WEED CONTROL AND BORON NUTRITION ON Eucalyptus IN SILVOPASTORAL SYSTEM

[CONTROL DE MALEZAS Y NUTRICIÓN DE BORO EN EL EUCALIPTO EN EL SISTEMA SILVOPASTORIL]

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SUMMARY

The objective of this study was to evaluate the control of weeds in the rows of eucalyptus (*Eucalyptus urograndis*) with herbicides applied singly or combined with boron (B), as well as, the response of Eucalyptus plants to this micronutrient. The experiments were carried out in a split-plot with randomized complete block design, with three replicates. Six treatments were applied to the plots: (i) weeded control, (ii) control without weeding, (iii) glyphosate (1080 g ae ha^{-1}) + chlorimuron-ethyl (10 g ai ha^{-1}) + 0.05% v / v mineral oil, (iv) glyphosate (1080 g ae ha^{-1}) + isoxaflutole (112.5 g ai ha^{-1}), (v) glyphosate (1080 g ae ha^{-1}) and (vi) oxyfluorfen (480 g ai ha^{-1}). The sub-plots consisted of the absence or presence of 4 kg of boric acid (H_3BO_3 - 17% B) in 100 L of water. The addition of boric acid in the solution containing the herbicides did not affect the weed control. There was an increase in boron content in the soil and consequently an increase in the boron levels in the eucalyptus leaves. The combined application of herbicides plus boric acid is perfectly suitable for preventing dry of the pointer on eucalyptus plants.

Keywords: *Eucalyptus urograndis*; chemical control; herbicides; micronutrients; *Urochloa decumbens.*

RESUMEN

El objetivo de este estudio fue evaluar el control de las malas hierbas en las filas de eucalipto (*Eucalyptus urograndis*) con herbicidas aplicados solos o en combinación con boro (B), así como la respuesta de las plantas de eucalipto a este micronutriente. Los experimentos se realizaron en un diseño de bloques completos al azar en parcelas sub-divididas con tres repeticiones. Seis tratamientos se aplicaron a las parcelas: (i) testigo desmalezado, (ii) testigo sin deshierbe, (iii) glifosato (1080 g ha^{-1}) + clorimurón -etilo (10 g ia ha^{-1}) + 0,05 % v / v de aceite mineral, (iv) glifosato (1,080 g ha^{-1}) + isoxaflutol (112,5 g ia ha^{-1}), (v) glifosato (1,080 g ha^{-1}) y (vi) oxifluorfeno (480 g ia ha^{-1}). Sub-parcelas consistieron en la ausencia o presencia de 4 kg de ácido bórico (H_3BO_3 - 17 % de B) en 100 L de agua. La adición de ácido en la solución de pulverización que contiene el herbicida no afectó el control de malezas. La adición de ácido bórico produjo un aumento en el contenido de boro en el suelo y por consiguiente en hojas de eucalipto. La combinación de ácido bórico a la solución de pulverización es una práctica adecuada en la prevención de seco del puntero en las plantas de eucalipto.

Palabras clave: *Eucalyptus urograndis;* control químico; herbicidas; micronutrientes; *Urochloa decumbens.*

INTRODUCTION

Silvopastoral systems have attracted the interest of farmers as an alternative to improve the physical and chemical properties of the soil (Neves *et al*., 2009), as well as the benefits related to the quality of the forage and weight gain of the animals (Paciullo *et al*., 2011).

However, the establishment of the silvopastoral systems depends on an efficient weed control until the trees have grown enough to be away from weed and grass competition. In relation to eucalyptus, weed competition causes mainly reduction of the stem diameter and of the dry matter of stems and shoots (Tarouco *et al*., 2009). A weed free period of 140 days after eucalyptus transplanting is necessary to assure normal crop development (Toledo *et al*., 2000).

