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COMPATIBILITY OF HERBICIDES WITH BORON FERTILIZERS FOR WEED DESICCATION AND MINERAL NUTRITION OF SUNFLOWER

Castro, C.*, Brighenti, A.M.

Embrapa Soybean, Rodovia Carlos João Strass/Orlando Amaral, P.O. Box 231, Londrina, Paraná State, Brazil

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SUMMARY

Two experiments were carried out to evaluate the efficiency of weed control by herbicides, applied singly or in combination with boron (B), and the response of sunflower (*Helianthus annuus* L.) to fertilization with this micronutrient. Herbicides were applied to the plots whose sub-plots involved the presence or absence of 2 kg ha^{-1} of B, from two different sources (H_3BO_3 – boric acid and $Na_2B_8O_{13} \cdot 4H_2O$ – sodium borate) mixed with the herbicides. The combinations of the herbicides and boron, preferentially from the source H_3BO_3, efficiently controlled the following weeds: wild poinsettia (*Euphorbia heterophylla*), hairy beggarsticks (*Bidens subalternans*), and alexandergrass (*Brachiaria plantaginea*). The application of B in association with herbicides increased the content of this micronutrient in the soil and consequently in sunflower leaves. The combined application of herbicides and boric acid appears to be perfectly suitable for controlling weeds while increasing the mineral nutrition of sunflower.

Key words: ***Helianthus annuus*, plant nutrition, weed management**

INTRODUCTION

The sunflower is vulnerable to low boron content in the soil, showing characteristic deficiency symptoms on leaves, stems and reproductive parts (Asad, 2002; Asad *et al.*, 2003). As this micronutrient is poorly translocated within the majority of plants, deficiency symptoms appear primarily on young leaves, which develop malformation, becoming hard and bronze in color. The reproductive stage of sunflower is more sensitive to low supply of B in the soil than the vegetative stage (Castro, 1999; Asad *et al.*, 2002). Under this condition, adult plants may present malformed heads, with the central area containing empty or a reduced number and/or weight of achenes, which consequently reduce the yield.

* Corresponding author, Phone: 55-4333716212; Fax: 55-4333716100; e-mail: ccastro@cnpso.embrapa.br

The content of B in Brazilian soils is generally low and the lack of this micronutrient has led to the appearance of deficiency symptoms in sunflower, mainly at flowering and maturation phases (Castro, 1999). Deficiency symptoms of B are more frequent in dry periods, and in such conditions they may be present even in soils with boron contents otherwise considered adequate (Castro, 1999). Therefore, yield reduction due to boron deficiency is frequent, even when typical visual symptoms on leaves and heads are not observed.

The application of B in the form of small pellets presents a disadvantage since B is segregated from the other components of the fertilizer during mixing and handling. The segregation interferes with the uniformity of soil application mainly due to the low quantities of this micronutrient (Mortvedt and Woodruff, 1993).

Besides being a controversial practice due to its variable effectiveness, foliar fertilization increases the production costs, soil compaction and breakage of plants as a consequence of increased transit of machinery in the production field. Additionally, the low mobility of B in the phloem may require several applications of the product to provide the B needed for new tissues, reproductive organs and achenes.

Another factor interfering with sunflower production is the occurrence of weeds, with magnitude of yield reduction ranging from 23% to 70% (Vidal and Merotto Jr., 2001). During the initial phase of sunflower growth, infesting weeds may lead to the occurrence of short and chlorotic plants with severely reduced foliar area and small stem and head diameters (Blamey *et al.*, 1997).

The sunflower plant coexists with weed species up to 21 days after emergence without compromising productivity, the critical period to prevent the interference extending from 21 to 30 days (Brighenti *et al.*, 2004). Thus, in this interval, weed control practices are essential. Thereafter, the infesting weeds will not significantly reduce sunflower productivity.

Simultaneous weed control and B supply to the crop, in a single operation, may be a feasible method of reducing sunflower production costs.

The present work was undertaken to evaluate the effect of desiccant herbicides with or without B on weed control as well as the sunflower response to this micronutrient.

MATERIALS AND METHODS

Since the solubility of boric acid is lower than that of sodium borate, a laboratory test was performed to determine the solubility curve for boric acid at different water temperatures, under constant agitation for 10 minutes. Under field conditions, farmers use water whose temperature varies depending on geographic location or season, and it may influence the dissolution of the boric acid, affecting the uniformity of product application.

