REVISTA FLORESTA
Engenharia Florestal
ISSN 1982-4688
Edição 54
Universidade Federal do Paraná
Setor de Ciências Agrárias

EUCALYPTUS ‘GG 100’ RESPONSE TO SIMULATED DRIFT OF ORTHOSULFAMURON

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Received for publication: 22 / 09 / 2021 – Accepted for publication: 02 / 10 / 2023

Resumo

Simulação de deriva de orthosulfamuron em eucalipto ‘GG 100’. Os reguladores de crescimento vegetal e subdoses de herbicidas são empregados em algumas culturas com função de atingir rendimentos satisfatórios. Estes compostos podem promover alterações morfológicas ou fisiológicas das plantas de formas qualitativas ou quantitativas, como a inibição e retardo de desenvolvimento vegetativo, maturação precoce ou acúmulo de açúcares em cana-de-açúcar. A aplicação desses produtos visa atingir a cultura alvo, mas algumas culturas vizinhas podem ser indevidamente atingidas devido ação da deriva. O presente trabalho objetivou avaliar os efeitos da deriva simulada de orthosulfamuron no crescimento inicial de mudas de *Eucalyptus urophylla*, clone GG 100. O experimento foi instalado em vasos com capacidade de 5 L, no delineamento experimental inteiramente casualizado, com nove tratamentos em quatro repetições. Os tratamentos consistiram em nove doses crescentes de orthosulfamuron, sendo: 0; 1,17; 2,34; 4,69; 9,38; 18,75; 37,5; 75,0 e 112,50 g i.a. ha^{-1}. Foram realizadas avaliações da altura das plantas de eucalipto aos 0, 14, 28, 42 e 63 dias após a aplicação do produto (DAA). Aos 63 DAA, ao término do experimento, avaliou-se o diâmetro do caule, a área foliar e a matéria seca de folhas, caules e raízes. Concluiu-se que não houve efeitos deletérios da aplicação de orthosulfamuron, até 112,50 g i.a. ha^{-1}, sobre o desenvolvimento e crescimento das mudas de *E. urophylla*, clone GG 100, até os 63 dias após a aplicação.
Palavras-chave: Maturador; *Eucalyptus urophylla;* Crescimento.

Abstract

Plant growth regulators and low doses of herbicides are used in some crops in order to achieve satisfactory yields. These compounds can promote qualitative and/or quantitative morphological or physiological changes in plants, such as the inhibiting and delaying the vegetative development in the early maturation or in sugar accumulation in sugarcane crops. The application of these products through spraying aims to reach the target crop, for example, the sugarcane fields, however, some neighboring crops may be contaminated through drift. The present study aims to evaluate the effects of simulated drift of orthosulfamuron on the initial growth of *Eucalyptus urophylla* seedlings, clone GG 100. The experiment was installed in pots of 5 L capacity in a completely randomized design, with nine treatments and four replicates. The treatments consisted of the following nine increasing doses of orthosulfamuron ripener: 0; 1.19; 2.39; 4.78; 9.56; 19.12; 38.25; 76.5; and 127.5 g a.i. ha^{-1}. The height of the eucalyptus plants was evaluated at 0, 14, 28, 42, and 63 days after application (DAA). At 63 DAA, in the end of the experiment, the stem diameter, leaf area, and the dry matter of leaves, stems, and roots were evaluated. Results show that there were no deleterious effects of the drift of orthosulfamuron up to the dose of 127.5 g a.i. ha^{-1} on the development and growth of *E.urophylla* seedlings, clone GG 100, up to 63 days after application.
Keywords: Ripeners; *Eucalyptus urophylla;* Growth

INTRODUCTION

Brazil is the world leader in wood productivity and in 2018 it led the ranking of forest productivity, with an annual average productivity of 38.9 m^3 ha^{-1} for eucalyptus plantations (*Eucalyptus* spp.). Eucalyptus plantations occupy 7.53 million hectares of the area of trees planted in the country (75.8% of total area) and are located mainly in Minas Gerais, São Paulo, and Mato Grosso do Sul States. Eucalyptus is a crop that requires high biomass production to meet growing market demands, as it used as raw material in several industrial processes such as a fuel source in thermal energy generation, furniture, paper, and cellulose production (INDÚSTRIA BRASILEIRA DE ÁRVORES, 2022).

