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Glufosinate-based products in the pre-harvest desiccation of wheat

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ABSTRACT

Glufosinate is the only herbicide registered for the preharvest desiccation of wheat, with new commercial formulations available for this herbicide. Therefore, glufosinate-based products must be assessed for use in wheat crops. The aim of this study was to evaluate the efficacy of glufosinate-based products in the pre-harvest desiccation of wheat when applied at pre-physiological maturity or physiological maturity. The experiment was performed in two trials in Palotina, PR, in 2020, using a randomized block design with four replicates. The treatments included the application of doses of the commercial glufosinate-based products Finale, Patrol SL, and Trunfo (Trial 1), or Fascinate BR (Trial 2) at pre-physiological maturity or physiological maturity of wheat, as well as the untreated control. Wheat maturation and grain yield were also evaluated. The slowest wheat maturation occurred with the application of Fascinate BR and the fastest with Finale, especially at the highest dose. However, under the 2020 experimental conditions, all products were equally effective at all doses and stages, with no yield reduction. The pre-harvest desiccation of wheat with glufosinate-based products at pre-physiological maturity or maturity did not affect grain yield or the accelerated harvest by 4–5 days, with differences among the tested products.

Keywords: Grain yield, Herbicide, Maturation, Phenological stage, *Triticum aestivum* L.

Produtos à base de glufosinato na dessecação pré-colheita do trigo

RESUMO

O glufosinato é o único herbicida registrado para a dessecação pré-colheita do trigo, com novos produtos comerciais disponíveis para este herbicida. Assim, produtos à base de glufosinato devem ser avaliados neste uso no cultivo de trigo. Este estudo teve como objetivo avaliar a eficácia de produtos à base de glufosinato na dessecação pré-colheita do trigo, aplicados na pré - ou maturidade fisiológica do trigo. O experimento foi realizado em duas áreas em Palotina - PR, em 2020, com delineamento em blocos casualizados com quatro repetições. Os tratamentos incluíram a aplicação de doses dos produtos comerciais à base de glufosinato Finale, Patrol SL e Trunfo (área 1), ou Fascinate BR (área 2) em pré-maturidade fisiológica ou maturidade fisiológica do trigo, bem como a testemunha não tratada. A maturação do trigo e a produtividade de grãos foram avaliadas. A maturação mais lenta do trigo ocorreu com a aplicação do Fascinate BR e a mais rápida com o Finale, especialmente na dose mais alta. No entanto, de acordo com as condições experimentais em 2020, ao final das avaliações, todos os produtos em qualquer dosagem ou estágio foram igualmente eficazes e não apresentaram reduções de rendimento. A dessecação pré-colheita do trigo com produtos à base de glufosinato na pré-maturidade ou maturidade fisiológica não prejudicou a produtividade de grãos e antecipou a colheita em quatro a cinco dias, com diferenças entre os produtos testados.

Palavras-chave: Produtividade de grãos, Herbicida, Maturação, Estágio fenológico, *Triticum aestivum* L.

1. Introduction

Wheat (*Triticum aestivum* L.) is one of the most important cereals cultivated worldwide. Increasing national production remains a challenge in Brazil since the country is a major importer of this grain. However, with increased research, Brazil has become both an exporter and importer of wheat, with a tendency toward self-sufficiency (Klein and Vidal, 2024).

Preharvest desiccation with herbicides is performed to standardize plant maturation, accelerate harvest, control weeds, and/or reduce seed quality losses. Therefore, the technique is important for yield protection. Pre-harvest desiccation of wheat is a complex cultural treatment that can affect the efficacy, seed quality, and yield, depending on factors such as the application stage, herbicide or formulation, cultivar, and weather conditions (Krenchinski et al., 2017, Seidler et al., 2019). Studies have indicated reductions in yield or physiological quality of wheat seeds with desiccation with herbicides such as glufosinate, paraquat, glyphosate, clethodim, and diquat (Fipke et al., 2018; Fipke et al., 2021a; Krenchinski et al., 2017).

Glufosinate is a non-selective broad-spectrum herbicide (selective only for cultures with *pat* or *bar* genes) that inhibits glutamine synthetase. It presents limited contact and translocation actions, and the first symptoms are the yellowing of leaves and other green tissues, followed by wilting and death (Brito et al., 2018; Takano et al., 2019; Takano and Dayan, 2020). This herbicide is the only herbicide registered in Brazil for preharvest wheat desiccation at 350 g of the active ingredient (a.i.) ha^{-1} (MAPA, 2024; Rodrigues and Almeida, 2018).

