Brief Report

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Efficacy of S-metolachlor + glyphosate for Weed Control in Different Levels of Eucalyptus Straw

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Abstract: The *Eucalyptus* genus is the most planted forest crop in the world, with Brazil being one of the countries with the greatest productive potential. However, the occurrence of weeds can cause losses in productivity. Chemical control is widely used, but the efficiency of herbicides depends on factors such as the presence of straw in the soil and the occurrence of rainfall. Due to the scarcity of results regarding the interaction between herbicide, straw, and water depth in the forest sector, the objective of this study is to evaluate the efficiency of *S*-metolachlor + glyphosate in the control of grasses in different densities of eucalyptus straw and with simulated rain after the application of the product. The experiment was conducted in DBC, factorial 3×3×2, with four replications. The first factor represented 0, 50 and 100% of the commercial dose of S-metolachlor + glyphosate, the second 0, 5, and 10 ton ha^{-2} of straw, and the third 25 and 50mm of water depth applied in soil with a mix of grasses previously sowed. The rainfall simulation was performed 24 hours after herbicide application on each straw volume. The fresh mass of the aerial part of the grasses was collected 43 days after sowing and dried in an oven to determine the dry mass. Visual analyzes of the percentage of control were performed with scales ranging from 0 to 100, where 0 represents no control and 100 efficient control. The fresh and dry mass and the grasses' dry mass/water ratio decreased with increasing herbicide dosage and straw density. The dosage of 2.12 + 1.59 kg i.a. ha^{-1} of S-metolachlor + glyphosate resulted in greater control of grasses, and the treatments without straw and with the application of the herbicide had the highest percentages of control. Applying different water depths (25 mm or 50 mm) did not influence the control. Despite the control of grasses, the efficiency of the herbicide mixture was affected by the presence of vegetation cover.

Keywords: forestry; grasses; herbicide; simulated rain

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1. Introduction

The genus *Eucalyptus*, originating in Australia and belonging to the Myrtaceae family, stands out as the most planted forest crop in the world [1,2]. Brazil has the greatest eucalyptus production potential, with increasing productivity, reaching 38.9 m^3/ha/year and 7.53 million hectares planted [3]. However, biotic disturbances threaten eucalyptus cultivation [4]. Physiological disturbances such as pests, diseases, and weeds can cause losses, negatively impacting productivity [5]

Grasses such as *Digitaria insularis, Digitaria horizontalis, Panicum maximum, Brachiaria decumbens* and *Brachiaria brizantha* were identified by the Ministry of Agriculture, Livestock, and Supply as priority pests in eucalyptus cultivation [6]. These species have a high ability to absorb and use nutrients [7], leading to nutritional imbalance, especially in the initial development of Eucalyptus [8]. Thus, weed control is essential for crop growth and yield [9].

Chemical control is widely used in eucalyptus cultivation [10], and about 207 products are registered in Brazil [11]. The glyphosate herbicide is used in agricultural and forestry crops, the increase in the use of this product was due to the adoption of the technology of genetically modified organisms tolerant to the herbicide [12]. The main glyphosate-tolerant crops are food crops or used in the production of biofuels, but transgenic eucalyptus has already been developed and released for planting in Brazil [13,14].

The constant use of glyphosate caused an increase in the number of resistant weed biotypes, requiring control alternatives [15]. Thus, the number of herbicides applied in pre-emergence and mixtures of products with different mechanisms of action increased [16]. In addition, the recent release of herbicide-tolerant eucalyptus may cause changes in chemical weed management in forest stands.

The most used herbicides include flumioxazin, glyphosate, indaziflam, isoxaflutole, oxyfluorfen, saflufenacil, and S-metolachlor [17-20]. S-metolachlor is a herbicide derived from chloroacetamide applied pre-emergence or incorporated pre-planting [21]. The product originated from a mixture of S-metolachlor and glyphosate. It has systemic action and, as it contains S-metolachlor in its formulation, has residual action on the germination and emergence of weeds [11].

Herbicides applied pre-emergence promote early weed control and help manage resistant biotypes [22-24]. However, the efficiency of these molecules depends on their bioavailability in the solution, the physicochemical characteristics of the soil, the method of preparing the area, and climatic factors during and after application [25-29].