The expansion of eucalyptus forest areas in Brazil occurs in parallel with sugarcane areas, causing eucalyptus areas to be planted adjacent to sugarcane areas. The simultaneous planting system is now common among border areas of production, mainly in the State of São Paulo, as a strategy for intensifying and diversifying income, strengthening the stability and resilience of producers for being able to lease a part of their properties (PETRINI.; ROCHA; BROWN, 2017; SEPLAG, 2017).

It is commonplace amongst sugarcane producers to make use of growth regulators or ripeners in sugarcane cropping systems. The objective can be multi-fold: anticipate crop ripening, improve crop planning/management, increase sucrose accumulation and raw material quality as well as promote higher productivity and biomass accumulation, besides improving raw material quality (LEITE; CRUSCIOL, 2008). At low doses, some chemical compounds such as some herbicides can also present characteristics of growth stimulants, a process known as hormesis (CALABRESE; BALDWIN, 2002). Glyphosate, trinexapac-ethyl, fluazifop-p-butyl, gibberellic acid, sulfometuron methyl, and ethephon are examples of chemical products registered by the Ministry of Agriculture, Livestock and Food Supply (MAPA), which can be used in Brazil as ripeners or plant growth regulators in sugarcane (MAPA, 2020).

The effectiveness of aerial spraying of phytosanitary products is frequent in sugarcane crops and is impacted by spray drift, which is defined as a part of the spraying that does not reach the target crop. Spray drift is considered one of the main causes of chemical losses and can be avoided by following standard application procedures (i.e., suitable spray nozzles, spraying pressure, etc) and following manufactures' tools and products label guidelines (CHECHETTO *et al.*, 2013). The occurrence of drift during application is considered a serious problem in agriculture, as it reduces the operation efficiency and puts nearby crops at risk due to inadequate doses (low or high dosage of non-target compounds) which can also lead to efficiency failures, besides possibly contaminating animals and the environment (COSTA; POLANCZYK, 2019).

Orthosulfamuron is classified as an herbicide and growth regulator belonging to the chemical group of sulfamoyl ureas and recommended for sugarcane cropping systems. As a plant ripener, it shows systemic action after being absorbed by the leaves of the crop, acting on the meristematic regions and affecting cell division and growth. Through temporary growth inhibition, the emission of new leaves does not occur and flowering is ceased (when applied prior to floral induction), decreasing pith, and promoting sucrose storage in sugarcane stems (MAPA, 2020).

Like any sprayed product, orthosulfamuron is susceptible to drift, which can reach neighboring crops, such as eucalyptus. As the proximity between sugarcane and eucalyptus crops is very frequent, the hypothesis that an eventual aerial application of orthosulfamuron as sugarcane ripener may lead to its drift on neighboring eucalyptus crops which would result in altered physiological processes, especially in the seedling stage. Therefore, the aim of the present study is to evaluate the effects of the simulated drift of orthosulfamuron on the initial growth of *Eucalyptus urophylla* seedlings, clone GG 100.

MATERIALS AND METHODS

Growth conditions and plant materials

The experiment was conducted in an open area, under semi-controlled conditions, in the municipality of Jaboticabal, State of São Paulo, Brazil, (21°14'05" S latitude and 48°17'09" W longitude; altitude of 590 m). According to the Köppen climate classification, the region's climate is Cwa, subtropical with rainy summers and dry winters, with an average annual temperature of 22°C and rainfall of 1,552 mm.

The experimental units consisted of pots of 5 L capacity filled with a substrate consisting of a soil mixture of Dystrophic Red Latosol and sand in the 3:1 (v/v) proportion. Seedlings of *E. urophylla*, clone GG 100 were used. Fertilization was carried out during planting of the seedlings, when an equivalent amount of 300 kg ha^{-1} N-P-K (4-14-8) was added. At 42 days after planting (DAP), supplementary topdressing was applied using 5% urea (w/v). The growth regulator used was orthosulfamuron, as the commercial product Strada 50WG®, from the class of herbicides and plant growth regulators from the chemical group of sulfamoyl ureas, formulated in water-dispersible granules.

