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Chemical weed management in autumn and its effect on soybean grain yield

Manejo químico de daninhas no outono e seu efeito no rendimento de grãos de soja

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Abstract

The chemical control of weeds in autumn, after the summer harvest, is a good agricultural practice with the potential to contribute to the reduction of the soil seed bank and to the prevention of pests and diseases that affect commercial crops from persisting in the area. This management practice is highly neglected by farmers in Rio Grande do Sul. The objective of this study was to evaluate the efficiency of herbicides in controlling weeds after soybean harvest and to assess the influence of this management on the biomass of the cover crop mix in winter and on soybean yield the following summer. The experiment was conducted in the field, using a randomized block design, with seven treatments and four replications. The treatments consisted of six herbicide applications and one untreated control. Weed control was evaluated at eight, 14, and 28 days after application. At 28 days after application, the dry mass of the weeds was also evaluated. In the spring, the fresh and dry mass of the cover crop mix was assessed, and in the summer, the productivity and yield components of soybean were evaluated. Rye control was more effective with the combination of glyphosate+cletodim, and for the control of volunteer Intacta 2 Xtend soybean, the combination of glyphosate with the herbicides 2,4-D or metsulfuron-methyl is recommended. The highest dry biomass production of the soil cover crop mix was observed in the treatment without herbicide application in the fall. Just one year of fall chemical management was not sufficient to demonstrate benefits of this agronomic practice in increasing soybean grain yield.
Keywords: Ryegrass; *Glycine max* L.; Herbicides; No-till farming.

Resumo

O controle químico de plantas daninhas no outono, pós-colheita de verão, é uma boa prática agrícola com potencial de contribuir para a redução do banco de sementes do solo e para a não perpetuação na área de pragas e doenças que atingem os cultivos comerciais. Esse manejo é bastante negligenciado pelos agricultores gaúchos. O objetivo do trabalho foi avaliar a eficiência de herbicidas no controle de plantas daninhas após a colheita de soja e avaliar a influência desse manejo sobre a biomassa do mix de plantas de cobertura no inverno e sobre o rendimento de soja no verão seguinte. O experimento foi realizado em campo, no delineamento de blocos ao acaso, contendo sete tratamentos e quatro repetições. Os tratamentos consistiram em seis aplicações de herbicidas e uma testemunha sem aplicação. Foi avaliado o controle das daninhas aos oito, 14 e 28 dias após a aplicação. Aos 28 dias após a aplicação, avaliou-se também a massa seca das plantas daninhas. Na primavera, foi avaliada a massa fresca e seca do mix de cobertura e, no verão, avaliou-se a produtividade e os componentes do rendimento da soja. O controle do azevém foi mais efetivo com a associação de glifosato+cletodim e, para o controle da soja Intacta 2 Xtend espontânea, recomenda-se a associação de glifosato com os herbicidas 2,4-D ou metsulfurom-metílico. A maior produção de biomassa seca do mix de cobertura do solo foi observada no tratamento sem aplicação de herbicidas no outono. Apenas um ano de manejo químico outonal não foi suficiente para evidenciar benefícios dessa prática agronômica no incremento do rendimento de grãos da soja.
Palavras-chave: Azevém; *Glycine max* L.; Herbicidas; Plantio direto.

INTRODUCTION

In the state of Rio Grande do Sul (RS), in the spring-summer, about 8.4 million hectares are cultivated with annual crops such as soybeans (*Glycine max* L.), maize (*Zea mays* L.) and rice (*Oryza sativa* L.). Already in the autumn-winter, the area under grain cultivation is only 2 million hectares (IBGE, 2025). Therefore, about 6.4 million hectares are cultivated with cover crops, pastures, or kept fallow, which can be an opportunity or even a problem regarding weed management and soil conservation.