Straw can be found in forested areas, where crop residues remain covering the soil, affecting the effectiveness of herbicides applied in subsequent cycles [17]. This is because herbicides, mainly pre-emergent, have to cross this barrier and reach the soil to control the seed bank [30,31]. However, straw also reduces exposure to light, photosynthesis, and, consequently, the emergence of weeds [32,33]; in addition to benefiting the soil with moisture, nutrients and an environment conducive to the microbiota [34].

The occurrence of rain is essential for the herbicide to pass through the straw and reach the soil solution [35], but in dry conditions, there is retention and adsorption of these products to the straw, which reduces weed control [36,37]. Thus, the efficiency of pre-emergent herbicides applied under straw depends on the product's characteristics, the nature and amount of straw in the soil, and rainfall [17]. Studying the interaction between these three factors is essential, especially in the forest sector, where these studies are little explored. This work aimed to evaluate the efficiency of the herbicide S-metolachlor + glyphosate (Sequence®) in the control of grasses in different densities of eucalyptus straw and with simulated rainfall after application of the product.

2. Material and Methods

2.1. Location and Soil

The experiment was carried out at the JK Campus of the Federal University of the Vales of Jequitinhonha and Mucuri, in Diamantina, Minas Gerais, Brazil, between November and December 2022, in a climate-controlled greenhouse with a minimum temperature of 15.3°C, a maximum of 43°C. 6ºC, and average 26.8ºC.

The soil was collected in Curvelo, Minas Gerais, Brazil (Table 1), sieved through a 4mm mesh, and fertilized as recommended for pastures in Minas Gerais, Brazil [38].

Table 1. Physical-chemical characteristics of the soil samples used in the experiment.

pH	P	K	Ca	Mg	Al	H+Al	SB	(t)	T	V	m	MO
($H_2$0)	mg dm^{-3}		----------------cmolc dm^{-3}------------------							---%---		dag kg^{-1}
5,5	2,3	88	1,24	0,44	0,1	2,97	1,91	2,01	4,88	39,1	5,0	1,9
P-rem	Zn	Fe	Mn	Cu	B		Sand			%	6	

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mg L^{-1}	-----------mg dm^{-3}-----------					Clay	69
20,1	2,0	37,8	148,	0,8	0,1	Silt	25

Source: Viçosa Soil Analysis Laboratory, LTDA. pH in water, KCl and CaCl Ratio 1:2.5; P - K - Fe – Zn - Mn – Cu - Mehlich extractor 1; Ca - Mg - Al - Extractor: KCl - 1 mol/L; H + Al - Calcium Acetate Extractor 0.5 mol/L - pH 7.0; S - Extractor - Monocalcium phosphate in acetic acid; SB = Sum of Exchangeable Bases; CEC (t) - Effective Cation Exchange Capacity; CEC (T) - Cation Exchange Capacity at pH 7.0; V = Base Saturation Index; m = Aluminum Saturation Index; Mat. Org. (MO) = C.Org x 1.724 - Walkley-Black; P-rem = Remaining Phosphorus.

2.2. Experimental Design

The experiment was designed in randomized blocks, in a 3×3×2 factorial, with four replications. Where the first factor represented the doses of the herbicide S-metolachlor + glyphosate (Sequence ®), equivalent to 0, 50, and 100% of the recommended commercial dose for eucalyptus (0; 1.06 + 0.79 and 2.12 + 1 .59 kg ai ha^{-1}); the second factor the straw density (0; 5 and 10 ton ha^{-2}), and the third the applied water depth (25 and 50mm).

2.3. Conducting the Experiment

The grass mix is composed of *Digitaria insularis*, *Urochloa brizantha* cv. marandu, *U. brizantha* cv. piatã, and *U. decumbens*, in equal proportions, were sown in trays with an individual capacity of 10L and an area of 0.28 m^2, containing sieved and fertilized soil. Grasses were chosen based on their occurrence in forest plantations and competition with eucalyptus plants. The eucalyptus straw was collected, weighed, and distributed in trays according to the pre-established treatments (0 and 10 ton ha^{-2}).

About 24 hours after sowing the grasses and adding the straw, the herbicide S-metolachlor + glyphosate (Sequence ®) was applied to the experimental units, according to the defined doses and with the aid of the electric backpack sprayer Yamaho FT5®, the capacity of 5L.

