Initial growth of sunflower in soils with high concentrations of boron and heavy metals

Adriana M. Moreno Pires[1], Cleide A. Abreu[2], Aline Renee Coscione[2], Vinicius Alberti da Silva[1], Nilza Patrícia Ramos[1]

[1]Embrapa Meio Ambiente, Rod. SP340, km 127.5, 13800-000, Jaguariúna/SP, Brazil,
E-mail: adriana@cnpma.embrapa.br, vinicius@cnpma.embrapa.br, npramos@cnpma.embrapa.br
[2]Instituto Agronômico de Campinas, Barão de Itapura, 1481, 1392-970, Campinas/SP, Brazil,
E-mail: cleide@iac.sp.gov.br, aline@iac.sp.gov.br

ABSTRACT

Phytoremediation studies have been conducted in an area contaminated by heavy metals, located in Piracicaba - SP, Brazil. This area was contaminated accidentally by the addition of auto scrap shredding to the soil and was limed later to reduce heavy metal mobility in the environment. Previous characterization showed that it also presents high concentration of boron, which has limited the initial plant development of some species. As sunflower plants require a high boron supply and the literature describes its use in the phytoremediation of soils contaminated with heavy metals under some conditions, the aim of this work was to evaluate its potential for the remediation of this area. In the present study, the results of preliminary tests are presented, aiming at the evaluation of sunflower plant germination and its initial development when cultivated in the contaminated soil described. Two sunflower hybrids were sown in soils treated with different rates of boron and in the soil from the contaminated area in study. The results showed that sunflower plants had a normal initial development, even in the soil from the contaminated area. Therefore, sunflower is a promising crop and further studies will be developed to evaluate the sunflower efficiency in phytoextraction or phytostabilization of heavy metals in areas where boron contamination also occurs, as is the case in the study area.

Key words: boron – contamination – *Helianthus annuus* L. – phytoremediation – phytotoxicity.

INTRODUCTION

Boron is an important micronutrient, but when found in soils at high phytoavailable concentrations it can cause phytotoxicity. Many crops are very sensitive to boron toxicity, showing severe symptoms, such as yellowing of the leaf tips and stunted growth. High concentrations of B may occur naturally in the soil or in groundwater, or can be added to the soil from mining, fertilisers, or irrigation water (Nable et al., 1997). Another anthropogenic source of boron in soils is the use of wastes as fertilizers. Some industrial residues, such as from steelmaking, should be highlighted, once they frequently contain boron and heavy metals in their composition.

Nable et al. (1997) consider that B concentrations in soil higher than 5 mg dm^{-3} are toxic to the plants. However, this value could vary as a function of plant species, sampling time, soil characteristics, among others. Studies carried out in Brazil, testing different soils and species, showed that toxics levels of Boron vary from 1.8 to 8.3 mg kg^{-1} (Mariano et al., 2000; Fageria, 2000; Lima et al., 2007).

In Piracicaba city, located in São Paulo state, Brazil, there is an area which was contaminated accidentally by the addition of auto scrap shredding to the soil and was limed later to reduce heavy metal mobility in the environment. The environmental protection agency of the state isolated the area due to its high heavy metal concentration, and allowed researchers to run remediation studies using the soil from this area. The soil presents the following concentrations of heavy metals (mg kg^{-1}): 8 of Cd; 268 of Pb; 160 of Cu; 103 of Cr; 47 of Ni and 2454 of Zn. So, we are concentrating our efforts in the phytoremediation of Zn and Pb. However, previous studies showed that the high concentrations of available boron found (4 to 14 mg kg^{-1}) were limiting plant development and/or causing the death of some plant species.

Sunflower plants (*Helianthus annuus* L.), when compared with other species, require a large supply of boron. That is why this species is frequently used as an indicator plant for boron deficiency (Schuster and Stephenson, 1940). In addition, sunflower is able to absorb heavy metals selectively (Tan, 2000), presenting potential to be used to phytoremediate (phytoextract and/or phytostabilize) contaminated areas.

Based on the following statements: (i) sunflower plants require large boron supply; (ii) the major factor that limits initial plant development in the contaminated area was the high concentration of boron in the soil; (iii) sunflower plants present potential to phytoremediate areas contaminated with heavy metals; we decided to evaluate the initial development of two sunflower hybrids cultivated in a test soil with increasing rates of boron and in the soil from the contaminated area in Piracicaba city.

