conventional), with 3 repetitions and 20 emitters each.

Ornamental sunflower seeds (*Helianthus annuus* L.), the 'Sunflower F1 Sunbright Supreme' cultivar, were planted in polystyrene trays containing 128 cells, with one seed per cell, in a commercial substrate (TopGraden Planter). Next, seedlings with fully expanded cotyledons were transplanted to sturdy plastic pots filled with the same substrate used in the trays.

To maintain plant size 10% chlormequat growth regulator was used at a concentration of 1,500 mg L^{-1} per dose, applied at 15-day intervals for a total of three repetitions.

For each treatment an individual 150 L water reservoir was used, where iron dosage was performed directly in the reservoir. A pump was used to force the water through the pipes as well as a 200-mesh metal filter, air outlet valve and a tested gauge to maintain working pressure at 1.0 kPa.

Two water sources were used for irrigation: in the control treatment (0.0 mg L^{-1} of iron) water treated by the SABESP (Basic Sanitation Company of the State of São Paulo) showed no iron content; in the other treatments water from a pond located at the Rural Engineering Department had a natural iron concentration of 0.5 mg L^{-1}, and iron sulfate was supplemented for treatments with higher doses (1.5 and 3.0 mg L^{-1}). Before and during the experiment iron was analyzed in order to maintain the concentration in each irrigation treatment, with the aid of a spectrophotometer.

The potential maximum water retention of the material was 50.8%, divided into three types: available water (5.5%), buffer water (4.9%) and remaining water (40.5%). The substrate could store and dispose only 5.5% water, which required greater irrigation frequency during the course of the experiment. In the vegetative stage the run time was 30 s for each irrigation and the reproductive stage time was 60 s. The adoption of this form of irrigation management was due to the potential water retention of the substrate, which could store and dispose only 5.5% of applied water, requiring more frequent irrigation.

At the end of the experiment the following characteristics were evaluated: shoot height (cm), stem length (cm), number of leaves, stem diameter (mm), root length (cm), shoot dry weight (g), root dry weight (g), flower dry weight (g) and total dry weight (g). Leaf area was determined using aLi 3100 leaf area meter. The contents of macronutrients (N, P, K, Ca, Mg and S) and micronutrients (B, Cu, Fe, Mn and Zn) were determined in dry and ground samples of the plant parts.

For emitter evaluation, water exiting the emitters was collected in flasks and weighed on an analytical scale (0.01 g) to determine the volume emitted. This allowed the flow to be calculated by transforming the weight into volume and disregarding viscosity.

To evaluate the emitters, the flows coefficients expressing uniform application were used as follows:

- coefficient of distribution uniformity [eq. (1)] and Christiansen uniformity coefficient [eq. (2)].

$$CUD = \frac{\text{média 25\% das vazões com menores valores}}{\text{média de todas as vazões}} \times 100 \quad (1)$$

$$CUC = 100 \times \left[1 - \frac{\sum_{i=1}^{n} |Yi - \bar{Y}|}{n \times \bar{Y}}\right] \quad (2)$$

where:
CUD= coefficient of uniform distribution, %;
CUC: Christiansen Uniformity Coefficient, %;
n: Number of samples on the lateral line;
Yi - Emitter flow, L h^{-1};
$\bar{Y}$ -. Average emitter flow , L h^{-1};

Data were subjected to analysis of variance using the F test. When there was no significant interaction between factors, the averages of the emitters were compared by the Tukey test at 5% probability, and the effects of Fe doses by means of linear and polynomial regression. When analysis of variance revealed a significant effect for the interaction between emitter types and Fe doses, the interaction between them was determined.

5 RESULTS AND DISCUSSION

The cycle of the ornamental sunflower was 67 days. Tables 1 and 2 show the results of analysis of variance.

