Introduction

Calcium and boron are two important nutrients for apical bud and root end development, since they are nutrients of low internal plant mobility, being not capable of retranslocating after synthesis as plant compounds. Their main function in taller plants is structural, improving the cell wall and plasma membrane. Without them, shoot and root growth are strongly inhibited (Yamada, 2000).

Available calcium in soil may be easily increased by lime or gypsum application. As calcium has no mobility in plant phloem (Marscher, 1995), it is necessary to make the correction in the whole soil profile until the depth effectively exploited by the root system. Liming is the most viable way to add calcium to soil, besides the addition of magnesium and soil pH elevation, by releasing of hydroxyls which neutralize H^+ and Al^{3+} in soil solution. Most of the time, soil pH correction is the main goal of lime application, since pH influences all the nutrients' availability.

Boron has a close relationship with some physiologic processes in plants, which are affected by its deficiency. Sugar transport, cell wall synthesis, lignification, cell wall structure, carbohydrates metabolism, ARN metabolism, respiration, IAA metabolism, phenolic metabolism, ascorbate metabolism and plasma membrane integrity are all affected by Boron. Among these functions, two of them are really proven: cell wall synthesis and plasma membrane integrity (Cakmak & Römheld, 1997; Marscher, 1995). The important function of boron on membrane integrity was demonstrated by Cakmak et al. (1995) in a study developed with sunflower plants. Comparing normal leaves with boron deficient leaves, authors observed that the influx release of elements was 35 times higher for potassium, 45 times higher for sucrose and 7 times higher for phenolic compounds and amino acids in deficient leaves than in leaves with normal levels of boron. It is possible to presume that boron deficiency would reduce potassium fertilizer efficiency, and also contribute to sucrose and amino acid release from plant leaves, reducing the efficiency on dry mass accumulation and grain yield.

The possible ways to apply boron on plants are: soil borate fertilization on the sow crop line or spread before seeding; and leaf application, applied alone or together with crop defensives. However, it is important to emphasize that the efficiency of nutrients applied via in leaves can be decreased by climate conditions and plant absorption system, which are different in each plant species. Compared with other species, sunflower has a lower efficiency to absorb boron from soil, and frequently presents deficiency symptoms mainly at the flowering and grain filling stages, consequently reducing grain yield (Castro et al., 1996; Martin and Sluszz, 2007). At flowering, boron deficiency promotes pollen tube deformation, inhibiting fertilization, which can reflect in higher quantities of empty seeds (Calle-Manzano, 1985).

This work aimed to evaluate the efficiency of boron and calcium rates, via leaf application, on sunflower grain yield and morphologic plant parameters.

Material and Methods

The experiment was carried out at the Federal Technology University of Paraná, *Campus* Dois Vizinhos, PR, Brazil, during the period of September, 2008 to April, 2009. The experimental area is located at latitude 25°44' South, longitude 53°04' West and mean altitude of 520 meters. The climate is classified as mesothermic humid (Cfa) by Koppen (Maak, 1968). The soil is a Nitossolo Vermelho distroférrico típico by Brazilian classification (EMBRAPA, 2006) and Oxisol by Soil Taxonomy (1999). Soil chemical analysis results are presented in Table 1. Soil nutrient availability (P, K, Ca and Mg) are interpreted as higher, and bases saturation (V) is good for a possible high grain yield, according to recommendations for this region by fertility researchers.

Table 1. Results of chemical soil analysis preceding sunflower experiment implantation. UTFPR, Dois Vizinhos, PR, Brazil, 2008.

Depth layer	**pH $CaCl_2$**	**O.M.**	**P (Mehlich1)**	**Al^{3+}**	**H+Al**	**Ca^{2+}**	**Mg^{2+}**	**K^+**	**V**
---- cm ----		g dm^{-3}	mg dm^{-3}	----------- $cmol_c$ dm^{-3} ------------					%
0-20	5,00	40,21	12,84	0,00	4,28	4,88	2,67	0,73	65,9

The experimental design was in completely randomized blocks, with four replicates. Plots were of six meters long and five seed lines of 0.9 meters spaced, harvesting only the three central lines. The number of plants after germination was adjusted to a final population of 50,000 plants per hectare. Sowing was done on September 26, 2008, putting three seeds per small line hole, and adjusting the population by hand after germination. The genotype used was Agrobel - La Tijereta. Seeds were treated with Metalaxil and Captan (300g and 160g in 100 kg of seeds) as fungicides.

Treatments were composed of: (i) Witness; (ii) 2000 g of B ha^{-1} applied via soil at sowing; (iii) 250 g of Ca ha^{-1} applied in leaves; (iv) 500 g of Ca ha^{-1} applied in leaves; (v) 750 g of Ca ha^{-1} applied in leaves; (vi) 1000 g of Ca ha^{-1} applied in leaves; (vii) 250 g of B ha^{-1} applied in leaves; (viii) 500 g of B ha^{-1} applied in leaves; (ix) 750 g of B ha^{-1} applied in leaves; and (x) 1000 g of B ha^{-1} applied in leaves. Leaf application was made by pulverization of 200 liters of water with the respective treatments, about two weeks before the flowering stage. Soil and leaf treatment with boron was made with Sodium Octaborate (20.5% of total B, and 9% of soluble B), considering the soluble concentration for leaf application. Calcium treatments were carried out with Calcium Chloride PA.