The weed management in forested areas, at various stages of their production process, is carried out primarily by the use of mechanical and chemical methods, singly or combined. Among the most widely used herbicides in forest areas stand out, especially the oxyfluorfen, glyphosate and isoxaflutole (Rodrigues and Almeida, 2005).

Another fact that should be considered in the implementation of trees is the aspect related to the mineral nutrition of plants. Recently, eucalyptus genotypes have been developed increasing more production, and therefore more demanding in terms of nutrition. Attention should be directed not only to the macronutrients but also micronutrients, particularly boron (B). The lack of B leads in inhibition of plant growth, due to the fact that this micronutrient is part of the cell wall. In its absence, there is a reduction in the synthesis of pectin, cellulose and lignin in the wood cell walls, making them thinner (Epstein and Bloom, 2005). Boron deficiency is one of the most limiting factor to the growth of the younger eucalyptus phase (Sgarbi *et al*., 1999). The leaves show marginal chlorosis followed by dried margins. The younger leaves become gnarled and thick. There is loss of plant dominance caused by the death of the apical bud. And in the final stage, there is dry of the pointer and descending death of the branches, with subsequent sprouting, resulting in the bifurcation of the trunk. In some situations, may occur break of the forked stem due to its fragility to winds. Thus, operations that can control weeds and provide boron, at the same time, allow to reduce production costs and ensure the establishment of the eucalyptus.

Hence, present study was undertaken to evaluate the weed control in the rows of eucalyptus with herbicides applied singly or combined with boron, as well as, the response of eucalyptus plants to this micronutrient.

MATERIAL AND METHODS

Two experiments were carried out in Coronel Pacheco, Minas Gerais State, Brazil (21^0 54' 69" S and 43^0 26' 56" W). The climate is Cwa type (mesothermal), defined as subtropical, with rainy summer and dry in winter. The average annual rainfall is 1500 mm. The monthly rainfall and average air temperature that occurred during the experimental periods are shown in Table 1.

The experiments were carried out in a split-plot with randomized complete block design, with three replicates. Six treatments were applied to the plots: (i) weeded control, (ii) control without weeding, (iii) glyphosate (1080 g ae ha^{-1}) + chlorimuron-ethyl (10 g ai ha^{-1}) + 0.05% v / v mineral oil, (iv) glyphosate (1080 g ae ha^{-1}) + isoxaflutole (112.5 g ai ha^{-1}), (v) glyphosate (1080 g ae ha^{-1}) and (vi) oxyfluorfen (480 g ai ha^{-1}). Sub-plots were consisted of absence or presence of 4 kg of boric acid (H_3BO_3 - 17% B) in 100 L of water.

The area of plots was 96 m^2 (2x48m) and 72m^2 (2x36m) for the experiments 1 and 2, respectively. The area of sub-plot was 16 m^2 (2x8m) with four eucalyptus plants in the row for the experiment 1 and 12 m^2 (2x6m) with three eucalyptus plants in the row for the experiment 2. The experimental areas were used as pasture aproximately 11 years and predominantly populated with signal grass (*Urochloa decumbens*). The soil is classified as Hapludox whose chemical analysis is described in Table 2.

Glyphosate (1,440 g ae ha^{-1}) was applied on signal grass plants in rows of 3 m wide, seven days before eucalyptus planting. The planting holes were digged by a ground drilling machine with 0.40 m deep by 0.20 m in diameter at a spacing of 2 m between planting holes and 20 m between rows, totaling 250 plants per hectare. The planting fertilization was performed with 120 g $plant^{-1}$ (NPK formulation 08-28-16).

The *Eucalyptus urograndis* (AEC-1528 commercial clone) was planted on November 16, 2011 (experiment 1) and on January 1, 2012 (experiment 2). Two side dressing were performed with 80 g $plant^{-1}$ (NPK formulation 20-05-20) at 60 and 90 days after planting.