The rainfall simulation was carried out 24 hours after herbicide application, using the sprinklers coupled in the greenhouse, with an intensity of 0.3mm min^{-1}. The blades applied corresponded to 25 and 50mm, varying according to the treatments. Irrigation was performed daily, maintaining the humidity between 60 and 70% of field capacity.

2.4. Evaluated Parameters

The aerial part of the grasses was collected 43 days after the sowing of the grasses (DAS) and weighed on a precision scale to establish the fresh mass. Subsequently, they were packed in paper bags, taken to an oven with forced air circulation at 60ºC until constant mass, and weighed to determine the dry mass.

Visual assessments of the percentage of control were performed at 43 DAS, with scales ranging from 0 to 100, where 0 represents no control and 100 efficient control.

2.5. Statistical Analysis

Analysis of variance (ANOVA) was performed using the F test, and when significant, the means were compared using the Tukey test at 95% probability with the statistical program R® version 4.1.1. Response surface graphs were generated using SigmaPlot® software version 12.0.

3. Results and Discussions

The fresh and dry mass of the grasses, in the treatments without the application of S-metolachlor + glyphosate and under the effect of the dose of 1.06 + 0.79 kg i.a. ha-1, were lower in the density of 10 ton ha-2 of eucalyptus straw (Table 2). The lower dry and fresh mass of grasses under the effect of higher straw density, with none or 50% of the recommended herbicide dose, is due to the control performed by this soil cover [39]. Grasses need an optimal temperature for germination between 25-35ºC [40-42]; however, the presence of a greater volume of straw can reduce the average daily temperature of the soil [43], which, together with less exposure to light and restrictions on the emergence of the epicotyl, results in a decrease in germination and, consequently, in the fresh and dry mass [44].

Table 2. – Fresh mass (g), dry mass (g), and fresh mass/dry mass ratio (g) of grasses at 43 days after sowing under 0, 5, and 10ton ha^{-2} of eucalyptus straw and application of 0.50 and 100% (0; 1.06 + 0.79 and 2.12 + 1.59 kg i.a. ha^{-1}) of the commercial dose of S-metolachlor + glyphosate (Sequence®).

Variable	Straw (ton ha^{-2})	*S*-metolachlor + glyphosate (kg i.a. ha^{-1})			CV%
		0	1,06 + 0,79	2,12 + 1,59	
Fresh mass (g)	**0**	155,31 Aa	54,79 Ab	12,34 ^{NS}c	21,1
	5	127,33 Aa	44,08 Ab	12,92 ^{NS}c	
	10	82,71 Ba	27,13 Bb	21,63 ^{NS}c	
Dry mass (g)	0	43,10 Aa	8,92 Ab	1,32 Cc	26,1
	5	32,86 Ba	7,82 Ab	1,73 ABc	
	10	19,15 Ca	3,90 Bb	2,92 Ab	
Dry mass/water ratio	0	0,397 Aa	0,216 ^{NS}b	0,105 ^{NS}c	20,3
	5	0,348 ABa	0,217 ^{NS}b	0,156 ^{NS}c	
	10	0,299 Ba	0,175 ^{NS}b	0,150 ^{NS}b	

NS: not significant by F-test at 95% probability. Means followed by the same letter, case in the column and lowercase in the row, do not differ by the Tukey test at 95% probability. CV: Coefficient of variation (%).

In general, grasses' fresh and dry mass decreased with increasing herbicide dosage (Table 2). The lowest fresh and dry mass of grasses submitted to the herbicide S-metolachlor + glyphosate occurred because S-metolachlor targets the condensing enzyme 3-ketoacyl-CoA synthase, which stops cell multiplication and division, inhibiting growth and causing embryonic mortality [45,46]. In grasses, the product acts on the epicotyl, which generates reductions in the aerial part and biomass accumulation [34]. The grasses' dry mass/water ratio was also reduced with increasing doses of S-metolachlor + glyphosate (Table 2). Grasses subjected to a higher dose of S-metolachlor + glyphosate produced less biomass using the same amount of water, which suggests that water use efficiency decreased as a function of the amount of herbicide applied [47,48].