Sunflower plant height and stem length were significantly influenced by iron concentration in the irrigation water (Table 1), and the emitter exerted no influence. However, the interaction between iron concentration and emitter type was significant only for plant height. In the case of ornamental sunflowers, where demand for smaller plants is dominant, this effect was not favorable for commercialization of the product. Thus, the greater increased iron content in irrigation water promoted an increase in plant size, which may preclude marketing of the product. According to NEVES et al. (2005), defining a standard height for the marketing of ornamental sunflowers in pots is a difficult task because it is a subjective variable, depending largely on consumer preference. However, plants encountered on the market were an average of 25 to 30 cm tall. Thus, an alternative would be to market the plants as cut flowers.

Stem diameter and plant height, are the variables that indicate the commercial value of ornamental sunflower plants. There was a reduction in sunflower quality with the addition of Fe doses for both emitters (Table 1). The highest Fe concentration (3.0 mg L^{-1}) caused a reduction in disc and capitula diameter (Table 1) when applied with both the conventional and self-compensating emitters. The reduction in disc diameter was 32% and 49%, respectively; and capitula were 25% and 32% smaller, respectively. This effect is undesirable and limits the use of high doses of the product, as observed in relation to the height of sunflower plants.

Table 1. Analysis of variance of plant height (PH), stem length (SL), stem diameter (SH), sheet number (SN), root length (RL), disc diameter (DD), capitulum diameter (CD) as a function of the different emitters (Self-compensating and Conventional) and iron levels (ferrous sulfate), in the production of ornamental sunflowers.

	Emitters		Emitters		Emitters		Emitters	
	C	S	C	S	C	S	C	S
Rates (mg L^{-1})	PH (cm)		SL (cm)		SH (mm)		SN	
0.0	37.2a	38.3a	31.4a	31.4a	13.4a	12.9a	11.3a	10.9a
0.5	49.4a	43.7b	43.4a	39.1b	5.9a	5.9b	11.7a	10.7b
1.5	43.8a	44.1a	38.9a	39.0a	5.8a	5.6a	11.2a	11.0a
3.0	43.6a	44.6a	38.3a	37.6a	5.8a	5.2b	11.2a	10.4b
Regression	Q**	Q**	Q**	Q**	L**	L**	NS	NS
Iron (I)	15.630**		22.472**		906.969**		0.405^{NS}	
Emitters (E)	1.972^{NS}		1.791^{NS}		27.10**		8.977**	
F x E	0.0488*		1.350^{NS}		2.283^{NS}		1.734^{NS}	
DMS	1.844		4.651		0.247		0.634	
CV %	13.78		15.13		10.58		18.46	

	Emitters		Emitters		Emitters	
	C	S	C	S	C	S
Rates (mg L^{-1})	RL (cm)		DD (mm)		DC (mm)	
0.0	33.2a	32.3a	57.3a	55.8a	110.1a	108.3a
0.5	20.3a	19.5a	36.0a	31.3a	88.13a	78.2a
1.5	19.3a	18.2a	34.3a	29.3b	88.0a	77.8a
3.0	18.9a	18.2a	34.3a	28.5b	83.7a	73.8b
Regression	L**	L**	L**	L**	L**	L**
Iron (I)	278,190**		200,897**		24,977**	
Emitter(E)	$1,647^{NS}$		42,347**		8,977**	
F x E	$0,305^{NS}$		5,776**		$1,084^{NS}$	
DMS	0,838		1,641		5,439	
CV %	11,84		13,49		19,64	

Means followed by the same letter, uppercase in the column and lowercase on the line, do not differ by the Tukey test at 5% probability. * - significant at 5% probability. ** - significant at 1% probability. NS - not significant at 5% probability. L- linear; Q- quadratic. Emitters: S – Self-compensating; C - Conventional.

A reduction was observed in sunflower leaf area (Table 2) with the highest doses of Fe. Compared to the control, the leaf area was 62%, 66% and 71% lower for the conventional emitter, and 72 %, 77% and 79% for the self-compensating emitter at concentrations of 0.5, 1.5 and 3.0 mg L^{-1} of Fe, respectively. Root growth was also compromised by the addition of iron to the irrigation water (Table 1). The continuous application of elevated doses in agriculture should be limited to water reuse, avoiding contamination of soil, water and plants. GRUSZYNSKI (2001) reported that the maximum Fe level for soils and culture media should be between 20 and 250 mg L^{-1}.