Experimental design and ripener application

We used a completely randomized experimental design with nine treatments in four replicates. The treatments consisted of eight doses of orthosulfamuron plus one treatment without application of the product (control), using the recommended dose (RD) of 75.0 g a.i. ha^{-1} as the standard. The following doses of orthosulfamuron were used: 1.17; 2.34; 4.69; 9.38; 18.75; 37.5; 75.0 and 112.50 g a.i. ha^{-1}. In all sprayed treatments, mineral oil was added to the spraying (0.1% v/v).

Orthosulfamuron was applied to eucalyptus seedlings with an average height of 46.1 cm, 15 days after transplanting. A backpack sprayer (CO_2) equipped with a spray tip model XR 11002, with a constant pressure of 2.2 bar and a spray volume of 200 L ha^{-1} was used. At the time of application, the relative air humidity was 68%, with an average temperature of 26°C, between 16:48 and 17:20 h.

Growth assessment

Plant height measurements were carried out at 14, 28, 42, and 63 days after application (DAA). At 63 DAA, stem diameter (digital caliper, ZAAs precision), leaf area (LiCor meter, LI 3000), and the dry matter of stem and branches (SBDM), leaves (LDM), and roots (RDM) were determined. Dry matter was obtained after drying the materials in a forced air circulation oven at 70 ± 2°C until reaching constant mass. The absolute growth rate in height (AGR) was calculated, where: AGR = ($Height_{63DAA}$ – $Height_{0DAA}$)/63 (cm day^{-1}).

Data analysis

The data obtained were submitted to analysis of variance by the F test and, when significant, the means were compared by Tukey test at 5% probability.

RESULTS

The height of eucalyptus plants at 14 DAA did not differ between plants treated with orthosulfamuron and the control (Table 1). At 28 DAA, the doses of 9.56 and 19.12 g a.i. ha^{-1} stood out with an 8.65% increase in plant height for both treatments when compared to the control. However, in the following evaluations, at 42 and 63 DAA, although these two doses presented a tendency to increase plant height, they did not significantly differ from the control or from the other doses, demonstrating that the probable effect of hormesis was temporary. These results demonstrate no damages to plant height caused by the application of orthosulfamuron were observed up to 63 DAA. In general, the AGR (Table 1) did not differ between treatments and values between 0.28 and 0.34 cm day^{-1} with an average AGR of 0.31 cm day^{-1} were observed, demonstrating again that the product did not affect the height growth of eucalyptus plants.

Table 1: Effect of orthosulfamuron doses on the height (cm) of *Eucalyptus urophylla* seedlings, clone 'GG100', at 0, 14, 28, 42, and 63 days after application (DAA) and absolute growth rate (AGR, cm day^{-1}) in the period from 0 to 63 DAA.

Tabela 1: Efeito das doses de orthosulfamuron sobre altura (cm) de mudas de *Eucalyptus urophylla*, clone GG100, aos 0, 14, 28, 42 e 63 dias após a aplicação (DAA) e taxa de crescimento absoluto (TCA, cm dia^{-1}) no período de 0 a 63 DAA.

Treatments	Height (cm)					AGR
Dose (g a.i. ha^{-1})	0 DAA	14 DAA	28 DAA	42DAA	63DAA	(cm day^{-1})
Control	43.9a	47.87a	52.0b	57.8a	63.5a	0.31a
1.17	46.1a	49.25a	52.9ab	57.8a	64.0a	0.28a
2.34	46.5a	49.87a	54.0ab	59.4a	66.0a	0.31a
4.69	45.6a	50.45a	54.5ab	59.2a	64.7a	0.30a
9.38	46.5a	51.37a	56.5a	61.4a	68.2a	0.34a
18.75	47.4a	51.12a	56.5a	59.6a	66.1a	0.30a
37.50	47.8a	51.00a	55.2ab	61.0a	67.6a	0.31a
75.00	45.6a	49.20a	54.2ab	60.0a	64.7a	0.30a
112.50	45.9a	49.00a	53.5ab	59.9a	65.1a	0.30a
F test	1.57ns	1.21ns	2.74*	1.92ns	1.25ns	1.72ns
MSD	4.27	5.07	4.39	4.27	6.77	0.08
CV(%)	3.89	4.27	3.39	3.01	4.34	4.21