The greatest control occurred at the dosage of 2.12 + 1.59 kg, i.a. ha^{-1} of S-metolachlor + glyphosate. Treatments without straw and with herbicide application, regardless of the water level applied, obtained the highest control percentages (Figure 1). The highest percentage of control in the treatments without the presence of straw occurred because there was less herbicide adsorption. Even though it is partially adsorbed, commercial doses allow good availability of herbicides in the soil solution [49]. Herbicide adsorption is influenced by the product's and straw's physicochemical characteristics [50]. Soil cover from forest species generally has a higher presence of lignin and cellulose, which causes greater adsorption [49]. Despite glyphosate having low adsorption in straw [50,51], S-metolachlor has a solubility in water of 530 mg L^{-1} and a standardized sorption coefficient for organic carbon (Koc) of 200 L kg-1 [52,53], which results in high adsorption of this compound in organic materials [34,50]. In general, the herbicide straw interaction controlled the grasses. However, the greater efficiency in the isolated use of S-metolachlor + glyphosate suggests that the presence of vegetation cover may have an antagonistic effect on the product.

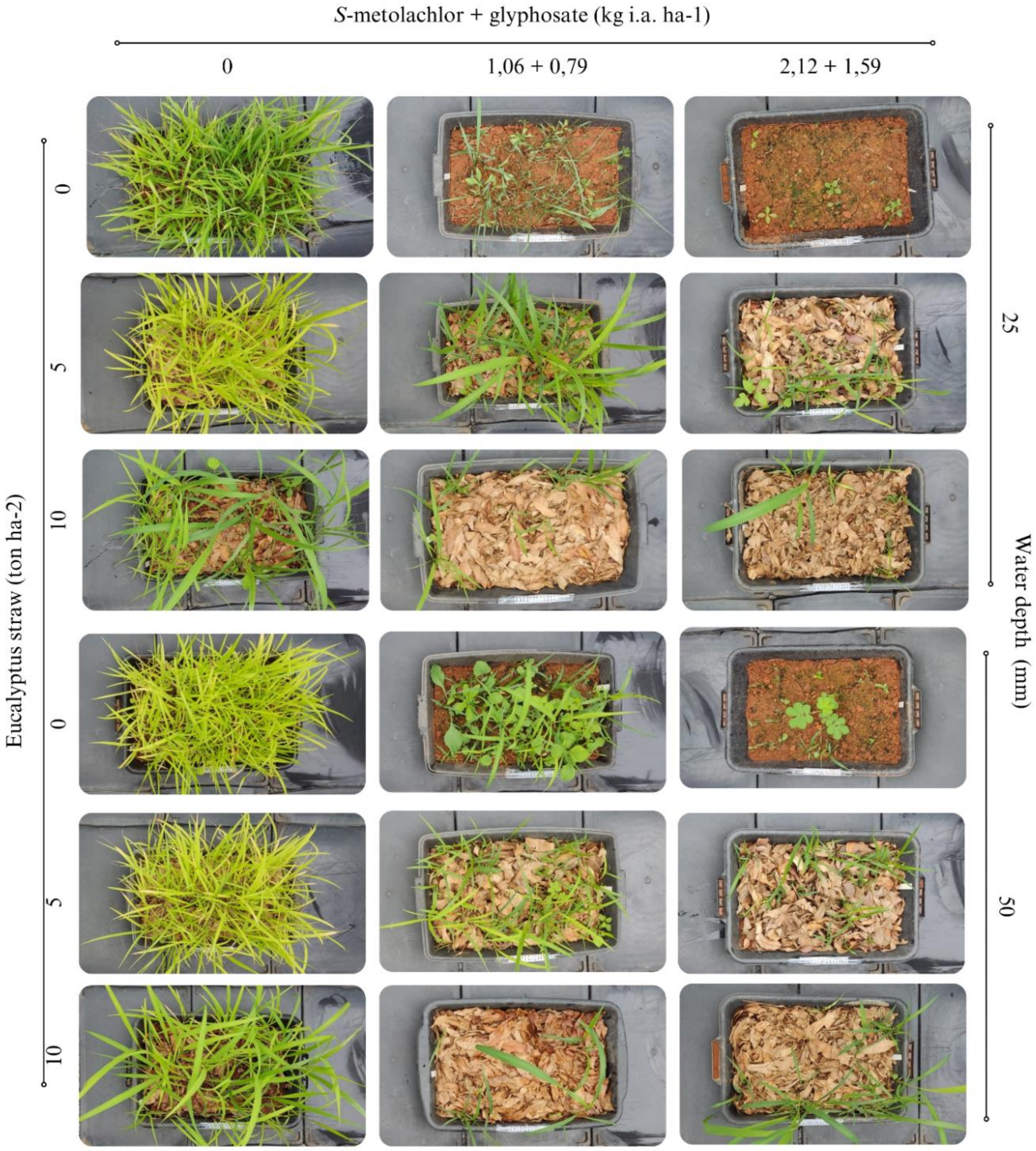

Figure 1. – Grasses at 43 days after sowing under 0, 5, and 10 ton ha^{-2} of eucalyptus straw, application of 0, 50, and 100% (0; 1.06 + 0.79 and 2.12 + 1.59 kg i.a. ha^{-1}) of the commercial dose of S-metolachlor + glyphosate (Sequence®) and water depth of 25 and 50 mm.