The sunflower has great potential as an ornamental plant due to its short harvest cycle, ease of propagation and popularity as an ornamental potted plants and in floral arrangements. For bouquets in vases, capitulum size is of greater importance and should be proportional to the vase size where it will be produced and marketed. A decrease in final stem height cannot significantly reduce capitulum size to ensure no loss in commercial value (ANEFALOS & GUILHOTO, 2003).

Analysis of dry stem weight, a parameter indicative of productivity in flower marketing, showed a reduction in dry weight with an increase in the supply of Fe in water, which is not of commercial interest (Table 2). The dry weight of flowers, leaves and roots decreased with increasing iron levels (Table 2). Lower doses of iron reduced plant dry matter when compared to the treatment without iron.

Table 2. Analysis of variance of leaf area (LA), root dry weight (RDW), stem dry weight (SDW), leaf dry weight (LDW), flower dry weight (FLDW), and total dry weight (TDW) as a function of different emitters (Self-compensating and Conventional) and iron concentrations (ferrous sulfate) on the production of ornamental sunflower.

	Emitters		Emitters		Emitters	
	C	S	C	S	C	S
Rates (mg L^{-1})	LA (cm^2)		RDM (g)		SDW (g)	
0.0	542.2a	522.2a	4.1a	3.8a	4.2a	4.0a
0.5	203.57a	145.49a	2.7a	2.2b	2.3a	2.0b
1.5	179.5a	116.8b	2.4a	2.0a	1.9a	1.5b
3.0	157.9a	102.26b	1.9a	1.7b	1.9a	1.3b
Regression	L**	L**	L**	L**	L**	L**
Iron (I)	676.108**		96.276**		265.089**	
Emitter(E)	44.736**		13.715**		31.120**	
F x E	6.812**		3.776^{NS}		1.329^{NS}	
DMS	14.496		0.183		0.143	
CV %	18.84		22.29		19.08	

	Emitters		Emitters		Emitters	
	C	S	C	S	C	S
Rates (mg L^{-1})	LDM (g)		FLDM (g)		TDM (g)	
0.0	3.1a	4.1a	3.8a	4.2a	16.0a	14.b
0.5	2.9a	2.7a	2.2b	2.3a	10.7a	8.5b
1.5	2.1a	2.4a	2.0a	1.9a	8.3a	7.5b
3.0	2.0a	1.9a	1.7b	1.9a	8.3a	6.2b
Regression	L**	L**	L**	L**	L**	L**
Iron (I)	46.263**		159.341**		478.476**	
Emitter(E)	20.934**		36.128**		95.210**	
F x E	2.293^{NS}		1.148^{NS}		6.037**	

DMS	0.1580	0.178	0.335
CV %	21.27	21.28	10.63

Means followed by the same letter, uppercase in the column and lowercase on the line, do not differ by the Tukey test at 5% probability. * - significant at 5% probability. ** - significant at 1% probability. NS - not significant at 5% probability. L- linear; Q- quadratic. Emitters: A – Self-compensating; C - Conventional.

For the different doses, plants accumulated greater quantities of iron in the roots, followed by the leaves, flowers and stems (Table 3). Product yield and quality are necessary for flower production, where important characteristics are: size, color, durability, diameter and stem length (AGUIRRE, 2002).

Table 3. Laboratory analysis of the different portions of the ornamental sunflower.