Two experiments were performed within this study, one in Londrina, Paraná, another in Chapadão do Céu, Goiás, Brazil.

Experiment 1 – The experiment conducted in Londrina

This experiment was carried out at Embrapa Soybean, Londrina. The chemical analysis of the soil (Rhodic Hapludox) from the experiment station is shown in Table 1.

Table 1: Chemical analysis of the soil samples (Rhodic Hapludox) collected at a depth of 0 to 10 cm in sunflower experiments carried out in Londrina, Paraná (1) and Chapadão do Céu, Goiás (2)[1]

Site	B	P	pH	Al	K	Ca	Mg	$H^+ + Al^{+3}$	SB	CTC	V %	C
	mg dm^{-3}		$CaCl_2$	$cmol_c\ dm^{-3}$								g dm^{-3}
(1)	0.21	6.9	5.02	0.0	1.00	5.01	2.06	5.23	8.07	13.30	60.6	23.6
(2)	0.18	2.9	5.21	0.0	0.12	2.56	1.36	4.37	4.04	8.41	48.0	23.5

[1]Results provided by the Soil and Plant Tissue Analysis Laboratory of Embrapa Soybean.

The experiment was arranged in a split-plot design with randomized complete blocks, in four replicates. Nine treatments were applied to the plots:

1. glyphosate (960 g a.i. ha^{-1} isopropilamine salt);
2. glyphosate potassium (1,240 g a.i. ha^{-1});
3. glyphosate (960 g a.i. ha^{-1} isopropilamine salt+sulfentrazone (300 g a.i. ha^{-1});
4. glyphosate potassium (1,240 g a.i. ha^{-1})+sulfentrazone (300 g a.i. ha^{-1});
5. glyphosate (960 g a.i. ha^{-1} isopropilamine salt)+flumioxazin (25 g a.i. ha^{-1});
6. glyphosate (960 g a.i. ha^{-1} isopropilamine salt)+carfentrazone (20 g a.i. ha^{-1});
7. glyphosate (1,188.7 g a.i. ha^{-1} isopropilamine salt);
8. hand-hoed control; and
9. weed-infested control.

Each herbicide treatment received 0.5% (v/v) mineral oil. Sub-plots included presence or absence of 2.0 kg ha^{-1} B, from two different sources [H_3BO_3 – boric acid (17% B) and $Na_2B_8O_{13} \cdot 4H_2O$ – sodium borate (20.7% B)].

The desiccants were applied on October 29, 2002, using a hand-sprayer with 296 kPa constant pressure, maintained by compressed CO_2. The sprayer was equipped with a 1.5 m wide bar and four plane jet spraying nozzles (110 03 XR), 0.5 m apart from each other, with a spraying volume equivalent to 260 l ha^{-1}.

Prior to application, samples of the carriers were collected and taken to the laboratory for pH determination. These determinations were performed within a maximum period of 15 min. Results of these analyses are shown in Table 2.

The crop was sown, under no-tillage system, on November 7, 2002, corresponding to nine days after desiccant application. The sunflower hybrid Cargill 11, with 0.5 m inter-row spacing and four seeds per linear meter were used. After thinning, an average of 2.5 plants per linear meter were maintained, corresponding to a density of 50,000 plants ha^{-1}.

The sub-plot area was 16 m^2 (2.0 m × 8.0 m). The fertilization at sowing time was made with 300 kg ha^{-1} of an 8-28-16 (NPK) formulation. Sidedressing was performed with 40 kg of N ha^{-1}, 30 days after sowing. Total rainfall during the crop cycle was 740 mm.

Table 2: pH values of the spray carriers determined prior to application, as a function of the herbicide dose, used singly or in combination with two boron sources (boric acid and sodium borate) in sunflower experiments carried out in Londrina (Paraná) and Chapadão do Céu (Goiás) (experiments 1 and 2, respectively)