Means followed by the same letter in the column do not differ statistically from each other at the 5% probability level by Tukey's test. ns= not significant (p >= 0.05) by the F test. MSD = minimum significant difference CV = Coefficient of Variation.

The doses and low doses of orthosulfamuron did not influence stem diameter growth, leaf area development, and the accumulation of LDM, SBDM, and RDM up to 63 days after application (Table 2) when compared to the control. These results demonstrate that even with the drift of this ripener at subdoses, at the standard dose or even at a dose 50% higher than the one recommended for sugarcane (75.0 g a.i. ha^{-1}), there was no damage to the initial growth of the 'GG100' eucalyptus seedlings. That is, the use of this ripener in sugarcane areas adjacent to eucalyptus proves to be safe or harmless in case there is a possible drift affecting the seedlings.

Table 2: Effect of orthosulfamuron doses on stem diameter (mm), leaf area (cm^2), and dry matter of leaves (LDM, g), stem and branches (SBDM, g) and roots (RDM, g) of *Eucalyptus urophylla* seedlings, clone 'GG100', at 63 days after application.

Tabela 2: Efeito das doses de orthosulfamuron sobre diâmetro do caule (mm), área foliar (cm^2) e matéria seca de folhas (MSF, g), de caule e ramos (MSCR, g) e de raiz (MSR, g) de mudas de *Eucalyptus urophylla*, clone GG100, aos 63 dias após a aplicação.

Treatments	Diameter	Leaf area	Dry matter (g)		
Dose (g a.i. ha^{-1})	(mm)	(cm^2)	MSF	MSCR	MSR
Control	8.40a	740.7a	11.28a	7.37a	6.41a
1.17	8.88a	765.0a	13.59a	8.08a	7.38a
2.34	9.02a	768.1a	10.35a	7.20a	7.53a
4.69	9.20a	742.1a	10.57a	6.98a	6.68a
9.38	8.85a	813.5a	13.74a	9.05a	7.76a
18.75	8.74a	587.5a	11.95a	7.86a	7.65a
37.50	8.40a	823.6a	13.18a	8.58a	6.83a
75.00	8.31a	749.7a	10.30a	7.32a	6.15a
112.50	8.90a	587.5a	10.95a	7.41a	6.34a
F test	0.68^{ns}	0.69^{ns}	1.76^{ns}	1.01^{ns}	1.70^{ns}
DMS	1.78	495.0	5.02	3.29	2.25
CV (%)	8.57	28.46	17.95	17.83	13.59

Means followed by the same letter in the column do not differ statistically from each other at the 5% probability level by Tukey's test. ns= not significant (p >= 0.05) by the F test. MSD = minimum significant difference CV = Coefficient of Variation.

DISCUSSION

Studies carried out with low doses of glyphosate in *Eucalyptus urograndis* revealed the effect of hormesis when glyphosate was applied at doses between 3.6 and 93.7 g a.i. ha^{-1}, and an increase in plant height between 5.92 to 33.18% was observed at 42 DAA (PEREIRA *et al.*, 2013). However, Cerveira Junior *et al.* (2020) did not verify the effects of hormesis in two different clones of E. *urograndis* (GG100 and I144) under application of increasing doses of glyphosate (9, 18, 36, 72, 90, 180, 360, 720 and 1440 g a.i. ha^{-1}) and noted that the magnitude of the effects of glyphosate on initial growth and leaf morphology depend on the genotype of the clones involved, as well as on the type of application, the metabolization of the product by the plant, and its gas exchanges with the medium, that is, specific plant properties.