Weed control is becoming increasingly difficult due to the numerous cases of herbicide resistance (Christoffoleti and López-Ovejero, 2008). In this sense, after harvesting the summer crops, the farmer has the opportunity to manage weeds in the fall, before planting cover crops. This practice, recommended by research, has little adoption among farmers in Rio Grande do Sul, since what is observed, most of the time, is the establishment of cover crops without proper management of the weeds left in the harvested stubble, as well as the lack of management of volunteer soybean and maize in the fields. This fact contributes to the increase of the soil seed bank, enabling the so-called green bridge, perpetuating weeds, pests, and diseases in the area, which can harm residue production in winter and commercial production in the following summer crop (Pinto *et al.*, 2021). Weed management in the fall is also fundamentally important for the success of commercial winter crops, such as wheat (*Triticum aestivum* L.) and the canola (*Brassica napus* L.). In this sense, identifying herbicides that are more efficient in controlling the species present in the area can optimize agricultural operations, reducing production costs and environmental impacts. Special attention should be given to the control of narrow leaves, such as ryegrass (*Lolium multiflorum* Lam.), weed species with resistance to multiple modes of action (Antunes, 2023). In addition, soybeans must be removed from the crops in Rio Grande do Sul from 07/03 to 09/30/2025, a period called the sanitary void, according to SDA/MAPA Ordinance No. 1,271, of April 30th, 2025 (Brazil, 2025). The purpose of this measure is to contain the spread of Asian soybean rust, caused by the fungus *Phakopsora pachyrhizi*, as it prevents the fungus from finding hosts, interrupting its multiplication cycle.

The no-till system with straw is the most suitable for soil conservation and is based on crop rotation and the permanent maintenance of live and dead plant cover (Fidelis *et al.*, 2003). According to the authors, the annual production of dry biomass must be greater than 10 Mg ha^{-1}, in order to improve the physical and biological properties of the soil. The soil's vegetation cover is also one of the measures recommended in the integrated weed management, as it helps herbicides in the suppression of various weed species. In RS, the use of oats is common (*Avena strigosa* Schreb) single or in consortium with the vetch (*Vicia sativa* L.) for green fertilization (Heinrichs *et al.*, 2001). The lack of autumn chemical management or the application of herbicides with residual effect may compromise the performance of cover crops in winter and also reflect on soybean production in the spring-summer. The objectives of this work were: to evaluate the efficiency of herbicides in controlling weeds in the autumn after soybean cultivation and to assess the influence of this management on the biomass production of the cover crop mix in winter and on soybean yield in the following summer.

MATERIAL AND METHODS

The experiment was conducted at the Federal Institute of Education, Science, and Technology Farroupilha (IFFar), Panambi Campus, RS (geographic coordinates 28°16'43.12"S, 53°31'6.06"W, altitude of 430 meters), from April 2024 to April 2025. The soil in the experimental area is classified as typical Dystrophic Red Latosol (Santos *et al.*, 2018), with a clayey texture, and the following characteristics in the 0-10 cm layer: Clay = 64%; SMP Index = 6.7; pH in water = 6.2; Organic matter = 2.8%; P = 7.6 mg dm^{-3}; K = 112 mg dm^{-3}; Ca^{2+} = 9.6 cmolc dm^{-3}; Mg^{2+} = 3.5 cmolc dm^{-3}; Al^{3+} = 0.0 cmolc dm^{-3}; H+Al = 2.0 cmolc dm^{-3}; CEC at pH 7 = 15.4 cmolc dm^{-3}; V = 86.9%; and m = 0.0%. The monthly averages of minimum and maximum temperatures, as well as the accumulated monthly precipitation during the experiment, are presented in Table 1.

Table 1. Monthly averages of maximum (TM) and minimum (Tm) temperatures and accumulated monthly rainfall (PPM) during the experiment period in Panambi, RS, 2025.*

Month/Year	TM (°C)	Tm (°C)	PPM (mm)
April/24	26.70	17.60	223.50
May/24	19.90	12.39	492.30
June/24	21.80	13.70	237.50
July/24	18.25	10.00	162.30
August/24	21.20	11.50	82.70
September/24	25.50	14.80	141.80
October/24	25.00	14.00	207.70
November/24	28.00	17.00	55.70
December/24	30.00	19.00	220.00
January/25	30.30	18.00	82.00
February/25	31.50	19.80	108.00
March/25	30.00	17.00	99.00
April/25	24.00	13.00	70.70

*Data provided by QualyAgro and Inmet.

The experimental design was in randomized blocks with four replications and seven treatments. The treatments were six different types of herbicides applied post-emergence to the weeds in the fall of 2024 (04/26/2024), after the soybean harvest, and a control without application (Table 2). The application was carried out with a pressurized backpack sprayer at CO_2 to 2,0 bar, equipped with a bar with four flat spray tips - "fan" type - 110.015, providing a spray volume of 120 L ha^{-1}. Each experimental plot had an area of 16 m² (4x4 m).

Table 2. Treatments applied in autumn for weed control, IFFar Panambi Campus, 2025.