Treatment	Boron source	Experiment 1 (Londrina)	Experiment 2 (Chapadao do Céu)
Glyphosate (960 g a.i. ha^{-1})	-	4.95	4.80
	Boric acid	4.42	4.40
	Sodium borate	7.91	7.70
Glyphosate potassium (1.240 g a.i. ha^{-1})	-	5.04	4.95
	Boric acid	4.51	4.60
	Sodium borate	7.88	7.68
Glyphosate + sulfentrazone (960 g a.i. ha^{-1} + 300 g a.i. ha^{-1})	-	4.86	4.84
	Boric acid	4.40	4.41
	Sodium borate	7.88	7.70
Glyphosate potassium + sulfentrazone (1.240 g a.i. ha^{-1} + 300 g a.i. ha^{-1})	-	5.02	5.00
	Boric acid	4.55	4.53
	Sodium borate	7.84	7.67
Glyphosate + flumioxazin (960 g a.i. ha^{-1} + 25 g a.i. ha^{-1})	-	4.94	4.83
	Boric acid	4.41	4.50
	Sodium borate	7.91	7.66
Glyphosate + carfentrazone (960 g a.i. ha^{-1} + 20 g a.i. ha^{-1})	-	4.88	5.11
	Boric acid	4.42	4.43
	Sodium borate	7.92	7.66
Glyphosate (1,188.7 g a.i. ha^{-1})	-	3,97	-
	Boric acid	3.77	-
	Sodium borate	7.79	-
Diuron + paraquat (200 + 400 g a.i. ha^{-1})	-	-	7.12
	Boric acid	-	4.55
	Sodium borate	-	7.83
Control (water)	-	6.94	6.98
	Boric acid	4.28	4.56
	Sodium borate	8.08	7.85

At the desiccant application date, the predominant weeds were wild poinsettia (*Euphorbia heterophylla*) and hairy beggartick (*Bidens subalternans*). Taken together, they accounted for an average of 25 plants m^{-2} at the three to four leaves stage. The resulting weed control efficiency was evaluated 12 and 22 days after treatment (DAT) using a visual scale in which 0% corresponded to no-control and 100% corresponded to death of all plants. Mean values of stem diameter and sunflower plant height were obtained by randomly measuring ten plants within the net area of each sub-plot. The third or fourth leaf from the apex of ten plants was col-

lected at the beginning of the flowering stage for boron content analysis. Soil samples were simultaneously collected from each sub-plot at two depths (0 to 10 cm and 10 to 20 cm) for boron content determination.

Sunflower yield and oil content in the achenes were not studied in experiment 1 due to heavy rains at harvest (740 mm during the entire crop cycle, 150 mm only during achenes filling) and the consequent occurrence of diseases and plant lodging. Nevertheless, as regards stem diameter and plant height in the experiment, the sunflower plants appeared to have developed according to the expectations for the hybrid Cargill 11 (Informes, 2001).

Experiment 2 – The experiment conducted in Chapadão do Céu

This experiment was carried out at Barra Bonita Farm in Chapadão do Céu (Goiás).

Results of the chemical analysis of the soil (Rhodic Hapludox) are shown in Table 1.

The experimental design and treatments were the same as those used in the preceding experiment, except for a larger number of replicates (five) and substitution of glyphosate (1,188.7 g a.i. ha^{-1} of isopropilamine salt) with diuron (200 g a.i. ha^{-1})+paraquat (400 g a.i. ha^{-1}). As in experiment 1, all herbicides were added with mineral oil (0.5% v/v), except for diuron + paraquat to which a non-ionic adjuvant was added at 2% (v/v). The sub-plots consisted of presence or absence of 2.0 kg ha^{-1} B from the same sources as in the previous experiment.

Herbicide application was performed on February 14, 2003. A hand-sprayer was used, under constant pressure (276 kPa) maintained by compressed CO_2. The sprayer was equipped with a 3 m bar and seven spraying nozzles (110 03 XR), 0.5 m apart from each other, with a spraying volume equivalent to 250 l ha^{-1}. The pH determination for the solutions was carried out as previously described for experiment 1, and the results are presented on Table 2.

The crop was sown, under no-tillage, on February 15, 2003, using the sunflower hybrid Morgan 734 with 0.80 m inter-row spacing. After thinning, an average of four plants per linear meter was maintained, corresponding to a density of 50,000 plants ha^{-1}. The area of the sub-plots was 28.0 m^2 (4.0 m × 7.0 m) with a net area of 14.4 m^2 (2.4 m × 6.0 m). Fertilization at sowing included 300 kg ha^{-1} of a 5-20-20 (NPK) formulation. Sidedressing was performed with 30 kg of N ha^{-1}, 25 days after sowing. Total rainfall during the crop cycle was 577 mm.