The applications of the treatments were performed on December 1, 2011 (experiment 1) and February 2, 2012 (experiment 2) when eucalyptus plant height was approximately 0.4 m. It was used a sprayer (Herbicat Ltda, Catanduva, São Paulo, Brazil), with 296 kPa and maintained by compressed CO_2. The sprayer was equipped with a 1.0 m wide bar and two plane jet spraying nozzles (110 01 AVI), 0.5 m apart from each other, with a spraying volume equivalent to 90 L ha^{-1}. Prior the application, samples of the spray solution were collected and taken to the laboratory for pH determination. The application was performed on signal grass plants, to 1.0 m wide, from each side of the eucalyptus rows without reaching the trees. Visual injury ratings on signal grass were obtained 7, 14 and 21 days after application (DAA), using the scale 0-100% (Gazziero *et al*., 1995). The SPAD indexes were evaluated at 25 DAA using the determiner of chlorophyll SPAD 502, Konica Minolta, Japan.

The circumference at breast height (CBH) (cm) and the total height (m) were measured using a metric tape and an Abney clinometer, respectively. The CBH was divided by pi (3.14159) to obtain the diameter at breast height. The volume per tree was obtained using the form factor of 0.4. These measurements were performed at six months after the application of treatments.

Table 1. Means values of monthly rainfall precipitation and air temperature during the conduct of the experiments. Coronel Pacheco, Minas Gerais State, Brazil[1]

	Month/Year													
	Nov /11	Dec /11	Jan /12	Feb /12	Mar /12	Apr12	May /12	Jun /12	Jul /12	Aug/12	Sep/12	Oct /12	Nov /12	Dec /12
Rainfall (mm)	316.7	345.4	397.3	108.0	92.6	71.0	107.5	53.8	4.2	5.0	72.9	49.4	273.6	209.2
Air temperature (^{0}C)	18.3	20.2	20.5	22.5	21.4	20.3	16.4	15.8	17.4	16.7	18.9	21.1	19.2	23.4

(1)Results provided by the Weather Station of the Universidade Federal de Juiz de Fora, Minas Gerais State, Brazil.

Table 2. Chemical analysis of the soil samples collected at depth of 0 to 10 cm in experiments 1 and 2, respectively. Coronel Pacheco, Minas Gerais State, Brazil (1)

Experiment	P	K	pH H_2O	Ca	Mg	Al	H^++Al^{+3}	SB	V%	CTC	C	B
	mg dm^{-3}			cmol$_c$ dm^{-3}							g dm^{-3}	mg dm^{-3}
1	1.0	22	4.90	0.2	0.1	1.0	4.62	0.36	7	4.98	31	0.18
2	1.3	17	4.7	0.1	0.0	1.1	4.79	0.14	3	4.93	32	0.20

(1)Results provided by the Soil and Plant Tissue Analysis Laboratory of Embrapa Soybean.

Soil samples were taken from each sub-plot in the 0-10, 10-20 and 20-40 cm soil layer at 120 DAA for boron content determination. The analyses were made in $BaCl_2$ 5 mmol L^{-1}. Eucalyptus leaves were collected at 120 and 240 DAA to determine the levels of boron. The leaves of third branch from the apex of the plants were collected in four and three plants per subplot in the experiments 1 and 2, respectively. The material was placed in craft paper and taken to dry in an oven forced ventilation of air at 65 ^{0}C until reaching constant mass. Boron determinations were made by dry digestion and subsequent solubilization of the ash with 50% hydrochloric acid (6 mol L^{-1}). The boron concentration in the extracts was determined by plasma emission spectrophotometry. Statistical analysis were performed using SAEG program (Ribeiro JR, 2001).

Data were submitted to analysis of variance and means were compared by the Scott-Knott test, $p \leq 0.05$.

RESULTS AND DISCUSSION

There were no significant interactions between factors of control treatments and the addition or not of boron source for the variables percentage of control at 7, 14 and 21 DAA and SPAD index for both experiments (Tables 3 and 4).