Pires *et al.* (2019) analyzed the effect of low doses of trinexapac-ethyl (15, 30, 45, 60, 75, and 90 g a.i. ha^{-1}) on the initial growth of *E. urograndis* seedlings and verified that all doses increased the growth of eucalyptus plants (height and root dry matter) at 35 DAA through foliar spraying. Regarding seedling height, the dose of 60 g a.i. ha^{-1} presented better performance compared to the plant without application, presenting a 12.8% increase.

Correia and Villela (2015) studied the effect of application of the ripener trinexapac-ethyl to young plants of *E. urograndis* at the recommended dose for sugarcane (200 g a.i. ha^{-1}) and at low doses (2; 5; 10, 20, 50, 100 g a.i. ha^{-1}) and noted that all treatments stimulated stem diameter growth at 15 and 30 DAA. However, the effect of increasing stem diameter growth was temporary, no longer being noticed at 60 DAA. This information provides evidence to the selectivity of trinexapac-ethyl to eucalyptus plants.

In this same study by Correia and Villela (2015), sulfometeuron methyl was evaluated in eucalyptus plants through the application of 100% of the recommended dose for sugarcane (15 g a.i. ha^{-1}) and the application of different dosages (1, 0; 2.5; 5.0; 10; 25; 50). The authors observed that eucalyptus plants presented mild injuries up to 30 DAA with subsequent recovery (60 DAA) and absence of visual signs of phytotoxicity or growth alteration at low doses of 5, 10, and 25%, while severe injuries were identified, with death of the apical buds, at doses of 50 and 100% at 30 DAA. Thus, it is considered that low doses of up to 25% of the recommended dose of sulfometeuron-methyl are selective for young eucalyptus plants, not interfering with their growth.

The results found in the Table 2, may be due to a genotypic characteristic of the clone regarding its morphological (for example, the amount and composition of waxes on the leaves) or physiological (product absorption and translocation process) traits, which reflect on the process of greater or lesser absorption of the growth regulator (CARVALHO; ALVES; COSTA, 2015).

Some studies have reported positive and negative effects of low doses of glyphosate on eucalyptus plants, including hormesis (VELINI *et al.*, 2008). However, these effects depend on factors such as plant species (VELINI *et al.*, 2008), genotypes (CARVALHO; ALVES; COSTA., 2015), period after treatment (NASCENTES *et al.*, 2015), plant age, plant physiological status (CARVALHO; ALVES; DUKE, 2013), and environmental factors (BELZ; DUKE, 2014).

Orthosulfamuron belongs to the class of sulfamoyl ureas and is used as a growth regulator for sugarcane and as an herbicide for rice crops (MAPA, 2020). It is selective and has systemic action, being used in early post-emergence of weeds with broad and narrow leaves, perennial and annual. It is absorbed by leaves and roots and translocated through the apoplastic and symplastic pathways. It inhibits the enzyme acetolactate synthase (ALS), which catalyzes the first step of the amino acid biosynthetic pathway, compromising branched-chain amino acids (valine, leucine, and isoleucine), interfering with DNA synthesis, and interrupting cell division and plant growth (MACBEAN, 2012). As a ripener, the sucrose storage process in the stem occurs instead of the emission of new leaves through the inhibition of cell division and growth, which leads to a pith decrease, consequently resulting in a raw material of better quality.

Selectivity consists of a differential level of tolerance of plants to a given product. The mechanisms of plant tolerance to ALS-inhibiting herbicides can be classified into two distinct groups. The first group is related to the mechanisms of the active site, such as the overexpression of proteins linked to the target enzyme (POWLES; SHANER, 2001), the multiple copies of the target enzyme (GAINES *et al.*, 2010), and the alteration of the ALS enzyme, which makes it insensitive to herbicides from different chemical groups (CRUZ-HIPOLITO *et al.*, 2013). The second group expresses mechanisms unrelated to the active site, such as reduced absorption, reduced translocation, metabolization, and degradation of herbicides by cytochrome P450 monooxygenase enzymes (cytP450) (DALAZEN *et al.*, 2018). Thus, it is assumed that the *E. urophylla* clone 'GG 100' employs some of these tolerance mechanisms, or a set of mechanisms, in its detoxification process or in the inhibition of the action of the growth regulator a in its physiological metabolism before its storage in the vacuole or even before orthosulfamuron molecules bind to insoluble cellular structures, such as lignin, metabolizing it into non-toxic compounds (ANDERSON; SWAIN, 1992).