The predominant weed was alexandergrass (*Brachiaria plantaginea*) with an average density of three plants per m^{-2}, with three to four sprouts at desiccant application. The control of alexandergrass was evaluated 18 and 28 DAT, using the same visual scale as in experiment 1. Data on the mean values of stem diameter, plant height and B content in sunflower leaves were collected using the procedure previously described for Experiment 1. At the same time, soil samples from each sub-plot were collected at a depth of 0 to 10 cm for B content analysis. The oil con-

tent in the achenes was determined by nuclear magnetic resonance equipment (NMR, Oxford, model 4000). Crop productivity was obtained within the net area of the sub-plots. These data were subsequently converted to kg ha^{-1}, considering 11% moisture content in the achenes.

Data from experiments 1 and 2 were submitted to ANOVA and the means were compared by the Tukey test, at 5% probability.

RESULTS AND DISCUSSION

In the experiments 1 and 2, the volume of the carrier used was 260 and 250 l ha^{-1}, respectively, applying 2 kg B ha^{-1} from the two different sources (boric acid and sodium borate), which were dissolved in H_2O at an approximated temperature of 25°C. Under these conditions, 11.76 kg and 7.4 kg of the products were respectively dissolved without any precipitates that possibly cause clogging of the nozzles. Nevertheless, increasing temperature to 30°C, it is possible to dissolve 63.5 g l^{-1} of boric acid (Weast and Astle, 1982) and 220 g l^{-1} for sodium borate (Lopes, 1999). Results of boric acid dissolution test, under different water temperatures, have shown that at 25°C it was possible to dissolve 55.2 g of boric acid per liter of water (Figure 1).

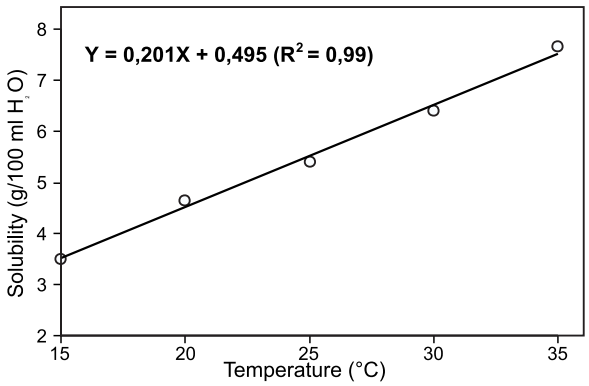

Figure 1. Solubility curve of boric acid (g/100 ml H_2O), as a function of water temperature

Using single and combined applications of pre-emergence herbicides with boron sources, Castro *et al.* (2002) observed that in a water carrier of 250 l ha^{-1} was possible to dissolve boric acid in the proportion of 2 kg of B ha^{-1}, which corresponds to 47 g of boric acid per liter of water.

In both evaluations of weed control in Experiment 1, glyphosate (960 g a.i. ha^{-1}), glyphosate potassium+sulfentrazone, glyphosate+flumioxazin, glyphosate+carfentrazone and glyphosate (1,188.7 g a.i. ha^{-1}) applied singly or combined with B from the boric acid source efficiently controlled weeds (Table 3). Glyphosate potassium plus B, from the boric acid source, did not provide the same efficiency in control-

ling weeds as the single application of the herbicide at 12 DAT. At 22 DAT, however, glyphosate potassium combined with boric acid achieved the same level of weed control as in the single application.

The application of glyphosate+sulfentrazone without B provided higher percentage of weed control (92.5%), in both evaluations. However, antagonistic effects may occur in controlling some weed species due to the combination of these two active ingredients. Starke and Oliver (1998) reported that a mixture of glyphosate+ sulfentrazone was ineffective for barnyardgrass (*Echinochloa crusgalli*), palmer amaranth (*Amaranthus palmeri*), goosegrass (*Eleusine indica*) and ivy leafed morningglory (*Ipomoea hederaceae*) control. Here, when this mixture of herbicides was combined with both B sources, the percentage of control was lower in relation to the herbicide application without B, indicating no additive effect of these two herbicides with the two boron sources in controlling *Euphorbia heterophylla* and *Bidens subalternans*.

All treatments that received B from the sodium borate source resulted in poorer weed control at 12 DAT, compared with the herbicides applied singly or in association with boric acid. Turner and Loader (1978) stated that the efficiency of glyphosate in controlling weed is affected by changes in the pH of the carrier spray. The constants of dissolution of this herbicide vary from 2.2 to 2.3 (pK_1 - carboxyl group), 5.5 to 5.9 (pK_2 - phosphate group), and 10.1 to 10.9 (pK_3 - amino group) (Wauchope, 1976). According to Motekaitis and Martell (1985), a pH variation of the glyphosate solution from 2.0 to 11.0 results in a successive loss of protons from the carboxyl group, followed by the phosphate group and finally the amino group.