Treatments	Active ingredient	Dose (g from i.a. ha^{-1} or g from e.a. ha^{-1})	Commercial product (L ha^{-1} or kg ha^{-1})
T1	Glyphosate	1440.0	3.0
T2	Diquat	1120.5	3.0
T3	Glufosinate ammonium salt	600.0	3.0
T4	Cletodim + Glyphosate	120.0 + 1440.0	0.6 + 3.0
T5	Clethodim + Glyphosate + Methyl met sulfuron	120.0 + 1440.0 + 0.006	0.6 + 3.0 + 10.0
T6	Glyphosate + 2.4-D	1440.0 + 1302.0	3.0 + 1.5
T7	Witness without application	-	-

The percentage of weed control (0-100%) was assessed visually by three independent observers. The weeds were ryegrass (*Lolium multiflorum* L.), oat (*Avena* spp.), vetch (*Vicia sativa* L.), guanxuma (*Sida rhombifolia* L.), soy (*Glycine max* L.), purple-flower (*Echium plantagineum* L.), brachiaria (*Urochloa* spp.), Morning Glory (*Ipomoea purpurea* (L.) Roth) and turnip (*Raphanus sativus* L.) that occurred spontaneously in the experimental area at eight, 14, and 28 days after herbicide application (DAA). At 28 DAA, samples of weeds were also collected in an area of 0,25 m² of each plot, through the throwing of a sample frame (0.5x0.5 m) and cutting the plants close to the ground. The biomass was dried in an oven with forced air circulation at 65 ºC until constant mass, determining the dry matter and the number of weeds of each species. The data were transformed by the function $Y=\sqrt{(x+0.5)}$ to meet the assumptions of analysis of variance (Banzato and Kronka, 2006; Silva *et al.*, 2023), the statistical interpretation being carried out with the transformed data and the representation of the results with the real values, in order to enable the technical use of the information. The analysis of variance and the Scott-Knott mean comparison test at 5% probability of error were performed using the Sisvar program (Ferreira, 2019).

On June 6th, 2024, on the experimental plots previously treated with herbicides, the mix of white oats was sown homogeneously, in a no-till system, with a seeder (*Avena sativa* L.) URS Corona cultivar (110 kg ha^{-1}) with common vetch (30 kg ha^{-1}). In each plot, on 09/25/2024 (111 days after sowing, flowering stage of the cover plants), a sample was randomly taken from 0,25 m², cutting the cover crop mix closely to the ground along with the weeds present in the area. The production of fresh mass and dry mass of the plants in each treatment was evaluated, after drying in an oven at 65 ºC. The data from this experiment were analyzed through analysis of variance and Duncan's multiple range test at 5% probability of error using the Genes program (Cruz, 2013).

The biomass present in the experimental plots was chemically managed on 10/03/2024 using the combination in the spray tank of the herbicides: Glyphosate (at a dose of 1.200 g e. a. ha^{-1}), clethodim (144 g i. a. ha^{-1}) and saflufenacil (35 g i.a. ha^{-1}); in addition to Cytro, Summer, and Defity adjuvants (each at a dose of 50 mL p.c. ha^{-1}). A new application of herbicides was carried out throughout the experiment in pre-planting of soybeans (11/12/2024) using glufosinate ammonium salt (500 g e. a. ha^{-1}). Both applications were carried out with a boom sprayer, flow rate of 150 L ha^{-1}, using a flat fan nozzle 110 015 at 3.0 bar of pressure.

Soybean, cultivar Neogen 590 I2X, was planted on the experimental plots on 11/21/2024 with a density of 15 seeds per meter and a spacing of 0.45 m between rows. Fertilization, according to the soil analysis and following the recommendations of the Fertilization and Liming Manual for the States of Rio Grande do Sul and Santa Catarina (CQFS-RS/SC, 2016), was 250 kg ha^{-1} fertilizer formula 05-20-20 and all other management practices related to pest and disease control were carried out according to the recommendations of research for soybean cultivation (Martin *et al.*, 2022). Weed management in the experiment, during the soybean cycle, was carried out with a single application of glyphosate (1440 g e. a. ha^{-1}) in post-emergence, in the V6 stage of the crop.