Glufosinate application (400 a.i. ha^{-1}) pre-harvest at the milky to pasty, pasty to farinaceous, and hard farinaceous grain stages did not reduce wheat yield; moreover, it did not leave grain residue at the hard farinaceous stage (Perboni et al., 2018). Thus, this herbicide will remain relevant for managing the preharvest desiccation of wheat to standardize practices, control weeds, improve quality, and reduce harvest losses (Albrecht et al., 2022).

Currently, 58 glufosinate-based products are registered in Brazil (MAPA, 2025). Glufosinate is a recently developed post-patent herbicide, and most results in the literature on its use in pre-harvest desiccation refer to only 2 of the 58 formulated products. Because variations in weed control may occur in response to different formulations of glufosinate (Polli et al., 2022), differences in the effectiveness of preharvest desiccation of wheat may occur.

Since glufosinate is the only herbicide registered for the pre-harvest desiccation of wheat, and new commercial products are available, it is important to evaluate glufosinate-based products for pre-harvest wheat desiccation. Therefore, the aim of this study was to evaluate the efficacy of glufosinate-based products in the preharvest desiccation of wheat applied at pre-physiological or physiological maturity.

2. Material and Methods

The experiment was performed in two areas in Palotina (Paraná, Brazil) (Trial 1:24°20'48.1"S 53°51'49.2"W, altitude: 350 m; Trial 2:24°20'53.2"S 53°51'39.6"W, altitude: 361 m), in the winter harvest of the 2019–2020 crop season. The climate is humid subtropical, Cfa (*C* = mild temperate, *f* = fully humid, *a* = hot summer), according to the Köppen classification (Alvares et al. 2013). Figure 1 shows the weather conditions during the experimental period. The soils in the experimental areas were classified as very clayey, eutrophic Red Latosols (Santos et al., 2025).

The TBIO Capricho CL wheat cultivar were planted at both locations under no-till conditions and a row spacing of 17 cm. Fertilization was performed by sowing 400 kg ha^{-1} of 10-15-15 (N-P-K). This study used a randomized block design with four replicates and nine treatments (Table 1). The experimental units consisted of 6 × 3 meter plots.

Applications were performed using a CO_2-pressurized backpack sprayer equipped with six AIXR 110.015 tips at a pressure of 2 kgf cm^{-1} and speed of 3.6 km h^{-1}, providing an application volume of 150 L ha^{-1} (Table 2). Pre-physiological maturity applications were performed approximately 120 days after wheat emergence in both trials.

The assessments used four central length meters and discarded the two rows on each side. The maturation rate of wheat plants was assessed at 3, 5, 7, and 9 days after application (DAA) at the pre-physiological maturity of wheat (Trial 1) and up to 12 DAA in Trial 2. The maturation rate was based on the Feekes scale (Large, 1954). For Trial 1, application at pre-physiological maturity enabled wheat harvesting at 9 DAA, and that at physiological maturity enabled harvesting at 6 DAA.

Harvesting was accelerated by 4 days due to the application of glufosinate-based products, regardless of the product or dosage. In Trial 2, application at pre-physiological and physiological maturity enabled harvesting at 12 and 7 DAA, respectively.

For grain yield, all ears were harvested from the four central length meters. Two rows on each side plot were discarded, and the grain weight was corrected to 13% moisture. The yield results were expressed in kg ha^{-1}.

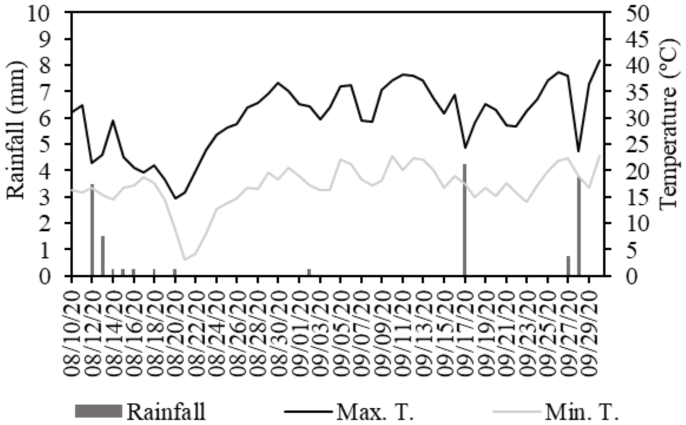

Figure 1. Representation of rainfall and temperature for the location of the experiments. Palotina, PR, 2020. (Source: weather station located at 24°10'44.5"S 53°50'16.4"W).