A reduction in a carrier pH occurred when glyphosate was added to the water, decreasing from 6.9 to 4.8, on average (Table 2). This decrease was even greater with added boric acid (pH~4.4). Under these conditions, the non-ionic form of this herbicide molecules prevails rapidly passing through the plasmatic membrane of the cells. Once in the plant, the charges of glyphosate shift depending on if the molecule is located within the apoplast (pH=5.0) or the symplast (pH=7.5) (Sterling, 1994).

The addition of B, in form of sodium borate, decreased the efficiency of glyphosate in controlling weeds as compared to glyphosate applied singly or combined with boric acid, mainly at the first evaluation. Sodium borate increases the pH of the carrier, which becomes alkaline (pH~7.8) (Table 2), decreasing weed control. Under these conditions, the anionic form prevails impairing the passage of molecules of the herbicide through the plasmatic membrane of the cells (Sterling, 1994). Polyborates tend to increase solution pH (Peryea, 2000) and when in tank mixtures with pH dependent products affect their stability and efficiency, consequently demanding a previous pH correction.

Besides the low glyphosate molecule absorption in more alkaline solutions, due to low membrane permeability to mono and divalent anions (Gougler and Geiger, 1981), repulsion of the molecules of this herbicide also occurs. This is caused by

Table 3: Weed control at the 12 and 22 days after herbicides application, stem diameter, plant height, soil B content (0 to 10 cm and 10 to 20 cm layers) and leaf B content as a function of the treatments. Data obtained in the experiment carried out in Londrina

Treatments	Boron sources	Control (%)		Stem diameter (mm)	Plant height (cm)	Soil B content (mg dm^{-3})		Leaf B content (mg kg^{-1})
		12 d.	22 d.			0 to 10 cm	10 to 20 cm	
Glyphosate (960 g a.i. ha^{-1})	-	96.2 A[1]	98.5 A	22.2 A	213.7 A	0.19 B	0.15 B	37.4 B
	Boric acid	92.5 AB	97.2 A	22.4 A	219.5 A	0.27 AB	0.16 B	47.7 A
	Sodium borate	91.2 B	95.2 A	22.6 A	219.6 A	0.28 A	0.21 A	42.2 AB
Glyphosate potassium (1.240 g a.i. ha^{-1})	-	100.0 A	99.5 A	24.7 A	217.7 A	0.19 A	0.16 A	37.5 A
	Boric acid	95.0 B	99.0 AB	25.5 A	218.7 A	0.27 A	0.19 A	49.5 A
	Sodium borate	93.7 B	95.0 B	24.4 A	209.5 A	0.26 A	0.18 A	46.0 A
Glyphosate + sulfentrazone (960 g a.i. ha^{-1} + 300 g a.i. ha^{-1})	-	92.5 A	92.5 A	23.1 A	208.4 A	0.14 B	0.15 B	37.2 B
	Boric acid	85.0 B	85.0 B	22.8 A	210.1 A	0.31 A	0.22 A	45.0 A
	Sodium borate	61.2 C	61.2 C	22.2 A	207.7 A	0.27 A	0.19 AB	46.3 A
Glyphosate potassium + sulfentrazone (1.240 g a.i. ha^{-1} + 300 g a.i. ha^{-1})	-	90.0 A	92.5 A	23.2 A	215.2 A	0.19 A	0.15 A	37.0 B
	Boric acid	89.5 A	92.5 A	22.2 A	214.1 A	0.26 A	0.18 A	47.0 A
	Sodium borate	75.0 B	75.0 B	22.7 A	214.2 A	0.26 A	0.17 A	42.7 AB
Glyphosate + flumioxazin (960 g a.i. ha^{-1} + 25 g a.i. ha^{-1})	-	96.2 A	97.5 A	22.8 A	210.9 A	0.23 A	0.18 A	38.2 B
	Boric acid	96.2 A	98.7 A	23.2 A	212.7 A	0.25 A	0.21 A	49.7 A
	Sodium borate	91.2 B	95.7 A	23.7 A	211.7 A	0.29 A	0.19 A	53.8 A
Glyphosate + carfentrazone (960 g a.i. ha^{-1} + 20 g a.i. ha^{-1})	-	97.5 A	100.0 A	20.9 A	209.9 A	0.15 B	0.18 A	33.5 B
	Boric acid	98.7 A	99.5 A	21.1 A	211.6 A	0.21 B	0.19 A	43.4 A
	Sodium borate	95.0 A	97.7 A	21.3 A	207.5 A	0.31 A	0.22 A	41.6 A
Glyphosate (1,188.7 g a.i. ha^{-1})	-	98.7 A	100.0 A	23.0 A	212.2 A	0.18 B	0.19 A	35.7 B
	Boric acid	96. 2 A	97.7 A	23.6 A	217.2 A	0.30 A	0.20 A	41. AB
	Sodium borate	88. 7 B	93.2 B	24.4 A	214.0 A	0.27 A	0.19 A	42.9 A
Hand-hoeing control	-	100.0 A	100.0 A	21.5 A	197.5 A	0.16 B	0.16 A	35.6 B
	Boric acid	100.0 A	100.0 A	21.7 A	200.7 A	0.27 A	0.19 A	40.9 AB
	Sodium borate	100.0 A	100.0 A	22.6 A	202.3 A	0.23 AB	0.19 A	42.2 A
Weedy control	-	0.0 A	0.0 A	0.0 A	0.0 A	0.18 B	0.18 A	0.0 A
	Boric acid	0.0 A	0.0 A	0.0 A	0.0 A	0.33 A	0.22 A	0.0 A
	Sodium borate	0.0 A	0.0 A	0.0 A	0.0 A	0.29 A	0.23 A	0.0 A
CV (%)		3.2	2.8	4.1	3.8	19.9	16.5	9.2