At soybean harvest maturity (04/04/2025), the height of five plants (cm) was randomly evaluated in the central part of the plot. These plants were identified and taken to the laboratory for counting the number of pods per plant (NLP) and the number of seeds per pod (NSP). In the central part of the plot, an area of two square meters of useful area was harvested to determine the grain yield (RG, in kg ha^{-1}, corrected to 13% moisture) and, in this set of grains, the mass of one thousand grains (MTG, in g, corrected to 13% moisture) was also evaluated. The data were subjected to analysis of variance and the Scott-Knott mean comparison test at 5% probability of error using the Sisvar program (Ferreira, 2019). Furthermore, a Pearson correlation analysis of the dry mass of the cover plants with the components of soybean yield was carried out, and regression analysis between grain yield (dependent variable) and the dry mass of the cover plants, at 5% probability of error using the Genes program (Cruz, 2013).

RESULTS AND DISCUSSION

The coefficient of variation (CV), the mean control, the significance of the analysis of variance (p-value), and the Scott-Knott mean comparison test at a 5% probability of error for the weed control percentage eight days after application (8 DAA) of the herbicides can be found in Table 3. Researchers, producers, and technical assistance should seek to identify in the tables and evaluation periods which herbicides are most effective for controlling the main weeds present in their crops, thus providing better support for rational decision-making regarding the positioning of the products. There was a significant effect of the herbicides on the control of all the evaluated weeds at 8 DAA at the 5% and 1% probability level of error according to the analysis of variance (p-value < 0.01) (Table 3). The mean comparison test showed that, for almost all species (except soy), there was a significant difference between the control and the tested herbicides. Turnip was the weed with the highest average control level (83.21%) at 8 DAA, suggesting that this species, which is widely used as a cover crop in the soil during autumn in no-till systems before the implementation of wheat in RS, is easy to control. Thus, wheat growers find it easy to manage this species when associating glyphosate with broadleaf herbicides.

Table 3. Percentage of weed control eight days after herbicide application (8 DAA), IFFar Panambi Campus, 2025.

Treatments	Control (%)								
	Ryegrass	Oat	Pea rust	Guanxuma	Soy	Purple Flower	Brachiaria	Morning Glory	Turnip
T4[*]	96.25 a	100.00 a	72.50 b	67.50 b	0.00 c	100.00 a	100.00 a	82.50 b	97.50 a
T5	92.50 a	100.00 a	77.50 b	78.75 b	73.50 b	100.00 a	95.00 a	85.00 b	100.00 a
T3	71.25 b	97.50 a	85.00 a	91.25 a	95.00 a	100.00 a	96.25 a	97.50 a	91.25 b
T2	65.00 b	87.50 a	67.50 b	87.50 a	97.50 a	95.00 a	75.00 b	96.25 a	96.25 a
T1	65.00 b	95.00 a	72.50 b	90.00 a	0.00 c	100.00 a	100.00 a	88.75 b	98.75 a
T6	65.00 b	100.00 a	90.00 a	70.00 b	96.25 a	100.00 a	97.50 a	100.00 a	98.75 a
T7	0.00 c	0.00 b	0.00 c	0.00 c	0.00 c	0.00 b	0.00 c	0.00 c	0.00 c
CV (%)	15.04	9.09	11.92	11.62	11.17	4.45	6.39	9.66	4.25
Average	65.00	82.85	66.43	69.29	51.79	85.00	80.54	78.57	83.21
p-value	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01

[*]Means followed by the same letter in the column do not differ from each other according to the Scott-Knott test at 5% probability of error. CV (%): coefficient of variation. T1: Glyphosate. T2: Diquat. T3: Glufosinate ammonium salt. T4: Clethodim + Glyphosate. T5: Clethodim + Glyphosate + Methyl metsulfuron. T6: Glyphosate + 2.4-D. T7: Witness without application.

The control of oats, purple flower, morning glory, and turnip was satisfactory with all the herbicides tested, with a control level above 80% (Table 3), thus indicating flexibility in managing these species. If brachiaria is the predominant species in the area, the use of the herbicide diquat should be avoided, as it showed a control level of 75%, lower than the other herbicides tested. It is recognized among producers that diquat does not perform well on grasses, especially if the species is perennial or at a more advanced stage of development. In an experiment conducted in boxes, Carbonari *et al.* (2003) observed that the control of brachiaria species was compromised 10 days after diquat application, due to the rapid regrowth of the plants, and the authors considered the herbicide ineffective for this target.