Table 1. Treatments by the application of glufosinate formulations in the pre-harvest desiccation of wheat. Palotina, PR, 2020.

Trial 1			Trial 2		
Product	Rate g ai ha^{-1}	Stage	Product	Rate g ai ha^{-1}	Stage
Untreated control	-	-	Untreated control	-	-
Finale[1]	350	PP	Finale[1]	350	PP
Finale[1]	350	PM	Finale[1]	350	PM
Finale[1]	400	PP	Finale[1]	400	PP
Finale[1]	400	PM	Finale[1]	400	PM
Patrol SL[2]	350	PP	Patrol SL[2]	350	PP
Patrol SL[2]	350	PM	Patrol SL[2]	350	PM
Trunfo[3]	350	PP	Fascinate BR[3]	350	PP
Trunfo[3]	350	PM	Fascinate BR[3]	350	PM

PP: pre-physiological maturity of wheat; PM: physiological maturity of wheat, according to the Feekes scale (Large, 1954). Adjuvant addition: [1]Mees (500 mL ha^{-1}), [2]Rumba (500 mL ha^{-1}), and [3]Lanzar (500 mL ha^{-1}).

Table 2. Dates and weather conditions during applications. Palotina, PR, 2020.

	Date	T	RU	Wind
		ºC	%	km h^{-1}
Trial 1 (PP)	Sep. 10, 2020	25.1	63.1	6.3
Trial 1 (PM)	Sep. 13, 2020	26.0	53.1	4.5
Trial 2 (PP)	Aug. 24, 2020	27.0	55.0	7.3
Trial 2 (PM)	Aug. 29, 2020	20.8	69.9	5.8

T: temperature, RU: relative humidity, PP: pre-physiological maturity of wheat, PM: physiological maturity of wheat.

Homogeneity of variances (Levene's test) and normality of residuals (Shapiro–Wilk test) tests were performed. With the assumptions met, the data were subjected to the analysis of variance (ANOVA) using the *F* test ($p \leq 0.05$). The Scott and Knott test grouped the treatment mean values ($p \leq 0.05$). Sisvar 5.6 software (Ferreira, 2011) was used for the analysis.

3. Results and Discussion

Trial 1 showed higher wheat plant maturation with glufosinate application at pre-physiological maturity (up to 62.5%) at 3 DAA, without differences in products or doses. However, the wheat plant stages differed. There was a higher maturation (93%) at 5 DAA, with the application of the highest dose of Finale at pre-physiological maturity being the highest of all treatments. Furthermore, maturation was higher when applications were performed at the pre-physiological maturity stage, without differences among products. The treatments were superior to the untreated control at 7 and 9 DAA, but without significant differences, and showed 100% maturation at 9 DAA (Figure 2).

In Trial 1, the temperatures were high between the first and second applications, with daily highs of around 35 °C, peaking at almost 40 °C, and approximately 4 mm of rain was recorded 4 DAA (Figure 1) at physiological maturity. These conditions favored the fast drying of plants that received glufosinate, similar to those observed by Albrecht et al. (2023) in the pre-harvest desiccation of soybeans with the same herbicide.