Means followed by the same letter in each column and for each treatment are not statistically different by the Tukey test at 5% probability.

negative electric potential of the membrane, reducing their entry and accumulation in the cytoplasm (Sterling, 1994). Stahlman and Phillips (1979) also observed that as the spraying carrier becomes more alkaline, the activity of glyphosate decreases. Higher pH may reduce glyphosate penetration through the negatively charged barriers such as the double phospholipid layer of cell membranes.

Moreover, the form with double ionization is subject to interactions with cations such as Ca^{+2} and Mg^{+2} in the solution (Thelen *et al.*, 1995), hence reducing herbicide efficiency.

A phosphate carrier ($H_2PO_4^-$) probably mediates the absorption of glyphosate through the plasmatic membrane (Denis and Delrot, 1993).

In Experiment 2, at 18 DAT (Table 4), all treatments with desiccant plus B, from the boric acid source, showed weed control similar to herbicides singly applied, except diuron+paraquat. These active ingredients as well as the mixture of glyphosate+carfentrazone had lower weed control efficiency when mixed with sodium borate compared to single application at 18 DAT. Herbicides such as paraquat are more stable in neutral and acid solutions (Inchem, 2005), but their stability can be affected at pH above 7.0 (Deer and Beard, 2005). On the other hand, diuron is not affected by solutions with pH above 8.0, being more stable in neutral pH (Lucy, 2005).

At that same evaluation date, all treatments in which glyphosate was used in combination with sodium borate had poorer weed control than the same treatments applied singly.

Nevertheless, in the evaluation performed at 28 DAT there was no statistical different among treatments.

At 0 to 10 cm depth (Experiment 1), the mean content of B in the soil from boric acid and sodium borate applied in combination with the desiccant herbicides was 0.27 mg dm^{-3}. On the other hand, when the herbicides were applied singly, the mean B content dropped to 0.17 mg dm^{-3}. In samples taken at 10 to 20 cm depth mean B contents were 0.19 mg dm^{-3} when the herbicides were applied in combination with both sources of boron. However, in the treatments without B, these figures were 0.16 mg dm^{-3}. In Experiment 2, B content increased from 0.16 mg dm^{-3}, in the treatments where the herbicides were applied singly, to 0.37 mg dm^{-3}, in the treatments associated with both B sources. The amount of B added to the soil at 0 to 10 cm was 2.0 mg dm^{-3} in both experiments. Nonetheless, B values recovered were lower than those applied to the soil, probably because B content in the soil was underestimated by the extraction method (hot water). Furthermore, B may have been retained in the plant debris until 50 DAT, and was also absorbed by the plants.