The control of ryegrass, vetch, guanxuma, and soybeans was less effective at 8 DAA (Table 3), compared to other weed species. Although there is no known resistance of common vetch and hairy vetch (*Vicia villosa Roth*) to glyphosate, this active ingredient has been showing difficulties in the isolated control of this invader in the field. The use of vetch as a cover crop has been increasing in the region in recent years, especially as part of cover crop mixes or in sole cropping before maize (Heinrichs *et al.*, 2001). Thus, in the chemical management of this species, for more efficient control at 8 DAA, glufosinate or glyphosate+2,4-D should be preferred.

Volunteer soybean must be eliminated from the crop by the farmer, which constitutes good production practice, as it aims to prevent it from remaining in the area and spreading root and foliar diseases. In this sense, successful control of Intacta 2 Xtend soybean can be achieved using glufosinate, diquat, or glyphosate+2,4-D (Table 3). Unfortunately, many farmers do not carry out post-harvest chemical management in the fall, and spontaneous soybean continues its development until the first widespread frost occurs, which, in RS, in a climate change scenario, is more likely to happen only in mid-July (Tazzo *et al.*, 2024). Thus, it is common to find spontaneous soybean producing viable seeds during the winter and having new emergence flows during the spring, making the so-called sanitary void unfeasible. In this sense, producer awareness action is necessary and should be carried out by public and private research and technical assistance.

Certainly, for winter crops, ryegrass is the weed with the greatest management difficulty in Rio Grande do Sul, due to resistance to glyphosate and ACCase-inhibiting herbicides (Da Silva *et al.*, 2021; Vargas *et al.*, 2016). Also, the control efficiency of single and non-sequential applications of the contact herbicides diquat and glufosinate is low (Table 3). At 8 DAA, ryegrass control in the area was satisfactory only with the association of glyphosate+cletodim. It is worth noting that the study area has a history of few applications of ACCase-inhibiting herbicides, as it remained fallow for a few years, which may have contributed to the good performance of this active ingredient.

At 14 DAA, there was a significant effect of the herbicides on the control of all evaluated weeds at the 5% and 1% probability of error levels according to the analysis of variance (p-value < 0.01). The mean comparison test showed that for nearly all species (except soybeans) there was a difference between the control and all the herbicides tested (Table 4). Once again, radish was the weed with the highest average control level (84.28%). Only the control of brachiaria and radish was satisfactory (>80%) with all the herbicides studied.

Table 4. Percentage of weed control 14 days after herbicide application (14 DAA), IFFar Campus Panambi, 2025.

Treatments	Control (%)								
	Ryegrass	Oat	Pea rust	Guanxuma	Soy	Purple Flower	Brachiaria	Morning Glory	Turnip
T4*	97.50 a	100.00 a	67.50 b	68.75 b	0.00 c	98.75 a	100.00 a	70.00 b	100.00 a
T5	81.25 b	96.25 a	72.50 a	75.00 a	85.00 b	97.50 a	95.00 a	90.00 a	100.00 a
T2	80.00 b	78.75 b	62.50 b	77.50 a	97.50 a	77.50 b	87.50 a	96.25 a	100.00 a
T3	76.25 b	96.25 a	66.25 b	88.75 a	91.25 b	98.75 a	100.00 a	97.50 a	92.50 b
T6	71.25 b	100.00 a	83.75 a	77.50 a	97.50 a	100.00 a	98.75 a	98.75 a	97.50 a
T1	61.25 c	93.75 a	57.50 b	60.00 b	0.00 c	100.00 a	100.00 a	93.75 a	100.00 a
T7	0.00 d	0.00 c	0.00 c	0.00 c	0.00 c	0.00 c	0.00 b	0.00 c	0.00 c
CV (%)	13.42	6.07	12.04	15.19	8.75	3.51	11.67	5.23	4.55
Average	66.79	80.71	58.57	63.93	53.03	81.79	83.03	78.04	84.28
p-value	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01

*Means followed by the same letter in the column do not differ from each other according to the Scott-Knott test at 5% probability of error. CV (%): coefficient of variation. T1: Glyphosate. T2: Diquat. T3: Glufosinate ammonium salt. T4: Clethodim + Glyphosate. T5: Clethodim + Glyphosate + Methyl metsulfuron. T6: Glyphosate + 2.4-D. T7: Witness without application.

In the control of ryegrass at 14 DAA, the combination of glyphosate+cletodim stood out, with superior performance to the combination glyphosate+cletodim+metsulfuron-methyl (Table 4). At the three evaluation times, in absolute values, there seems to be a small antagonism, that is, a compromise in the control efficiency of ryegrass when the broadleaf herbicide is added to the mixture, also observed by Trezzi *et al.* (2007). For better control of soybean at 14 DAA, diquat and glyphosate+2,4-D are recommended, while for better control of vetch, it is recommended to add a broadleaf herbicide to the mixture with glyphosate.