The treatments with glyphosate applied singly or in combination with boric acid provided results of percentages of signal grass control ranging from 67% to 73%, at 7 DAA, for both experiments. The addition of boric acid in the spray solution did not affect the efficacy of glyphosate in controlling signal grass. The symptoms were characterized by leaf chlorosis with progression to necrosis and death of leaves at 21 DAA, keeping the tree rows free of signal grass in 1m on each side of the eucalyptus plants (Figure. 1). Eucalyptus plants grown with fixed control ranges from 1m on each side of the crop row proved superior diameter at breast height, height and volume compared to plants grown to 0.5m (Toledo *et al*., 2003).

The effectiveness of glyphosate in controlling weeds is affected by changes in the pH of the spray solution (Turner and Loader, 1978). The dissociation constants 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). Variation in pH of glyphosate solution from 2.0 to 11.0 results in successive loss of proton from the carboxyl group, followed by the phosphate group and finally the amino group (Motekaitis and Martell, 1985). This fact makes the molecule of this herbicide has greater difficulty in terms of absorption due to low permeability of the membrane to mono and divalent anions. There may also occur repulsion of the molecules of herbicide (Gougler and Geiger, 1981). This is caused by the negative electric potential of the membrane, reducing their entry and accumulation in the cytoplasm (Sterling, 1994).

When the spray solution becomes more alkaline, the activity of glyphosate decreases (Stahlman and Phillips, 1979). 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 solution, hence reducing the glyphosate action (Thelen *et al*., 1995).

A reduction in spray solution pH occurred when glyphosate was added to the water, decreasing from 6.6 to 4.8, on average, in both experiments. This decrease was even greater with addition of boric acid (pH = 4.5). Under this condition, the non-ionic form of herbicide molecules prevails, rapidly passing through the plasmatic membrane of the cells. This fact can be confirmed by the efficacy of the glyphosate in controlling signal grass plants in both experiments.

For the oxyfluorfen, this herbicide is selective for eucalyptus and can be applied even on transplanted seedlings (Rodrigues and Almeida, 2005). However, the values of percentage of control of the signal grass plants were low. These values ranged from 37% to 39% in the first evaluation and approximately 75% at 21 DAA, for both experiments (Tables 3 and 4). This fact occurred because the effectiveness of this herbicide applied on post emergence is dependent on the growth stage of the weeds at the application time. At the moment of the application, the signal grass plants had many tillers per plant, affecting the efficacy of the oxyfluorfen.

There were no significant interactions between factors of SPAD index data and the addition or not of boric acid.The SPAD index values confirm that the addition of boric acid did not interfere with the efficacy of the herbicides on the signal grass plants (Tables 3 and 4).

The values of circumference at breast height, total height and volume increased by the addition of boric acid in experiment 1 and in treatments involving control without weeding and glyphosate plus chlorimuron-ethyl (Table 3). However, these results were not confirmed in the experiment 2 (Table 4). Increments in height, growth and biomass production of aerial part of the six clones of Eucalyptus with application of boron were observed by Barreto *et al*. (2007) and São José *et al*. (2009). The gains were between 35% and 54% in height and between 21% and 64% for biomass.

There were significant interactions between factors of boron content in the soil (0-10 and 10-20 cm soil layer) and the addition or not of boric acid for both experiments (Tables 5 and 6).

The treatments with addition of boric acid resulted in increase of boron in the 0-10 cm soil layer, in both experiments. The means values were 0.19 mg dm^{-3} and 0.18 mg dm^{-3} on treatments without boric acid and 0.37 mg dm^{-3} and 0.35 mg dm^{-3} with the addition of boric acid for experiments 1 and 2, respectively. Increments on boron content were also observed in the depth of 10-20 cm. However, there were no increments on boron content in 20 to 40 cm soil depth. Mass flow is the predominant mechanism for the transport of boron in the soil (Mattiello *et al*., 2009). And, the diffusion is a complementary mechanism of greater relative importance in B poor soils and water deficit. The addition of boron in poor soils becomes an important practice in preventing dry of the pointer in Eucalyptus (São José *et al*., 2009). The application of 2.2 kg ha^{-1} B in sandy soil resulted in 35% reduction of the dry of the pointer and 45% in clay soil (Sgarbi *et al*., 1999).