Analyzed at the flowering stage of the sunflower plants were the number of achenes per plot (NA), plant stature (PS), and number of green leaves (NL). Sunflower harvest was on March 07, 2009. The achenes were processed by the following parameters: mass of one hundred grains (MHG) and grain yield.

The data was submitted to ANOVA, which was a mean comparison run by a Skott-Knott test at 5% error probability, using the software Assistat.

Results and Discussion

Variance analysis presented in Table 2 shows that the treatments applied on sunflower were not significant by most of the variables analyzed. Only for plant stature was there an observed difference between treatments. It is important to emphasize here that the season for sunflower field growth was very dry this year, with only forty days of any precipitation between November 10 and December 20, 2008; and with only small precipitation happening after this period. Low precipitation inhibited plant growth and promoted a substantial reduction to possible plant reactions to the treatments, especially on grain yield. Another important consideration is that leaf application probably was not as efficient as could be on soil hydrous in normal conditions.

As described by Malavolta et al. (1997), boron reached the root predominantly as mass flow. Although knowing that the absorption is very low in water deficient conditions, most of the sunflower cultivated in Brazil is on non-irrigated areas, which can compromise the results obtained with this nutrient application. Calcium follows the same behavior as boron under low water availability in soil, as all elements are dependent on water to achieve the plant's root system.

Table 2. Variance analysis, variation factor (VF): block (Bl), treatments (Treat) and error; freedom degree (FD) and mean square for the variables: number of achenes per plot (NA), grain yield (kg ha^{-1}), number of green leaves per plant at flowering (NL), mass of one hundred grains (MHG, g) and plant stature (PS, cm), as function of calcium and boron rates. UTFPR, *Campus* Dois Vizinhos, PR, Brazil, 2009.

VF	FD	NA	Grain Yield	NL	MHG	PS
Bl	3	1,40000 ns	54326,307 ns	6,288 ns	0,099 ns	0,017 ns
Treat	9	10,51111 ns	40207,280 ns	0,801 ns	0,154 ns	0,034 **
Error	27	13,51111 ns	24273,135 ns	2,587 ns	0,081 ns	0,010 ns

**, * and ns: significant at 1%, 5% of error probability and not significant by F test.

The mean comparison of treatments on plant parameters are presented in Table 3. Only for plant stature was some variation observed; calcium rates had promoted lower plant growth (treatments iii and v). Other parameters were similar between all treatments, however, it is important to remember again that water deficiency probably inhibited any possible plant responses to the applied treatments.

Table 3. Mean multiple comparison test by Scott-Knott at 5% of error probability applied to the variables: number of achenes per plot (NA), grain yield (kg ha^{-1}), number of green leaves per plant at flowering (NL), mass of one hundred grains (MHG, grams) and plant stature (PS, cm), as function of calcium and boron rates. UTFPR, *Campus* Dois Vizinhos, PR, Brazil, 2009.

Treatment	NA	Grain Yield	NL	MHG	PS
i	34,75 ns	914,07 ns	19,25 ns	4,365 ns	1,73 a*
ii	37,25	977,59	19,60	4,400	1,80 a
iii	36,00	1132,77	18,23	4,747	1,62 b
iv	36,50	1136,48	18,75	4,835	1,80 a
v	33,25	973,33	18,83	4,757	1,51 b
vi	37,75	1073,70	18,63	4,885	1,77 a
vii	37,25	879,63	19,28	4,630	1,74 a
viii	35,25	1007,59	18,70	4,582	1,71 a
ix	33,25	938,70	18,20	4,702	1,76 a
x	34,75	847,40	18,93	4,345	1,81 a
Mean	35,60	988,12	18,84	4,625	1,73
CV (%)	10,33	15,77	8,54	6,17	5,80

* Means not followed by the same letter are different at 5% of error probability by Skott-Knott test.
ns: not significant by F test.

Although not significant by statistical comparison, treatments iii and iv showed a higher grain yield, which may be an answer to low calcium soil absorption by plants on flowering and grain filling stages of sunflower, since in that period soil water availability was restricted. So, leaf calcium application may have promoted higher grain yield since the soil absorption was inhibited. In general, grain yield was very low when compared to normal precipitation years, what may explain no statistical answers to the applied treatments.

As reported by Castro et al. (2006), sunflower plants that suffer water stress in the flowering or grain filling stage had lower grain yield, dry mass production of seeds, and seed oil accumulation than plants in normal water condition. This explanation can be confirmed by the results presented here, as all of the sunflower growth season was under water deficient conditions, restricting possible results other then the possible occurrence of other nutrient deficiency, by low water availability. The effect of boron and calcium could be more expressive in conditions of high production management, where an irrigation system is used and soil fertility corrections are made frequently.

Conclusion

No answer to calcium and boron leaf application was observed on the present study, probably as consequence of low soil water availability during sunflower growth season, which resulted in low mean sunflower grain yield and compromised plant morphological parameters.

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