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Effect of boron and soil moisture on nutritional status and grain yield of sunflower (*Helianthus annuus*)

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Sunflower (*Helianthus annuus* L.) presents desirable agronomic characteristics such as short cycle, high quality and good profit in oil, which qualifies it as a good option for Brazilian producers. In addition, from 2007 the Brazilian government has incentivized its cultivation for biodiesel production, inside the national energy matrix, sunflower oil is added to the marketed diesel. Sunflower culture is viable because it safeguards enviornment (Silva *et al.* 2007).

Effect of an appropriate fertilizer is shown only in good water availability. On the other side, the irrigation benefits only occur if the soil is fertile or well fertilized. The fertilizion and irrigation are costly technologies, and, so, they must be appropriately planned and handled (Marschner 2005). Adequate soil moisture and fertility are the two major husbandry problems reducing sunflower achene yield and hence, vegetable oil and other products (Abayomi and Adefila 2008).

According to Marschner (2005), the irrigation represents the most efficient way of food production increase. It is estimated that in the year 2020 the water consumption rates for the agricultural production will be more elevated in the South America, Africa and Australia. It is possible to predict a bigger agricultural production growth in the southern hemisphere, under irrigation, it may produce up to three crops yearly. In relation to sunflower fertilization, among all micronutrients, boron stands out because sunflower is particularly sensitive to B deficiency and is used as an indicator crop for assessing available B in soils (Marschner 2005). In addition, yield, yield components and plant nutritional status are positively or negatively affected by boron as indicated by studies around the world such as Oyinlola (2007) and Mostafa and Abo-Baker (2010). Hence the present study aimed to evaluate the effect of irrigation and boron fertilization on yield and nutritional status of sunflower. Sunflower plants of hybrid C 11, were used in this study, with germination rate of 97%. The experiments were carried out under field conditions at the Experimental Irrigation Area (ADEI) of Sao Paulo State University, Jaboticabal County, Brazil, evaluating two cultivation cycles of sunflower, from August 2006 to March 2007. A completely randomized block design was adopted with treatments distributed in a factorial arrangement 4 × 2, referring to boron fertilization doses and soil moisture contents (50% and 100% of plant requirement), respectively, with six repetitions. The following boron doses were studied: 0; 0.75; 1.5 and 2.25 kg of boron/ha, which were defined according to sunflower demand proposed by Quaggio and Ungaro (1996). Boron was applied in the planting furrow during the sowing. Boric acid was dissolved in water with a wash bottle properly calibrated. Covering fertilization was done with 40 kg/ha, at 40 days after sowing. The experimental plots measured 4.0 m × 6.0 m with area of 16.0 m^2 each, being the border plot 1.0 meter between plots and 2.0 between blocks. The site is located at 590 m above sea level, with climate classified as Cwa accordinf Köppen, average precipitation 1400 mm/year and driest month 13.9 mm, between temperature 22°C.

The soil (Table 1, 2) is a purple eutrophic Oxisol (Andrioli and Centurion 1999) with a very clayey texture, gentle wavy and wavy relief.

Before sowing the area was plowed, followed by two harrowings. The furrows were opened in the preceding day of the sowing, spaced at 0.80 cm and depth around 0.15 cm. Liming was done aiming to increase the saturation of bases to 70%, i e 2.5 tonnes/ha of limestone (MgO 18%) with PRNT 61% was applied. Mineral fertilization was performed at 90 days after liming with 10 kg/ha of N, 50 kg/ha of P_2O_5 and 20 kg/ha of K_2O. At the sowing, it established 4 plants by linear meter after thinning it spaced 0.8 m between lines.

The water was supplied by a central pivot aspersion

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Table 1 Some physical and chemical characteristics of the soil used in the experiment

pH $CaCl_2$ 0,01/mol L^1	O.M. g/dm³	P resin mg/dm³	K	Ca	Mg	H + Al mmol$_c$/dm³	SB	CEC	V %	Clay	Silt g/kg	Sand	Texture classes
5,1	25	12	3,2	27	8	38	38,2	76,2	50	630	190	180	Very clayey

pH in $CaCl_2$; OM, organic matter (g/dm³); P and S-SO_4^2 (mg/dm³); K, Ca, Mg, Al, H+Al, SB (sum of bases) and CEC = cationic exchangeable capacity (mmol$_c$/dm^{-3}); V%, saturation of bases.

Table 2 Micronutrient concentrations of the soil used in the experiment.

Zn	B	Cu mg/dm³	Mn	Fe
1,2	0,25	8,0	68,0	29,3

system based on a daily evaporation defined in Class A Tank and corrected according to the sunflower culture coefficient (Kc) reported by FAO (1979). The central pivot irrigation system had 2 towers and a swing, 98 m of side line, diffusers and 1 gun sprinkler, with capacity to irrigate area of 5.2 ha. After the sowing, the soil was taken to field capacity, using methodology described by Reichardt (1978).