The analyzes of leaf boron contents showed increases in B levels in treatments that received boric acid (Tables 5 and 6). The means values were 13.71 mg kg^{-1} and 14.45 mg kg^{-1} on treatments without boric acid and 36.19 mg kg^{-1} and 37.18 mg kg^{-1} with the addition of boric acid for experiments 1 and 2, respectively. Increments on boron content were also observed at 240 DAA with the addition of boron.

Visual symptoms of dry of the pointer were observed on new tissues of the aerial part of eucalyptus plants in treatments which did not receive the boron source (Figure 2B). The youngest leaves from the apex of the plants were characterized by malformation and reddish, with subsequent necrosis and drop. Symptoms of boron deficiency in young tissues indicate that boron is immobile in phloem for the majority of species (Epstein and Bloom, 2005).

Table 3. Percentage values of signal grass (*Urochloa decumbens*) control at 7, 14 e 21 days after application of the treatments (DAA), chlorophyll content (SPAD index), circumference at breast height (CBH), total height (H) and volume (V), in function of the treatments. (Experiment 1). Coronel Pacheco, Minas Gerais State, Brazil (1)

Treatments	Boric Acid	%			SPAD	CBH (cm)	H (m)	V (m^3 $plant^{-1}$)
		7DAA	14 DAA	21 DAA				
Weeded control	Without	100	100	100	0.0	18.7 A	16.6 A	0.017 A
	With	100	100	100	0.0	17.7 A	17.1 A	0.016 A
Control without weeding	Without	0.0	0.0	0.0	40.1	15.1 B	14.8 B	0.010 B
	With	0.0	0.0	0.0	40.5	18.6 A	17.4 A	0.018 A
Glyphosate + chlorimuron	Without	73.0	84.0	98.6	8.0	10.5 B	6.7 B	0.003 B
	With	71.6	83.3	97.6	9.9	17.5 A	18.2 A	0.017 A
Glyphosate + isoxaflutole	Without	72.3	82.6	97.6	9.2	16.8 A	16.0 A	0.013 A
	With	71.3	84.0	98.0	9.1	17.5 A	17.2 A	0.015 A
Glyphosate	Without	72.0	84.0	98.0	3.9	16.7 A	16.2 A	0.013 A
	With	73.3	83.3	97.0	4.6	18.2 A	17.9 A	0.017 A
Oxyfluorfen	Without	39.0	64.0	74.0	8.8	18.6 A	17.5 A	0.018 A
	With	39.6	64.0	74.6	8.8	17.5 A	17.6 A	0.016 A
Coef. of Variation (%)		-	-	-	10.2	5.2	15.1	15.7
Standard Error Mean		-	-	-	0.204	0.149	0.409	0.004

(1)Means followed by the same letter in each column and for each treatment are not statistically different by the Scott-Knott test, $p \leq 0.05$

Table 4. Percentage values of signal grass (*Urochloa decumbens*) control at 7, 14 e 21 days after application of the treatments (DAA), chlorophyll content (SPAD index), circumference at breast height (CBH), total height (H) and volume (V), in function of the treatments. (Experiment 2). Coronel Pacheco, Minas Gerais State, Brazil (1)