			N	P	K	Ca	Mg	S	B	Cu	Fe	Mn	Zn
I	E	P.P	-------------g.kg^{-1} ------------					--------------------- mg.kg^{-1}---------------					
-													
0.0	C	L	45.0	4.0	45.0	23.0	9.9	2.6	288.0	17.0	122.0	120.0	40.0
0.5	C	L	25.8	4.3	47.6	22.1	9.7	3.1	293.6	18.0	883.0	121.0	42.0
1.5	C	L	23.4	4.1	44.2	23.3	11.1	3.5	283.5	15.0	1135.0	115.0	35.0
3.0	C	L	23.5	3.6	37.4	21.7	9.8	3.4	295.9	15.0	1570.0	102.0	37.0
0.0	S	L	43.0	4.0	44.0	24.0	10.0	2.5	287.0	18.0	123.0	122.0	39.9
0.5	S	L	23.6	4.5	34.5	26.0	12.0	2.9	336.3	20.0	1082.0	128.0	38.0
1.5	S	L	21.4	3.1	44.2	23.3	11.1	3.5	283.5	15.0	1135.0	115.0	35.0
3.0	S	L	21.9	3.4	42.6	21.0	11.0	3.4	320.1	16.0	1316.0	104.0	31.0
0.0	C	Fl	18.0	4.1	32.0	10.0	4.8	1.9	110.0	12.0	99.0	40.0	28.0
0.5	C	Fl	20.9	4.6	29.6	9.4	5.0	2.0	115.3	13.0	252.0	46.0	30.0
1.5	C	Fl	19.6	4.6	31.2	8.4	4.9	1.9	140.6	14.0	356.0	43.0	30.0
3.0	C	Fl	18.6	4.7	30.2	6.6	4.7	1.9	113.9	12.0	507.0	34.0	29.0
0.0	S	Fl	25.0	4.4	30.0	9.0	5.0	1.8	100.0	18.0	98.0	40.0	28.0
0.5	S	Fl	20.9	4.3	30.8	10.2	5.5	1.9	140.3	26.0	280.0	50.0	30.0
1.5	S	Fl	24.5	4.6	31.2	8.4	4.9	1.9	140.6	14.0	504.0	43.0	30.0
3.0	S	Fl	30.0	4.3	30.5	6.9	4.9	1.8	126.6	12.0	507.0	36.0	28.0
0.0	C	R	10.0	3.3	20.0	9.0	11.8	3.0	40.0	30.0	111.0	99.0	35.0
0.5	C	R	9.7	3.2	13.5	9.5	12.5	2.7	44.6	33.0	5963.0	117.0	41.0
1.5	C	R	9.0	3.7	24.0	7.8	10.5	3.4	55.1	26.0	5671.0	92.0	33.0
3.0	C	R	8.9	3.1	10.5	8.0	12.0	2.6	38.6	29.0	6075.0	122.0	43.0
0.0	S	R	10.0	3.2	21.0	9.0	11.6	2.9	41.0	29.0	112.0	98.0	34.0
0.5	S	R	10.6	2.9	21.9	8.4	9.9	3.7	49.0	33.0	5829.0	106.0	34.0
1.5	S	R	9.7	3.7	24.0	7.8	10.5	3.4	55.1	26.0	5671.0	92.0	33.0
3.0	S	R	8.9	3.3	26.0	7.5	10.8	3.7	59.2	25.0	5629.0	92.0	40.0
0.0	C	St	10.0	3.5	40.0	9.0	3.0	1.2	50.0	5.0	69.0	44.0	23.0
0.5	C	St	14.8	3.8	41.3	9.0	3.0	1.3	51.2	4.0	166.0	45.0	26.0
1.5	C	St	8.3	3.7	39.3	9.3	3.1	1.3	53.1	4.0	160.0	50.0	23.0
3.0	C	St	6.0	4.1	45.0	7.9	2.9	1.3	62.9	4.0	152.0	36.0	27.0
0.0	S	St	11.0	3.6	44.0	9.0	3.0	1.1	49.0	4.0	68.0	45.0	25.0

0.5	S	St	6.8	3.5	42.0	10.1	3.5	1.4	52.8	5.0	172.0	50.0	25.0
1.5	S	St	6.0	3.7	39.3	9.3	3.1	1.3	53.1	4.0	152.0	50.0	23.0
3.0	S	St	6.0	3.1	37.7	8.4	2.9	1.3	46.6	4.0	111.0	44.0	24.0

F- Iron, E – Emitters, P.P – Plant Part; S- Self-compensating, C- Conventional; L- Leaf, Fl – Flower, R- Root, St- Stem. N- nitrogen; P- phosphorus; K- potassium; Ca- calcium; Mg- magnesium; S- sulfur; B- boron; Cu- copper; Fe- iron; Mn- manganese; Zn- zinc.