The water availability demand was considered in which the quantity of water in the evapotranspiration, should correspond to 60% of the available water, i e a blade of approximately 18 mm. Under this condition, the water volume was applied to put the whole quantity back in the evapotranspiration period, considering 100% of soil moisture content, the half of the water in the evapotranspiration period was considered 50% of soil moisture content.

For leaf content analyses, six replicates of 30 leaves at the beginning of plant blooming. According to recommendations of Ambrosano *et al*. (1997), the fifth leaves from the apex were collected to do the nutritional analyses. Leaves were chemically analysed after washing and rinsing with distilled water and drying at 70°C for 48 hr according to analytical methods described by Bataglia *et al*. (1983).

At 128 days after sowing, in the two central lines (40 plants/plot) the sunflower crop was harvested by hand and crop yield was determined. At this moment grain moisture was recorded, whose average was 11%.

Statistical analysis included analysis of variance, mean separation on irrigation blades was conducted using Tukey test and regression analysis when pertinent,using SAS software. Terms were considered significant at P≤0.01.

In this study no significant interactions between soil moisture contents and boron fertilization were registered (Table 3), showing that these factors are not interdependent on sunflower yield.

The soil moisture content levels significantly affected magnesium and zinc foliar concentrations and yield of sunflower (Table 3). The differences between soil moisture contents presented in Table 4 is explained by Giminez *et al*. (1975) who argued that the maintenance of at least 50% of soil moisture content commonly is considered satisfactory. The same authors found that soil moisture contents from 75 to 100% promoted better profits compared with 50% or less. These findings are in agreement with Wojcik (2006). In addition, the water requirements of sunflower have been identified to be higher than for other crops while the water stress symptoms are not easily recognizable in this crop (Nazir 1994).

Comparatively, Abayomi and Adefila (2008) in study about the effect of soil moisture contents from 25% to 100% concluded that soil moisture content of 75% of field capacity associated to 60 kg N/ha was optimum for good grain yield under greenhouse conditions in Nigeria.

Grain yield from plants under 100% of soil moisture content was below results reported by Kasap and Coskun (2006) in Turkey; close to Oyinlola (2007) for sunflower cultivars in Nigeria; and Mostafa and Abo-Baker (2010) and

Table 3 Variance analysis for foliar nutrient concentrations and grain yield of sunflower as a function of soil moisture contents (SMC) and boron doses

Variation causes	Mean square N	P	K	Ca	Mg	S	B	Cu	Fe	Mn	Zn	Yield
SMC. (I)	11.20^{NS}	0.06^{NS}	30.60^{NS}	11.20^{NS}	5.90*	0.08^{NS}	150.00^{NS}	8.16^{NS}	392.04^{NS}	2360.1^{NS}	100.04**	177881.5**
Doses (D)	6.14^{NS}	0.04^{NS}	55.99^{NS}	11.48^{NS}	0.34^{NS}	0.32^{NS}	39.27^{NS}	14.94^{NS}	657.15*	134.05^{NS}	36.81 *	90912.50^{NS}
Int. I × D	0.96^{NS}	0.01^{NS}	32.71^{NS}	9.56^{NS}	0.06^{NS}	0.03^{NS}	112.66^{NS}	15.61^{NS}	94.93^{NS}	116.27^{NS}	3.48 ^{NS}	29371.3^{NS}
CV (%)	5.72	9.96	19.21	8.75	15.44	9.82	28.51	14.75	8.59	18.48	‘10.65	291.14

**Significant at P ≤ 0.01 probability error; *significant at P ≤ 0.05 probability error; ns, non significant; CV, coefficient of variation