The analysis of variance indicated a difference between the treatments in the control of all weeds evaluated at 28 DAE at the 5% and 1% probability levels of error (p-value < 0.01). The mean comparison test also showed that for almost all species (except soybean) there was a significant difference between the control and the herbicides tested. In the evaluation of weed control at 28 DAE (Table 5), the species with the highest average level of control was brachiaria (82.50%). Only brachiaria and morning glory were controlled with an efficiency greater than 80% by all the herbicides studied. In general, a reduction in the level of control is observed in this evaluation, which is due to new waves of weed emergence, since only metsulfuron-methyl has a residual pre-emergence action. This fact reinforces the importance of using other pre-emergent herbicides in the autumn-winter, especially when the commercial crop is wheat, since post-emergence control, particularly of ryegrass, is difficult in this crop. Soybean control was satisfactory (> 80%) with the herbicides diquat, glufosinate, 2,4-D, and metsulfuron-methyl, whereas ryegrass control was satisfactory only with the cletodim+glyphosate mixture.

Table 5. Percentage of weed control 28 days after herbicide application (28 DAA), IFFar Panambi Campus, 2025.

Treatments	Control (%)								
	Ryegrass	Oat	Pea rust	Guanxuma	Soy	Purple Flower	Brachiaria	Morning Glory	Turnip
T4*	80.00 a	90.00 a	62.50 a	65.00 b	0.00 b	87.50 a	100.00 a	97.50 a	73.75 b
T5	65.00 a	90.00 a	57.50 a	77.50 a	97.50 a	92.50 a	97.50 a	100.00 a	85.00 a
T2	52.50 b	70.00 b	60.00 a	57.50 b	95.00 a	67.50 b	85.00 b	97.50 a	72.50 b
T3	50.00 b	82.50 a	62.50 a	82.50 a	92.50 a	85.00 a	100.00 a	92.50 a	77.50 b
T6	52.50 b	95.00 a	65.00 a	70.00 b	97.50 a	85.00 a	97.50 a	95.00 a	82.50 a
T1	52.50 b	87.50 a	67.50 a	65.00 b	0.00 b	80.00 a	97.50 a	90.00 a	92.50 a
T7	0.00 c	0.00 c	0.00 b	0.00 c	0.00 b	0.00 c	0.00 c	0.00 b	0.00 c
CV (%)	18.04	10.45	14.21	14.01	11.53	9.63	4.83	7.06	10.24
Average	50.35	73.57	53.57	59.64	54.64	71.07	82.5	81.79	69.11
p-value	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01

*Means followed by the same letter in the column do not differ from each other according to the Scott-Knott test at 5% probability of error. CV (%): coefficient of variation. T1: Glyphosate. T2: Diquat. T3: Glufosinate ammonium salt. T4: Clethodim + Glyphosate. T5: Clethodim + Glyphosate + Methyl metsulfuron. T6: Glyphosate + 2.4-D. T7: Witness without application.

The coefficient of variation (CV), the mean, as well as the significance of the analysis of variance (p-value) and the Scott-Knott mean comparison test at 5% probability of error for the dry mass of weeds 28 DAA can be seen in Table 6. It is noted that purple flower was the species that had the highest dry biomass accumulation in the infesting community maintained without herbicide application (control), presenting almost twice that of the second species (guanxuma). In general, the weed with the highest amount of dry mass in the area was the purple flower, and the one with the lowest biomass was the Morning Glory.

The various species of Sida are known in Brazil by the common name "guanxumas," being very important in the country (Constantin *et al.*, 2007). Guanxuma was heavily infesting the area, accumulating 26.7 g m² of biomass in the control plot. In the region, larger and more developed guanxuma plants are generally tolerant to glyphosate, requiring an increased dose for more effective control. In this study, the herbicide glyphosate alone did not provide the same control of guanxuma biomass as when combined with other herbicides, and therefore, the combination of herbicides is a recommended practice for better management of this difficult-to-control weed (Table 6).

Table 6. Dry mass of weeds (g/m²) 28 days after herbicide application, IFFar Panambi Campus, 2025.