A deficiency or excess of macro or micronutrients causes a decrease in the lifespan of metabolically active leaves, affecting the production of total dry weight (MALAVOLTA et al., 1976) and consequently crop productivity.

The use of self-compensating and conventional emitters had no influence on the amount of iron provided by irrigation, exhibiting similar results for both cases (Table 4). Because the values of the coefficient of uniform distribution (CUD) were > 90%, and based on the recommendations of KELLER & KARMELI (1974) it was considered that the results obtained in this study were excellent. The self-compensating and conventional emitters differed, according to the F test ($p < 0.05$), in most evaluations, except for the coefficient of variation (CV).

Analysis of flow values showed that there was no total or partial blockage of emitters when the solutions were applied, not interfering with performance (Table 4). Ribeiro et al. (2008) observed the degree of obstruction in micro sprinklers by calculating the uniformity of water distribution by the micro-aspiration irrigation system and variations in flow rate in relation to the designed flow, concluding that water with high iron content (2.3 to 3.0 mg L^{-1}) in a system after ten months of use showed sectors with flows 5% to 57% lower than the designed flow rate.

Table 4. Analysis of variance of the flow (Q), Coefficient of Variation (CV), Coefficient of Uniform Distribution (CUD) and Christiansen Uniformity Coefficient (CUC) in function of different Emitters (Self-compensating and Conventional) and iron doses (ferrous sulfate).

Rates	Emitters	Q(L.h^{-1})		CV		CUD (%)		CUC (%)	
		Zero h$^{(1)}$	3h 45min$^{(2)}$	Zero h	3h 45min	Zero h	3h 45min	Zero h	3h 45min
0,5 mg L^{-1}	A	4.06a	4.03b	0.022a	0.029a	93.39a	93.28a	91.07a	91.98b
	C	3.74b	3.59a	0.088a	0.035a	91.89a	91.40a	88.64b	86.40a
	F	42.543**	37.615**	3.359^{ns}	8.308^{ns}	0.479^{ns}	0.120^{ns}	630.887**	889.571**
1,5 mg L^{-1}	A	4.06a	4.02a	0.022a	0.043a	93.39a	95.20a	91.07a	89.72a
	C	3.74b	3.67a	0.088a	0.030a	91.89a	90.93a	88.64b	87.93b
	F	42.543**	2.242^{ns}	3.359^{ns}	8.251^{ns}	0.479^{ns}	1.848^{ns}	630.887**	3378.69**
3,0 mg L^{-1}	A	4.06a	4.02a	0.022a	0.042a	93.39a	93.05a	91.07a	89.27a
	C	3.74b	3.70b	0.088a	0.039a	91.89a	91.04a	88.64b	88.39b
	F	42.543**	09.702**	3.359^{ns}	0.976**	0.479^{ns}	5.753^{ns}	630.887**	440.567**

Means followed by the same letter, lowercase on the line, did not differ according to the Tukey test at 5% probability. * - significant at 5% probability. ** - significant at 1% probability. ^{NS} – not significant at 5% probability. $^{(1)}$ Zero h: new emitters, with no use time. $^{(2)}$ 3 h and 45 min: Emitters previously used for three hours and 45 minutes. Emitters: A- Self-compensating, C- Conventional.

6 CONCLUSION

For the conditions tested in the present study, it was concluded that:
- Ornamental sunflower production did not provide satisfactory results compared to commercial standards when iron was present in the irrigation water at concentrations of 0.5, 1.5 and 3.0 mg L^{-1}.
- The iron became toxic to sunflower plants when successive doses of low or high concentrations were applied, precluding production.

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