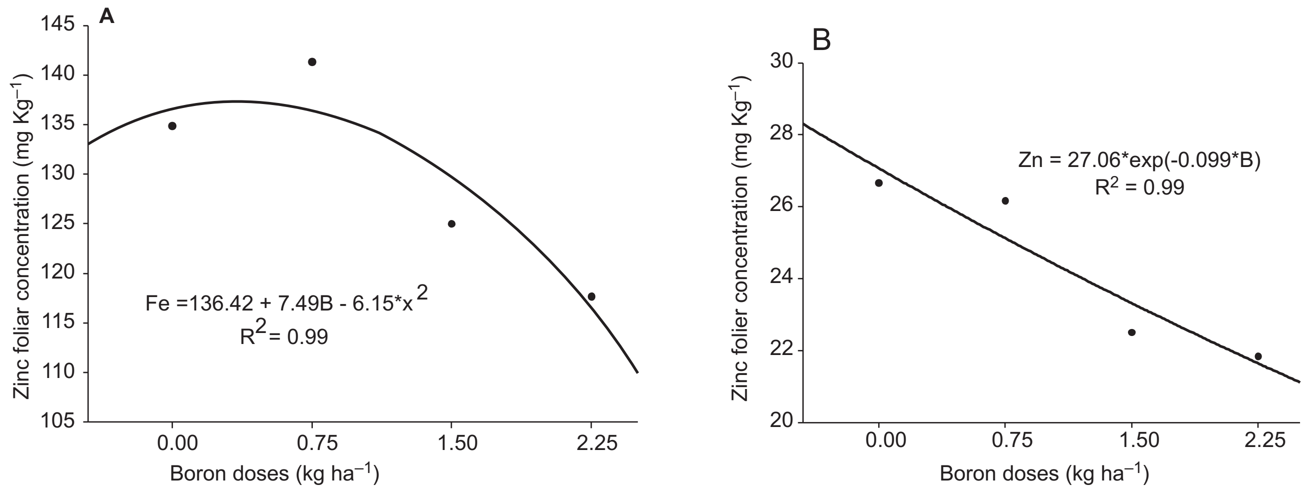

Fig 1 Iron (A) and zinc (B) foliar concentrations of sunflower plants as a function of boron doses.

Table 4 Magnesium and zinc foliar concentrations and grain yield of sunflower as a function of soil moisture contents

	Mg (g/kg)	Zn (mg/kg)	Yield kg/ha
Irrigation 100 %	4.73 a	22.25 a	2170 a
Irrigation 50 %	5.73 b	26.33 b	1631 b

Data followed by different letters in columns are significantly different according to Tukey test

Sathyapriya *et al*. (2009) in India.

Boron doses affected only zinc and iron foliar concentrations studied (Table 3).

In a global evaluation of zinc and iron foliar concentrations, it is verified that the foliar concentrations of both nutrients were significantly reduced with boron doses increase (Fig 1) that occurred due to the competitive inhibition phenomenon, where the elements compete for the same biding sites, reducing the nutrient absorption which presents lower soil concentration (Marschner 2005).

Among the macronutrients, sulphur and calcium presented high foliar concentrations and the phosphorus presented an average drastically below the stated adequate range of supply described by Ambrosano *et al*. (1997) for sunflower. The phosphorus foliar concentrations reduction could be associated to the interactions between nutrients since the interaction P × B occurs when low P level interferes on B metabolism, aggravating both the deficiency or excess symptoms of B (Sinhá *et al.* 2003).

In relation to the micronutrients, iron and manganese presented foliar concentrations above stated adequate range of supply described by Ambrosano *et al*. (1997), while other nutrients studied presented compatible satisfactory levels, except zinc.

It s well-documented that Zn-deficiency symptoms are often aggravated by high rates of P fertilization or high soil concentrations of P to high levels of P available in the ground or to phosphate elevated fertilization (Marschner, 2005, Alloway 2008). This relationship was characteristically verified in the present study since zinc foliar contents were below the stated adequate range of supply.

Boron absorption by roots is performed, fundamentally, by mass flow, thus it depends on soil moisture content (Marschner 2005). This way, in the present work, under 100% of water moisture content, the lower boron doses were sufficient to sunflower plants; and under 50% of water moisture content, the biggest boron doses were more efficient, what explains the non-significant differences among the boron doses, inside each shallow pool. In addition, zinc-deficient plants can absorb high concentrations of boron in a similar way to zinc enhancing phosphorus toxicity in crops and it is probably due to impaired membrane function in the root (Alloway 2008).

The results of this study indicate that i) Soil moisture concentration significantly affects grain yield and foliar concentrations of magnesium and zinc; ii) soil moisture content of 100% promotes higher grain sunflower yield; and iii) boron doses until 2.25 tonnes/ha do not affect grain yield and boron foliar concentrations, nevertheless, iron and zinc foliar concentrations decrease.

SUMMARY

A field experiment was carried to evaluate the effect of irrigation and boron fertilization on yield and nutritional status of sunflower. A completely randomized blocks design was adopted with treatments distributed in a factorial arrangement 4 × 2, referring to boron fertilizer doses (0, 0.75, 1.5 and 2.25 kg of boron/ha) and soil moisture contents (50% and 100% of plant requirement), respectively, with six repetitions. Soil moisture concentration significantly affected grain yield and foliar concentrations of magnesium and zinc. Soil moisture content of 100% promotes higher grain

sunflower yield. Boron doses until 2.25 tonnes/ha do not affect grain yield and boron foliar concentrations, nevertheless, iron and zinc foliar concentrations decrease.

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