MATERIALS AND METHODS

Two hybrids of sunflower, Helio 250 and Helio 358, were sown in pots containing 500 g of soil, in a greenhouse located in Embrapa Environment Unit, Jaguariúna city, SP, Brazil. The soil samples used corresponded to subsurface soil samples (B horizon) of a typical oxisol and surface soil samples (A horizon) of the area contaminated (CA) with heavy metals and boron, located in Piracicaba (Cambisol). The experimental design was completely randomized with three replicates, and the treatments were arranged in a 2x6 factorial design, that is, two sunflower hybrids and six boron rates.

The evaluated variables were plant height, dry matter, shoot boron concentration and soil boron concentration (extracted by hot water). The data were submitted to variance analysis by the SISVAR software and the means of the treatments were compared by Tukey test (5%).

The experiment was performed based on the following treatments, corresponding to B rates added to the oxisol, for each hybrid evaluated: Control – Co (oxisol, no fertilization); Boron 0 – B0 (oxisol + mineral fertilization, no boron added); Boron 2 – B2 (oxisol + mineral fertilization + 2 kg ha^{-1} of B); Boron 4 – B4 (oxisol + mineral fertilization + 4 kg ha^{-1} of B); Boron 8 – B8 (oxisol + mineral fertilization + 8 kg ha^{-1} of B) and Contaminated Area – AC (soil from contaminated area, no fertilization). Boron was added in the form of boric acid.

After filling the pots with soil, lime was added to the oxisol treatments, in order to raise the base saturation to 70%, as indicated by Ambrosano et al. (1996). The soil from the contaminated area presented a pH of 7.4, so it was not necessary to lime it. Then, all the pots were incubated for fifteen days, and soil humidity was maintained at 70% of the soil water retention capacity.

The mineral fertilization consisted of 63 mg dm^{-3} of N (NH_4NO_3), 150 mg dm^{-3} of P ($Na_2HPO_4.2H_2O$), 120 mg dm^{-3} of K (KCl), 30 mg dm^{-3} of S ($MgSO_4.7H_2O$), 1 mg dm^{-3} of Cu ($CuSO_4$), 5 mg dm^{-3} of Zn ($ZnSO_4.7H_2O$) and 5 mg dm^{-3} of Mn ($MnCl_2.4H_2O$).

After the incubation period, mineral fertilization and boron addition were performed according to each treatment and ten seeds were sown per pot. During germination and the initial development of the sunflower plants, soil humidity was also maintained at 70% of the soil water retention capacity.

Twenty five days after sowing, plant shoots were harvest, washed, and dried (60 $^{\circ}$C). Dry matter was quantified, and the samples were ground (2 mm) and analyzed for boron concentration (US-EPA, SW-846, method 3050B, with determination by ICP-AES). Soil samples from each pot were collected, dried (60 $^{\circ}$C), ground (2 mm) and homogenized to be analyzed for concentration of boron extracted by hot water (Berger and Truog, 1939).

RESULTS AND DISCUSSION

For the evaluated variables (plant height, dry matter, shoots B concentration and soil B concentration), only dry matter production was statistically different when considering the sunflower hybrids. Helio 358 was more efficient (24.02 g per pot) than Helio 250 (20.09 g per pot) in dry matter production. For the other variables, differences were only observed for boron rates factor. Plants cultivated in the soil from the contaminated area presented the highest dry mass production in the study. Plant height was not different for the treatments containing increasing B rates, except for treatments with no boron added, which were lower than the others (Fig. 1).

Fertilizer recommendation of Boron in sunflower cultivation for the São Paulo State is 1 kg ha^{-1} of B when the soil presents 0 to 0.20 mg dm^{-3} of B extracted with hot water and 0.5 kg ha^{-1} of B when the soil presents 0.21 to 0.60 mg dm^{-3} (Ambrosano et al., 1996). The original concentration of boron in the oxisol soil used in the experiment was 0.30 mg dm^{-3}. The rates of B added to the soil (2, 4 and 8 kg ha^{-1}) were deliberately higher than the recommendation, since the aim was to evaluate sunflower tolerance to the excess of boron in the soil. Despite this, the available Boron concentration in the soil was not as high as expected, even for the highest rate added (B8), which was 1.91 mg kg^{-1} (Fig. 2). Boron availability depends on different attributes of the soil, such as pH, organic matter content, parent material, mineralogy (Gupta, 1993); and, consequently, it depends on its adsorption on soil colloids (Goldberg, 1993). Therefore, the low concentration of available boron observed could be the result of high adsorption of this element on the oxisol studied.