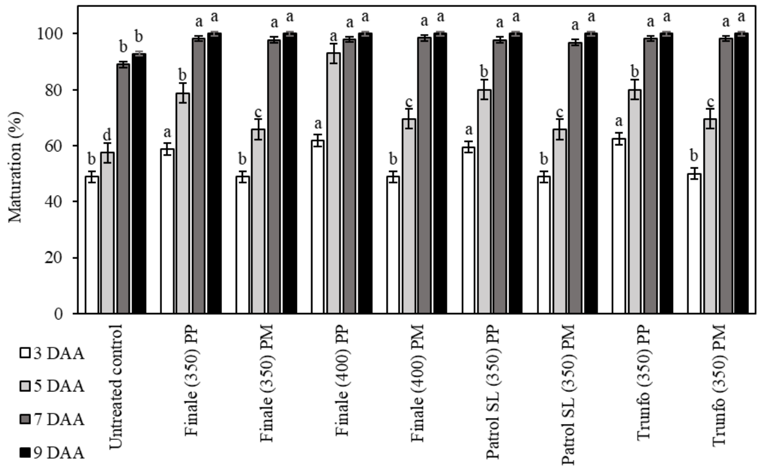

Figure 2. Maturation of wheat plants at 3, 5, 7 and 9 days after application (DAA) with application of glufosinate-based products at pre-physiological maturity (Trial 1). PP: pre-physiological maturity of wheat; PM: physiological maturity of wheat; rates in parentheses of the products in g ai ha^{-1}. Bars of the same color with the same letter do not differ from each other according to the Scott–Knott test at a 5% probability level. Vertical bars over the mean correspond to standard error (n = 4).

Environmental conditions may also affect the activity of glufosinate (Takano and Dayan, 2020). For instance, high temperatures (Kumaratilake and Preston, 2005) and light intensities (Sellers et al., 2003; Takano and Dayan, 2021) are beneficial under the action of this herbicide. Greater differences among the evaluated treatments may have been recorded if high temperatures, favorable for maturation, had not prevailed.

Trial 2 showed higher maturation with applications at pre-physiological maturity at 3 DAA, without differences in products or doses. There was a higher maturation with Finale (regardless of dose) and Patrol SL applications at pre-physiological maturity at 5 DAA. The results of Finale (both doses) application at pre-physiological maturity stood out at 7 DAA, with levels up to 84%. All the applied products promoted higher wheat plant maturation than the untreated control at 9 DAA, except for the application of BR at physiological maturity. Differences were detected between Finale and Patrol applications at prematurity, with favorable results for Finale. All herbicide treatments provided 100% wheat plant maturation at 12 DAA, which was superior to that of the untreated control 85.3% (Figure 3).

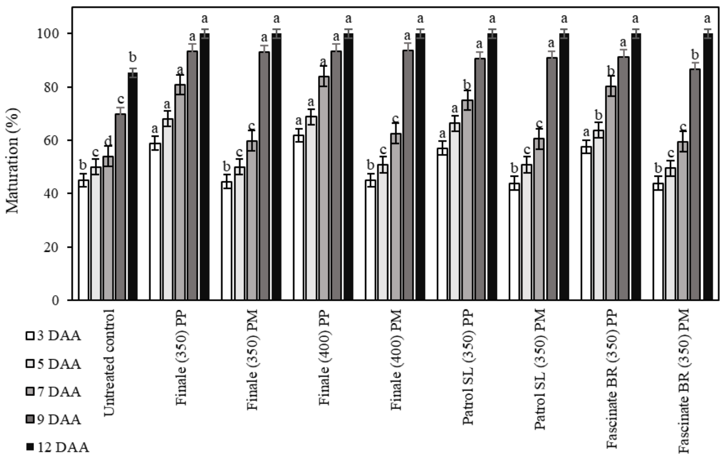

Figure 3. Maturation of wheat plants at 3, 5, 7, 9 and 12 days after application (DAA) with application of glufosinate-based products at pre-physiological maturity (Trial 2).
PP: pre-physiological maturity of wheat; PM: physiological maturity of wheat; rates in parentheses of the products in g ai ha^{-1}. Bars of the same color with the same letter do not differ from each other according to the Scott–Knott test at a 5% probability level. Vertical bars over the mean correspond to standard error (n = 4).

Trials 1 and 2 had average yields of 2,036 kg ha^{-1} and 2,798 kg ha^{-1}, respectively (Table 3). Low average wheat yields occurred due to the interaction between the yield potential of the genotype and environmental conditions, considering that dry and warm weather prevailed after the wheat spike, primarily affecting Trial 1. Perboni et al. (2018) emphasized the efficacy of glufosinate in accelerating wheat harvest in the milky to pasty, pasty to farinaceous, and hard farinaceous grain stages, without yield reduction.

Table 3. Yield of wheat plants under application of glufosinate-based products.