Treatments	Boric Acid	%			SPAD	CBH (cm)	H (m)	V (m^3 $plant^{-1}$)
		7DAA	14 DAA	21 DAA				
Weeded control	Without	100	100	100	0.0	14.1	13.3	0.015
	With	100	100	100	0.0	14.4	13.5	0.016
Control without weeding	Without	0.0	0.0	0.0	49.6	13.2	12.8	0.012
	With	0.0	0.0	0.0	48.9	13.8	13.2	0.014
Glyphosate + chlorimuron	Without	68.0	83.6	98.6	5.6	13.6	13.8	0.014
	With	69.6	85.3	99.0	6.4	11.9	11.9	0.010
Glyphosate + isoxaflutole	Without	67.0	85.3	99.0	8.8	9.0	9.3	0.009
	With	67.0	84.3	98.0	9.4	4.2	4.3	0.004
Glyphosate	Without	68.3	85.3	98.0	9.9	12.7	13.0	0.012
	With	69.6	84.3	97.6	10.1	13.3	13.2	0.013
Oxyfluorfen	Without	37.3	59.3	76.0	8.1	12.7	13.3	0.013
	With	38.3	60.0	75.6	9.3	11.9	11.9	0.010
Coef. of Variation (%)		-	-	-	8.3	36.7	38.9	42.5
Standard Error Mean		-	-	-	0.193	0.741	0.779	0.001

(1)Means followed by the same letter in each column and for each treatment are not statistically different by the Scott-Knott test, $p \leq 0.05$

Table 5. Mean values of boron content (0 to 10, 10 to 20, 20 to 40 cm soil layer), leaf boron content at 120 (LBC_1) and 240 (LBC_2) days after application, in function of the treatments. (Experiment 1).Coronel Pacheco, Minas Gerais State, Brazil [(1)]

Treatment	Boric Acid	Boron content (mg dm^{-3})			LBC_1	LBC_2
		0-10	10-20	20-40	(mg kg^{-1})	(mg kg^{-1})
	Without	0.19 B[1]	0.19 B	0.14	19.0 B	10.8A
Weeded control	With	0.45 A	0.27 A	0.12	42.0 A	15.5A
	Without	0.20 B	0.17 B	0.15	10.6 B	11.8A
Control without weeding	With	0.36 A	0.26 A	0.15	37.2 A	16.5A
	Without	0.19 B	0.17 B	0.12	17.0 B	13.5B
Glyphosate + chlorimuron-	With	0.39 A	0.28 A	0.17	37.6 A	21.6A
	Without	0.19 B	0.18 B	0.19	12.1 B	15.2A
Glyphosate + isoxaflutole	With	0.31 A	0,25 A	0.18	34.0 A	15.5A
	Without	0.23 B	0.12 B	0.18	10.5 B	10.6B
Glyphosate	With	0.33 A	0.26 A	0.17	33.3 A	17.3A
	Without	0.17 B	0.20 B	0.18	13.1 B	8.3A
Oxyfluorfen	With	0.43 A	0.27 A	0.21	33.0 A	10.7A
Coef. of Variation (%)		15.0	10.9	29.3	10.5	20.3
Standard Error Mean		0.007	0.004	0.008	0.439	0.568

[((1)]Means followed by the same letter in each column and for each treatment are not statistically different by the Scott-Knott test, $p \leq 0.05$

Table 6. Mean values of boron content (0 to 10, 10 to 20, 20 to 40 cm soil layer), leaf boron content at 120 (LBC_1) and 240 (LBC_2) days after application, in function of the treatments. (Experiment 2), Coronel Pacheco, Minas Gerais State, Brazil [(1)]