Bacha *et al.* (2019), who studied the application of trinexapac-ethyl at doses of 30 and 60 g a.i. ha^{-1} to the clone 'I-144' of *Eucalyptus urophylla* after planting, noted that the application of 60 g a.i. ha^{-1} of the ripener under conditions of no water deficit provided a beneficial effect on stomatal conductance and transpiration (gas exchange) at 3 DAA. At 50 DAA, the application of 30 g a.i. ha^{-1} of trinexapac-ethyl favored stomatal conductance. The application of the ripener increased the chlorophyll content in the plants. Under water deficit conditions, at 3 DAA, the highest dose of the product had a positive effect on the net CO_2 assimilation rate. The authors showed that the application of the ripener, under water deficit conditions or not, favored the photosynthetic process, which underscores the idea that, in the present study, there was a metabolization of the ripener by the plant due to the improvement of some physiological characteristics such as stomatal conductance, respiratory rate or net CO_2 assimilation, factors that may have potentiated or favored photosynthesis and photosynthate accumulation.

In other studies, it was also verified that the application of ripeners at low doses did not interfere in the eucalyptus development. According to Pires *et al.* (2013), the application of low doses of the ripeners sulfometuron-methyl (1.2 g ha^{-1} and 1.6 g ha^{-1}) and trinexapac-ethyl (0.06 L ha^{-1} and 0.08 L ha^{-1}) did not cause harmful effects to the growth of *E. urograndis* seedlings up to 42 DAA.

CONCLUSION

- There were no deleterious effects of the application of orthosulfamuron, up to 112.5 g a.i. ha^{-1}.
- On the development and growth of seedlings of *Eucalyptus urophylla*, clone GG 100, up to 63 days after application.

REFERENCES

ANDERSON, J. L.; SWAIN, R. S. Metabolism of sulfometuron-methyl in wheat and its possible role in wheat intolerance. **Journal of Agricultural and Food Chemistry**, Washington, v. 40, n. 11, p. 2279-2283, 1992.

BACHA, A.L. *et al*. Effect of trinexapac-ethyl, at two applicationtimings, on the initial development of eucalyptus under water deficit. **Planta Daninha**, Viçosa, v. 37, p. 1-12, 2019.

BELZ, R. G.; DUKE, S. O. Herbicides and plant hormesis: herbicides and plant hormesis. **Pest Management Science**, Hoboken, v. 70, n. 5, p. 698–707, 2014.

CALABRESE, E. J.; BALDWIN, L. A. Defininghormesis. **Human and Experimental Toxicology**, London, v. 21, p. 91-97, 2002.

CARVALHO, L. B.; ALVES, P. L. C. A.; COSTA, F. R. Differential response of clones of eucalipto toglyphosate. **Revista Árvore**, Viçosa, v.39, n.1, p.177-187, 2015.

CARVALHO, L. B.; ALVES, P. L. C. A.; DUKE, S. O. Hormesiswithglyphosatedependsoncoffeegrowthstage. **Annals of the Brazilian Academy of Sciences**, Rio de Janeiro, v. 85, n. 2, p. 813-822, 2013.

CERVEIRA JUNIOR, W. R. *et al.* Growth, morphological, metabolic and photosynthetic responses of clones of eucalyptus to glyphosate. **Forest Ecology and Management**, Amsterdam, e118218, p. 470–471, 2020.

CHECHETTO, R. G. *et al*. Influence of spray nozzles and adjuvants in drift reduction potential in wind tunnel. **Semina: Ciências Agrárias**, Londrina, v. 34, n. 7, p.37-46, 2013.

CORREIA, N. M.; VILLELA, G. B. Trinexapac-ethyl and sulfometuron-methyl selectivity to young eucalyptus plants. **Planta Daninha**, Viçosa, v. 33, n. 2, p. 259-266, 2015.