Treatments	Control (%)								
	Ryegrass	Oat	Pea rust	Guanxuma	Soy	Purple Flower	Brachiaria	Morning Glory	Turnip
T4*	0.42 a	0.20 a	0.60 a	0.26 a	11.94 b	0.48 a	0.04 a	0.00 a	0.37 a
T1	1.56 b	0.00 a	0.62 a	1.58 b	11.58 b	0.23 a	0.00 a	0.00 a	0.08 a
T2	2.81 c	0.75 a	0.80 a	1.78 b	0.00 a	0.84 a	0.21 a	0.06 a	0.58 a
T3	2.93 c	0.03 a	0.77 a	0.12 a	1.28 a	1.36 a	0.00 a	0.00 a	0.3 a
T6	3.23 c	0.00 a	0.23 a	0.00 a	0.00 a	0.71 a	0.00 a	0.00 a	0.32 a
T5	4.31 c	0.03 a	2.57 b	0.84 a	0.00 a	0.23 a	0.00 a	0.00 a	0.25 a
T7	14.01 d	3.38 b	4.82 c	26.70 c	10.74 b	64.09 b	1.66 b	0.86 b	2.88 b
CV (%)	15.37	23.06	23.43	21.09	21.4	31.11	13.73	8.64	22.55
Average	4.18	0.63	1.48	4.47	5.07	9.7	0.27	0.13	0.69
p-value	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01

*Means followed by the same letter in the column do not differ from each other according to the Scott-Knott test at 5% probability of error. CV (%): coefficient of variation. T1: Glyphosate. T2: Diquat. T3: Glufosinate ammonium salt. T4: Clethodim + Glyphosate. T5: Clethodim + Glyphosate + Methyl metsulfuron. T6: Glyphosate + 2.4-D. T7: Witness without application.

In the control of volunteer soybeans, the lowest biomass was obtained with the treatments diquat, glufosinate, glyphosate+2,4-D, and glyphosate+cletodim+metsulfuron-methyl. The use of the contact herbicide glufosinate was sufficient to reduce soybean dry mass by more than 88%, while the use of broadleaf herbicides, that is, 2,4-D or metsulfuron-methyl, resulted in total control (100%). Therefore, in this study, only the treatments with broadleaf herbicides were acceptable, since during the established fallow period there should be no emerging soybean plants, in order to reduce the inoculum of the fungus that causes Asian rust. (Kajihara *et al.*, 2021).

The dry matter data at 28 DAA reinforce that the best control of ryegrass occurred only with the combination of glyphosate and clethodim. On the other hand, the ryegrass biomass results, along with the visual control assessment results, show that the combination of glyphosate + clethodim + metsulfuron-methyl impaired control, probably due to antagonism between these herbicides. In general, the efficiency of ACCase-inhibiting herbicides is reduced when applied together with broadleaf herbicides (Trezzi *et al.*, 2007). Also studying the control of ryegrass, Trezzi *et al.* (2007) identified the existence of antagonism of metsulfuron-methyl with an herbicide with the same mode of action as clethodim (ACCase inhibitor), clodinafop-propargyl. Considering that the use of a broadleaf herbicide is essential to control volunteer soybean and respect the fallow period, a strategy to circumvent the antagonism would be to increase the doses of the grass herbicide, when used in combination, to achieve the same level of ryegrass control obtained with its isolated application (Barbieri *et al.*, 2022).

The interpretation of the analysis of variance for the fresh mass and dry mass of the aerial parts of the cover plants collected along with the weed biomass in spring indicated no significant difference between the treatments studied at the 5% significance level (p-values 0.07 and 0.13, respectively) (Table 7). The coefficient of variation in this experiment was high (> 20%) due to the natural variability in the occurrence of weeds in the area, which may have compromised the statistical significance of the results. The Duncan's multiple range test at 5% probability of error indicated that for both fresh mass and dry mass there was greater biomass accumulation in the treatment without herbicide application in autumn (control, due to the abundance of the purple flower), and the lowest biomass accumulation occurred in the clethodim+glyphosate treatment. It would be expected that the lowest biomass accumulation would occur in the treatment with the presence of residual pre-emergent herbicide (metsulfuron-methyl, T5), which was not confirmed in this study.

Table 7. Fresh mass of aboveground part (FMAP, kg/ha) and dry mass of aboveground part (DMAP, kg/ha) of cover plants in response to herbicide application, IFFar Campus Panambi, 2025.