The higher B content in the soil combined with adequate water availability to the plants during the crop cycle, probably helped increase the absorption of this micronutrient by the roots, raising B concentration in sunflower leaves.

Table 4: Weed control at 18 and 28 days after treatments application, stem diameter, plant height, soil B content (0 to 10 cm soil layer), leaf B content, oil content in the achenes and productivity of sunflower. Data obtained in the experiment carried out in Chapadão do Céu

Treatments	Boron sources	Control (%)		Stem diameter (mm)	Plant height (cm)	Soil B Content 0 to 10 cm (mg dm^{-3})	Leaf B content (mg kg^{-1})	Oil content (%)	Productivity (kg ha^{-1})
		18 d.	28 d.						
Glyphosate (960 g a.i. ha^{-1})	-	100 A[1]	90 A	26.0 A	202 A	0.17 B	85.5 A	40.7 A	2,086 A
	Boric acid	100 A	90 A	25.4 A	199 A	0.39 A	100.7 A	40.8 A	2,036 A
	Sodium borate	97 A	91 A	24.4 A	198 A	0.34 A	83.6 A	41.0 A	1,952 A
Glyphosate potassium (1.240 g a.i. ha^{-1})	-	100 A	90 A	25.0 A	201 A	0.16 B	70.9 B	40.9 A	2,091 A
	Boric acid	100 A	92 A	25.5 A	200 A	0.39 A	97.1 A	41.3 A	1,982 A
	Sodium borate	99 A	90 A	24.0 A	198 A	0.45 A	93.6 A	41.1 A	1,911 A
Glyphosate + sulfentrazone (960 g a.i. ha^{-1} + 300 g a.i. ha^{-1})	-	100 A	90 A	24.7 A	200 A	0.15 B	75.8 B	41.1 A	2,066 A
	Boric acid	100 A	91 A	24.4 A	201 A	0.39 A	100.3 A	40.7 A	1,960 A
	Sodium borate	97 A	91 A	24.2 A	200 A	0.32 A	89.7 AB	41.0 A	1,999 A
Glyphosate potassium + sulfentrazone (1,240 g a.i. ha^{-1} + 300 g a.i. ha^{-1})	-	100 A	94 A	25.3 A	200 A	0.15 C	67.9 B	40.9 A	2,127 A
	Boric acid	100 A	94 A	26.0 A	199 A	0.43 A	90.4 A	40.8 A	1,960 A
	Sodium borate	99 A	94 A	24.9 A	203 A	0.32 B	95.2 A	41.0 A	2,011 A
Glyphosate + flumioxazin (960 g a.i. ha^{-1} + 25 g a.i. ha^{-1})	-	98 A	91 A	25.8 A	202 A	0.15 B	71.2 B	40.7 A	1,889 A
	Boric acid	98 A	92 A	24.2 A	201 A	0.32 A	101.9 A	41.4 A	2,116 A
	Sodium borate	95 A	92 A	25.3 A	200 A	0.38 A	91.5 AB	41.1 A	1,881 A
Glyphosate + carfentrazone (960 g a.i. ha^{-1} + 20 g a.i. ha^{-1})	-	100 A	91 A	26.2 A	201 A	0,15 B	72.7 A	41.3 A	2,122 A
	Boric acid	100 A	93 A	25.4 A	198 A	0,39 A	94.3 A	407 A	1,953 A
	Sodium borate	94 B	92 A	25.6 A	201 A	0,40 A	85.8 A	40.9 A	2,008 A
Diuron + paraquat (200 g a.i. ha^{-1} + 400 g a.i. ha^{-1})	-	100 A	91 A	26.4 A	201 A	0.16 B	71.9 A	40.4 A	2,192 A
	Boric acid	92 B	93 A	25.9 A	199 A	0.39 A	92.2 A	40.3 A	1,987 A
	Sodium borate	94 B	92 A	25.3 A	206 A	0.36 A	83.4 A	40.2 A	2,071 A
Hand-hoeing control	-	100 A	100 A	25.2 A	203 A	0.16 B	73.0 A	40.7 A	2,084 A
	Boric acid	100 A	100 A	25.1 A	196 A	0.39 A	86.5 A	41.6 A	1,878 A
	Sodium borate	100 A	100 A	24.5 A	202 A	0.38 A	79.4 A	41.0 A	2,096 A
Weedy control	-	0.0 A	0.0 A	25.2 A	198 A	0.16 B	80.9 A	41.0 A	2,045 A
	Boric acid	0.0 A	0.0 A	24.6 A	197 A	0.33 A	83.8 A	41.5 A	1,903 A
	Sodium borate	0.0 A	0.0 A	25.3 A	199 A	0.35 A	76.4 A	41.2 A	1,904 A
CV (%)		3.2	2.0	4.6	2.9	19.3	17.1	1.6	8.4

Means followed by the same letter in each column and for each treatment are not statistically different by the Tukey test at 5% probability.