COSTA, L. L.; POLANCZYK, R. A. **Tecnologia de aplicação de caldas fitossanitários**. 1°Ed. Jaboticabal: Funep, 2019.

CRUZ-HIPOLITO, H. *et al.* Resistance mechanism to tribenuron-methyl in white mustard (*Sinapis alba*) from southern Spain. **Weed Science**, Cambridge, v. 61, p. 341-347, 2013.

DALAZEN, G.; *et al.* Degradation enhancement as the mechanism of resistance to imazethapyr in barnyardgrass. **Planta Daninha**, Viçosa, v.36:e018179504, p. 1-13, 2018.

GAINES, T. A. et al. Gene amplification confers glyphosate resistance in *Amaranthus palmeri*. **Proceedings of National Academy of Sciences of USA**, Washington, v. 107, n. 3, p. 1029-1034, 2010.

INDÚSTRIA BRASILEIRA DE ÁRVORES. **Relatório 2022**. Brasília: IBÁ, 2022. Disponível em: https://www.iba.org/datafiles/publicacoes/relatorios/relatorio-anual-iba2022-compactado.pdf. Acesso em: 03 may. 2022.

LEITE, G. H. P.; CRUSCIOL, C. A. C. Reguladores vegetais no desenvolvimento e produtividade da cana-de-açúcar. **Pesquisa Agropecuária Brasileira**, Brasília, v.43, n.8, p. 995-1001, 2008.

MACBEAN, C. **The pesticide manual:** a world compendium. 16. ed. Hampshire: Cabi, 2012.

MINISTÉRIO DA AGRICULTURA, PECUÁRIA E ABASTECIMENTO (MAPA). AGROFIT - Sistema de Agrotóxicos Fitossanitários. 2020. Disponível em http://agrofit.agricultura.gov.br/agrofit_cons/principal_agrofit_cons. Acesso em: 05 ago. 2020.

NASCENTES, R. F. *et al.* Hormesis de glyphosate em *Brachiaria brizantha* cv. Marandu. **Cerrado Agrociências**, Patos de Minas, v. 6, n. 1, p. 55–64, 2015.

PEREIRA, F. C. M. *et al.* Response of eucalyptus (*Eucalyptus urograndis*) plants at different doses of glyphosate. **Journal of Agricultural Science**, Toronto, v. 5, n. 1, p. 66-74, 2013.

PETRINI, M. A.; ROCHA, J. V.; BROWN, J. C. Mismatches between mill-cultivated sugarcane and smallholding farming in Brazil: Environmental and socioeconomic impacts. **Journal of Rural Studies**, v. 50, p. 218–227, 2017.

PIRES, R. N. *et al*. Effects of the simulated drift of ripeners on *Eucalyptus urograndis*. **Journal of Agricultural Science**, Toronto, v. 5, n. 12, p. 78-86, 2013.

PIRES, R. N. *et al*. Pode o etiltrinexapac estimular o crescimento de mudas de eucalipto? **Ciência Florestal**, Santa Maria, v. 29, p. 385, 2019.

POWLES, S. B.; SHANER, D. L. Herbicide resistance and world grains. In: POWLES, S. B.; SHANER, D. L. (Ed.). **Herbicide resistance and world grains**. Boca Raton: CRC Press, 2001.

SEPLAG. SECRETARIA DE ESTADO DO PLANEJAMENTO, GESTÃO E PATRIMÔNIO. **Diversificação produtiva como alternativa para a área canavieira de Alagoas**. Maceió: SEPLAG. 2017. 29 p. Disponível em: https://dados.al.gov.br/catalogo/dataset/fab1d5e2-e649-40fd-a965-cd5b73235914/resource/cba8eba9-8254-4056-ad08-dc8c07268188/download/canavieira.pdf. Acesso em: 22 ago. 2021.

VELINI, E. D. *et al.* Glyphosate applied at low doses can stimulate plant growth. **Pest Management Science**, Chichester, v. 64, n. 4, p. 489-496, 2008.