Treatment	Boric Acid	Boron content (mg dm^{-3})			LBC_1	LBC_2
		0-10	10-20	20-40	(mg kg^{-1})	(mg kg^{-1})
	Without	0.17 B	0.17 B	0.17	10.4 B	11.2B
Weeded control	With	0.36 A	0.28 A	0.20	33.3 A	15.6A
	Without	0.21 B	0.19 B	0.13	9.4 B	9.8A
Control without weeding	With	0.34 A	0.31 A	0.16	37.6 A	13.3A
	Without	0.18 B	0.18 B	0.17	16.9 B	11.4B
Glyphosate + chlorimuron	With	0.33 A	0.31 A	0.14	37.3 A	20.5A
	Without	0.17 B	0.16 B	0.14	17.3 B	11.4B
Glyphosate + isoxaflutole	With	0.34 A	0.28 A	0.14	36.6 A	16.5A
	Without	0.19 B	0.17 B	0.13	11.9 B	9.6B
Glyphosate	With	0.40 A	0.32 A	0.14	39.3 A	19.0A
	Without	0.18 B	0.21 B	0.14	20.8 B	11.7A
Oxyfluorfen	With	0.35 A	0.29 A	0.13	39.0 A	14.3 A
Coef. of Variation (%)		13.4	8.6	19.4	8.0	17.7
Standard Error Mean		0.006	0,003	0.005	0.348	0.403

[(1)]Means followed by the same letter in each column and for each treatment are not statistically different by the Scott-Knott test, $p \leq 0.05$

Figure 1. Signal grass (*Urochloa decumbens*) control with glyphosate plus boric acid at 30 days after application (DAA).

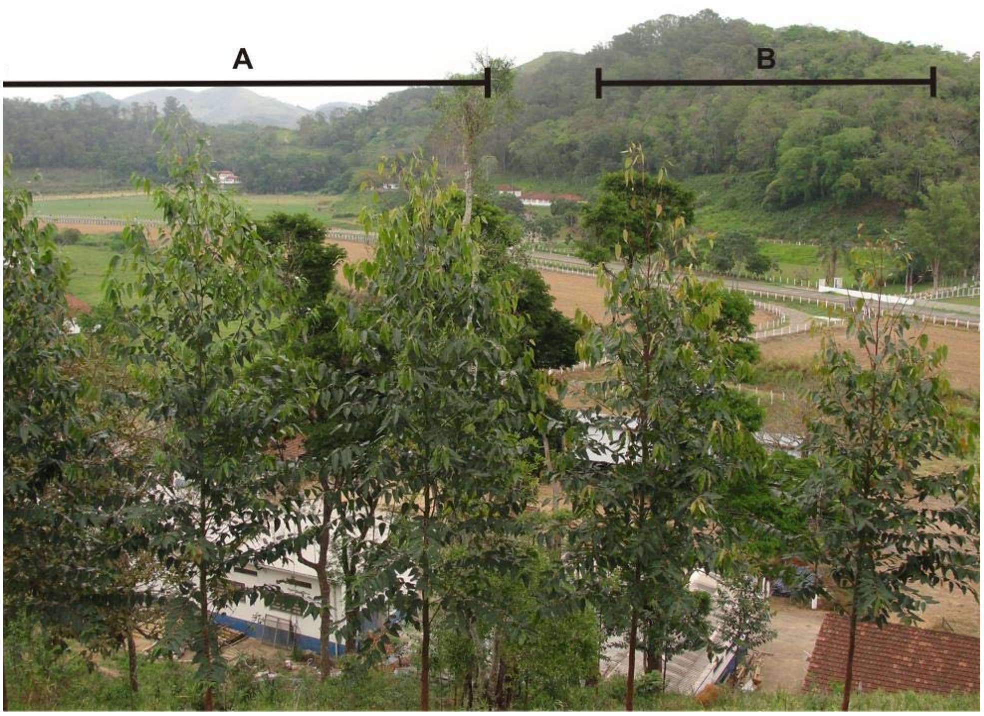

Figure. 2. Eucalyptus plants treated with (A) or without (B) boric acid.

CONCLUSION

The addition of boric acid in the solution containing the herbicides did not affect the signal grass control. There was an increase in boron content in the soil and consequently an increase in the boron levels in the eucalyptus leaves. The combined application of herbicides plus boric acid is perfectly suitable for preventing dry of the pointer on eucalyptus plants.

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