There was no significant difference in the percentage of grass control depending on the rainfall simulation (25 or 50 mm) (Figure 2). The water level applied after S-metolachlor + glyphosate did not influence the control of grasses because about 20 to 50mm of precipitation is needed for pre-emergent herbicides to cross the residues present in agricultural and forestry areas and reach the soil [17,54,55]. Harvest residues can retain, degrade and intercept herbicides [17]. Therefore, the occurrence and volume of rain after application can influence the efficiency of chemical control [56]; mainly causing the molecule to reach the soil and not remain in the straw, where microbial degradation may occur [57]. In this case, 25 and 50mm precipitations facilitated the herbicide molecule to cross the straw and reach the soil, controlling the grasses.

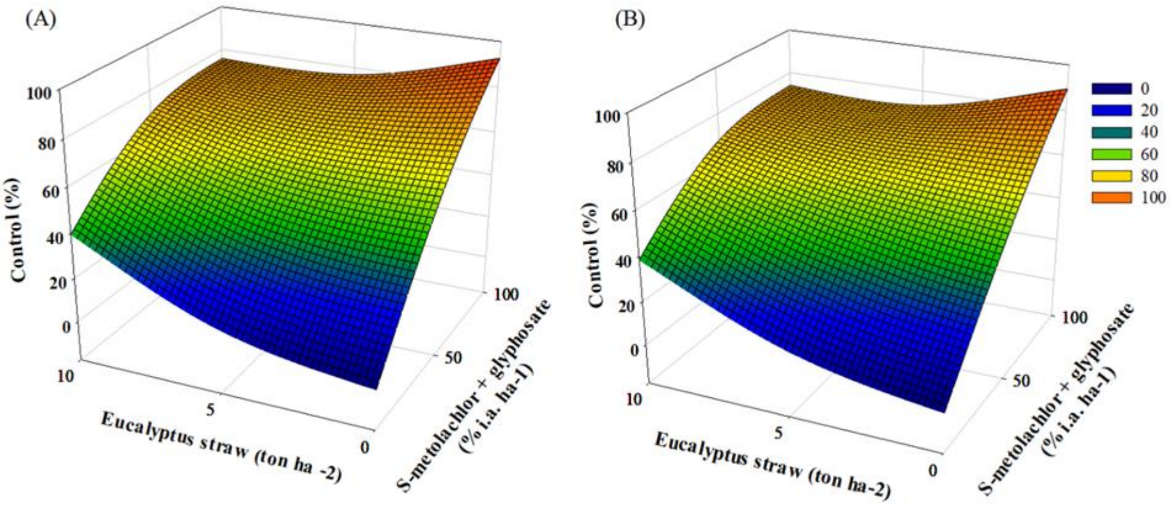

Figure 2. – Surface response of the percentage of grass control at 43 days after sowing, under 0, 5, and 10 ton ha^{-2} of eucalyptus straw, application of 0, 50, and 100% (0; 1.06 + 0.79 and 2.12 + 1.59 kg i.a. ha^{-1}) of the commercial dose of S-metolachlor + glyphosate (Sequence®) and water depth of 25 (A) and 50 mm (B).

4. Conclusions

The eucalyptus straw at a density of 10 ton ha^{-2} exerted control of approximately 40% without applying the herbicide and reduced the fresh and dry mass of the grasses.

The greatest control was observed without straw and at a dose equivalent to 100% of the commercial dose of S-metolachlor + glyphosate. This suggests that, in treatments with straw, the herbicide was partially adsorbed by the vegetation cover.

Grass control was not influenced by the rainfall simulation (25 and 50mm) performed after herbicide application.

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