In the treatments where the herbicides were applied singly (Experiment 1; Table 3) the mean B content in sunflower leaves was 37.7 mg kg^{-1}, a value close to that established by Blamey *et al.* (1979) as critical (34 mg kg^{-1}). For Blamey (1976) and Machado (1979) however, adequate B contents in the sunflower leaves are 47.0 mg kg^{-1} and 50 mg kg^{-1}, respectively. In tank mixtures of desiccants and B, from the sources boric acid and sodium borate, those values reached 45.6 mg kg^{-1} and 44.7 mg kg^{-1}, respectively.

In Experiment 2 (Table 4), mean values of B in sunflower leaves were 74.4 mg kg^{-1} (only the herbicides) and 90.3 mg kg^{-1} (herbicides plus B). These are above the critical values proposed. Higher available in the soil and uptake by plants is evidence of the efficiency of combining boron and herbicide application.

There were no differences between treatments regarding stem diameter, plant height (Experiments 1 and 2), oil content in the achenes and sunflower yield (Experiment 2).

The combined application of herbicides and boric acid appears to be perfectly suitable for controlling weeds and increases mineral nutrition of sunflower.

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COMPATIBILIDAD DE HERBICIDAS Y BORO EN LA DESECACIÓN DE MALEZAS Y LA NUTRICIN MINERAL DEL CULTIVO DE GIRASOL

RESUMEN

Se realizaron dos experimentos con la finalidad de evaluar el control de malezas mediante la aplicación de herbicidas, aislados o combinados con boro (B), tambien se evaluó la respuesta del girasol (*Helianthus annuus* L.) a la fertilización con ese micronutriente. En una parcela se aplicó el herbicida, esta parcela fue dividida em 3 subparcelas de las cuales dos recebieron 2 kg de B ha^{-1} en dos formas (H_3BO_3 - ácido bórico y $Na_2B_8O_{13}{\cdot}4H_2O$ - borato de sodio), asociados a los herbicidas. Parcelas testigos no recibieron ningún tratamiento de herbicida. La combinación del herbicida con boro, principalmente la forma H_3BO_3, controló eficazmente las malezas *Euphorbia heterophylla*, *Bidens*

subalternans y *Brachiaria plantaginea*. La aplicación de B, junto con los herbicidas, elevó el tenor de ese micronutriente en el suelo y en las hojas de girasol. Por lo tanto, la aplicación conjunta de herbicidas y ácido bórico para el control de malezas y para la nutrición mineral del cultivo de girasol es viable.

COMPATIBILITÉ D´HERBICIDES AVEC DU BORE POUR LE DESSÈCHEMENT DE MAUVAISES HERBES ET POUR LA NUTRITION MINERALE DE LA CULTURE DU TOURNESOL

RÉSUMÉ

Deux expériences ont été conduites afin d´évaluer d´une part le contrôle des mauvaises herbes au moyen de l´pplication d´herbicides, isolés et combinés avec le bore (B), et d´autre part la réaction du tournesol (*Helianthus annuus* L.) au fertilisant contenant ce micronutriment. Des traitements avec des herbicides ont été a appliqués dans les parcelles et les subparcelles ont été constituées par la présence ou l´abscence de 2 kg ha^{-1} de B de deux sources (H_3BO_3-acide borique et $Na_2B8O_{13}{\cdot}4H_2O$ borate de sodium) associés aux herbicides. La combinaison d´herbicides avec le bore, de préférence de source H_3BO_3 a eu un contrôle efficace sur les mauvaises herbes *Euphorbia heterophylla*, *Bidens subalternan* et *Bracharia plantaginea*. L´application combinée du bore et des herbicides a élevé la teneur de ce nutriment dans le sol et dans les feuilles de tournesol. Il est donc possible l´applicaton conjointe d´herbicides et acide borique pour le contrôle des mauvaises herbes et dans la nutrtion minerale de la culture du tournesol.