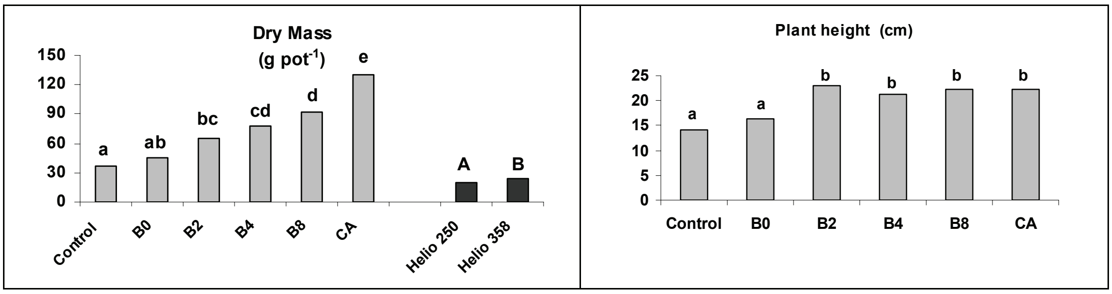

Fig. 1. Dry matter production and plant height of sunflower hybrids cultivated in soils treated with different boron rates[1].

[1]Control (oxisol with no fertilization); B0 (oxisol + mineral fertilization, no boron added); B2 (oxisol + mineral fertilization + 2 kg ha^{-1} of B), B4 (oxisol + mineral fertilization + 4 kg ha^{-1} of B), B8 (oxisol + mineral fertilization + 8 kg ha^{-1} of B); CA (soil from the contaminated area, no fertilization). Within each figure, values followed by the same letter (lower case: boron treatments; upper case: sunflower hybrids) are not statistically different (Tukey, 5%).

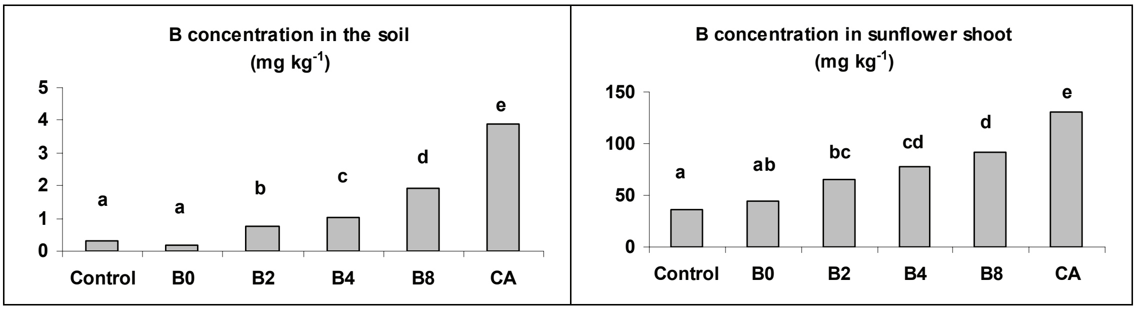

Fig. 2. Soil boron extracted with hot water and Boron concentration in the shoots of sunflower hybrids cultivated in soils with different boron rates[1].

[1]Control (oxisol with no fertilization); B0 (oxisol + mineral fertilization, no boron added); B2 (oxisol + mineral fertilization + 2 kg ha^{-1} of B), B4 (oxisol + mineral fertilization + 4 kg ha^{-1} of B), B8 (oxisol + mineral fertilization + 8 kg ha^{-1} of B); CA (soil from the contaminated area, no fertilization). Values followed by the same letter are not statistically different (Tukey, 5%).

In the treatment with soil from the contaminated area, available boron concentration was 3.90 mg kg^{-1} (Fig. 2). Although this concentration could be considered high, it was expected to be even higher, since other determinations performed with soil samples from the same area found boron concentrations extracted with hot water up to 14.87 mg kg^{-1} (Gonçalves et al., 2007a, b). This result reflects the high heterogeneity of the soil from the contaminated area.

Boron concentrations in the leaves from 15 to 20 mg kg^{-1} are considered adequate for plant nutrition (Malavolta, 2006). Specifically for sunflower, Sfredo et al. (1984) suggested that the suitable boron level in the leaves should be 40 mg kg^{-1}, based on studies carried out in the south region of Brazil (Paraná state). In the present study, boron levels in the shoots varied from 36 to 130 mg kg^{-1} (Fig. 2). Even for the plants cultivated in the soils that received the highest amount of boron, no toxicity symptoms were observed, neither was there any initial development reduction. This indicates that sunflower plants have a potential for being cultivated in soils contaminated with Boron, which is frequently found in soils contaminated with heavy metals.

It can be concluded that sunflower plants present a normal initial development when cultivated in soils that receive high amounts of boron. Therefore, sunflower is promising and should be tested as a phytoextractant and/or phytostabilizer of heavy metals in areas where boron contamination also occurs, as is the case of the study area.

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