Trial 1				Trial 2			
Product	Rate g ai ha^{-1}	Stage	Yield kg ha^{-1}	Product	Rate g ai ha^{-1}	Stage	Yield kg ha^{-1}
Untreated control	-	-	1,852	Untreated control	-	-	2,538
Finale	350	PP	2,077	Finale	350	PP	2,854
Finale	350	PM	2,202	Finale	350	PM	3,017
Finale	400	PP	2,055	Finale	400	PP	2,815
Finale	400	PM	2,057	Finale	400	PM	2,918
Patrol SL	350	PP	2,006	Patrol SL	350	PP	2,824
Patrol SL	350	PM	1,978	Patrol SL	350	PM	2,784
Trunfo	350	PP	2,069	Fascinate BR	350	PP	2,760
Trunfo	350	PM	2,026	Fascinate BR	350	PM	2,676
Mean			2,036	Mean			2,798
CV (%)			6.4	CV (%)			7.1
F			ns	F			ns

PP: pre-physiological maturity of wheat; PM: physiological maturity of wheat, according to the Feekes scale (Large, 1954).
^{ns} Non-significant ($p < 0.05$); means do not differ according to the F-test.

Other studies have highlighted the use of this glufosinate modality in wheat (Krenchinski et al., 2017; Santos and Vicente, 2009; Tarumoto et al., 2015; Tavares et al., 2018) as an alternative to preharvest desiccation. Fipke et al. (2021b) verified wheat harvest acceleration with glufosinate application. However, contrary to the results of the present study, wheat yield reductions were observed, confirming the need for further research that considers the diversity of environments and genotypes.

According to the 2020 experimental conditions, all products and dosages were equally effective at all stages, and did not show yield reductions. There were no differences among the glufosinate formulations, which requires further clarification. Additional studies are needed to confirm whether increasing the Finale dose accelerates wheat maturation, considering potential gains in wheat quality and yield from earlier harvesting, as well as benefits to the productive system, such as clearing fields for the next crop. In addition, higher glufosinate doses may be valid for weed control at the end of the cycle if it does not affect the final yield, enabling the delivery of a crop area that is clearer from weeds to introduce the next crop.

The slowest wheat maturation occurred with the application of Fascinate BR and the fastest with Finale, especially at the highest dose. The maturation rate with one of the application modes of Patrol was slower than that of Finale in Trial 2. These results indicated the potential differences between commercial formulations/products.

Most studies assessing glufosinate for the pre-harvest desiccation of wheat use Finale or Liberty. Few studies have compared or evaluated different products, which strengthens the significance of the present study after the patenting of glufosinate. There are also a few studies on weed control that compare formulations of glufosinate-based products, which potentially differ in efficacy. However, their interactions with other factors, such as species and application technology, are complex (Polli et al., 2022).

Ammonium-salt formulations are used in most commercial glufosinate-based products (Takano and Dayan, 2020). There are other possibilities for synthesizing different glufosinate formulations (Tang et al., 2021; Zhou et al., 2020), but at a higher cost than the most common and available formulation (Takano and Dayan, 2020). All products used in this study and all commercial products registered in Brazil contain an ammonium salt (MAPA, 2025). Notably, despite having the same ammonium salt composition, different commercial products or formulations may differ in their active ingredient concentrations and the composition/concentration of surfactants and other components. All these factors may influence the effect of herbicides on weed control or pre-harvest desiccation.

4. Conclusions

Pre-harvest desiccation of wheat with glufosinate-based products at pre-physiological maturity or maturity did not harm grain yield and accelerated harvest by 4–5 days, with differences among the products.

Authors' Contribution

Conceptualization and methodology: Leandro Paiola Albrecht, Alfredo Junior Paiola Albrecht, André Felipe Moreira Silva; data collection and curation: William Felipe Larini, Emanuele Scapin Piccin, Lucas Martins da Silva; formal analysis: André Felipe Moreira Silva; data interpretation: Leandro Paiola Albrecht, Alfredo Junior Paiola Albrecht, André Felipe Moreira Silva; project administration: Leandro Paiola Albrecht, Alfredo Junior Paiola Albrecht; supervision: Leandro Paiola Albrecht, Alfredo Junior Paiola Albrecht; original draft preparation: André Felipe Moreira Silva; writing-review and editing: William Felipe Larini, Emanuele Scapin Piccin, Lucas Martins da Silva, Leandro Paiola Albrecht, Alfredo Junior Paiola Albrecht. All authors read and approved the final version of the manuscript.

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