Treatments	Variables	
	MFPA	MSPA
T7*	32350 a	5763 a
T3	25450 ab	5166 ab
T1	24690 ab	5221 ab
T5	23720 ab	4627 ab
T6	21540 b	4864 ab
T2	19510 b	4440 ab
T4	17450 b	3572 b
Average	23530	4807.57
p-value	0.07	0.13
CV (%)	26.48	20.86

*Means followed by the same letter in the column do not differ from each other according to Duncan's test at 5% probability of error. CV (%): coefficient of variation. T1: Glyphosate. T2: Diquat. T3: Glufosinate ammonium salt. T4: Clethodim + Glyphosate. T5: Clethodim + Glyphosate + Methyl metosulfuron. T6: Glyphosate + 2,4-D. T7: Untreated control.

The biomass production of the set of cover crops and weeds can be considered high in the area, with an average of 23,530 kg ha^{-1} of fresh mass and 4,807 kg ha^{-1} of dry mass. Heinrichs *et al.* (2001), also working with an oat and vetch consortium, obtained dry matter production around 5,000 kg ha^{-1} in RS, concluding that the biomass produced in this mix has a good balance between soil protection by crop residues and nitrogen supply to the subsequent crop. Lamego *et al.* (2013), studying the effect of soil cover on weed control, concluded that vetch was the species that had the greatest suppressive effect on the germination and initial development of *Conyza bonariensis* (L.) Cronq. There was no significant linear correlation between the dry mass of cover crops and soybean grain yield (r = 0.04), and the regression analysis also indicated a lack of significant linear model fit between grain yield (dependent variable) and the dry mass of cover crops (explanatory variable) in this experiment (data not shown).

The herbicides tested in the fall did not have a significant effect on grain yield, thousand-grain weight (TGW), number of pods per plant (NPP), number of grains per pod (NGP), and soybean plant height in the 2024/2025 growing season according to the analysis of variance (p-value > 0.05) (Table 8). Quadros *et al.*, (2020) also did not identify a significant effect from the application of post-emergence herbicides (glyphosate+sethoxydim; glyphosate+2,4-D; glyphosate+2,4-D+sethoxydim) applied in pre-planting of soybean on the crop's grain yield. In this season, in RS, there was significant drought (Table 1), especially in the months of March and April, a critical phase of flowering and grain filling, which resulted in low productivity (average of 1103 kg ha^{-1}), affecting all components of the crop's grain yield (MMG, NLP and NGL).

Table 8. Variáveis produtivas e morfológicas de soja em resposta a herbicidas aplicados no outono-inverno, IFFar Campus Panambi, 2025.

Treatments	Variables				
	RG (kg ha^{-1})	MMG (g)	NLP	NGL	AP (cm)
T3*	1157.17 a	128.04 a	20.90 a	2.03 a	68.00 a
T1	1139.59 a	122.52 a	21.40 a	2.06 a	69.85 a
T7	1125.38 a	137.76 a	22.00 a	2.14 a	72.05 a
T5	1116.87 a	132.29 a	19.25 a	2.07 a	68.35 a
T2	1079.38 a	130.48 a	23.5 a	2.08 a	69.20 a
T4	1057.48 a	127.05 a	17.75 a	2.13 a	66.70 a
T6	1047.65 a	134.27 a	21.50 a	2.11 a	68.00 a
CV (%)	20.16	5.86	35.33	6.98	6.78
Average	1103.36	130.35	20.90	2.09	68.87
p-value	0.98	0.17	0.94	0.94	0.77

*Means followed by the same letter in the column do not differ from each other according to the Scott-Knott test at 5% probability of error. CV (%): coefficient of variation. RG: grain yield. MMG: thousand-grain weight; NLP: number of pods per plant. NGL: number of grains per pod. AP: plant height. T1: Glyphosate. T2: Diquat. T3: Glufosinate ammonium. T4: Clethodim + Glyphosate. T5: Clethodim + Glyphosate + Methyl metsulfuron. T6: Glyphosate + 2,4-D. T7: Untreated control.

There is variability in the efficiency of herbicides in controlling weeds in the fall, with the association of glyphosate + clethodim being recommended for controlling ryegrass, and for controlling spontaneous Intacta 2 Xtend soybean, the association of glyphosate with the herbicides 2,4-D or metsulfuron-methyl is recommended. The highest production of dry biomass of cover plants was observed in the treatment without herbicide application in the fall, and just one year of fall chemical management was not enough to show benefits of this agronomic practice in increasing soybean grain yield. It is suggested that a longer-term study be conducted in order to try to prove this hypothesis.

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