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SCIENTIFIC ARTICLE

Efficacy of Pre-Emergent Herbicides Alone and in Combination for Weed Control in Cassava

Eficacia de herbicidas pre-emergentes solos y en mezcla para el control de malezas en mandioca

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The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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ABSTRACT

Cassava is essential for food security and the starch industry in Paraguay. This study was conducted to evaluate the efficacy of pre-emergent herbicides, alone and in combination, for weed control. A randomized complete block design was used with eight treatments and three replications: the treatments were Clomazone 50% (2.5 L ha^{-1}) + Sulfentrazone 50% (0.5 L ha^{-1}); Flumioxazin 48% (150 g ha^{-1}) + Pyroxasulfone 85% (200 g ha^{-1}); Metolachlor 96% (2 L ha^{-1}) + Flumioxazin 48% (150 g ha^{-1}); Flumioxazin 48% (150 g ha^{-1}) + Clomazone 50% (2.5 L ha^{-1}); Flumioxazin 48% alone; Metolachlor alone; Pyroxasulfone 85% alone; and an untreated control. Weed control was evaluated at 21 days using a visual percentage scale (ALAM, 1974). Data were analyzed by ANOVA and Tukey's test ($p \leq 0.05$). The Clomazone + Sulfentrazone (99.53%), Flumioxazin + Pyroxasulfone (99.1%), and Metolachlor + Flumioxazin (98.43%) mixtures exceeded 98% control, classified as optimal according to the scale used, with no significant differences among them. Flumioxazin alone and Pyroxasulfone alone achieved "very good" control (89.33% and 88.67%), while Metolachlor alone achieved "good" control (78.33%). It is concluded that mixtures with different mechanisms of action outperform individual herbicides, with combinations including Flumioxazin and Clomazone standing out for their efficacy exceeding 98%.

Keywords: *Manihot esculenta*, pre-emergent herbicides, weed control, agronomic efficacy, herbicide mixtures.

RESUMEN

La mandioca es esencial para la seguridad alimentaria y la industria almidonera en Paraguay. Este estudio se realizó con el objetivo de evaluar la eficacia de herbicidas solos y en mezcla en preemergencia para el control de malezas. Se utilizó un diseño de bloques completos al azar con ocho tratamientos y tres repeticiones: los tratamientos fueron: Clomazone 50% (2,5 L ha^{-1}) + Sulfentrazone 50% (0,5 L ha^{-1}); Flumioxazina 48% (150 g ha^{-1}) + Piroxasulfona 85% (200 g ha^{-1}); Metolaclor 96% (2 L ha^{-1}) + Flumioxazina 48% (150 g ha^{-1}); Flumioxazina 48% (150 g ha^{-1}) + Clomazone 50% (2,5 L ha^{-1}); Flumioxazina 48% sola; Metolaclor solo; Piroxasulfona 85% sola; y testigo sin aplicación. El control de malezas se evaluó a los 21 días mediante escala visual porcentual (ALAM, 1974). Los datos se analizaron con ANOVA y prueba de Tukey ($p \leq 0,05$). Las mezclas Clomazone + Sulfentrazone (99,53 %), Flumioxazina + Piroxasulfona (99,1 %) y Metolaclor + Flumioxazina (98,43 %) superaron el 98 % de control, catalogado como óptimo según la escala utilizada, sin diferencias significativas entre ellas. Flumioxazina sola y Piroxasulfona sola alcanzaron control "Muy bueno" (89,33 % y 88,67 %), mientras que Metolaclor solo logró control "Bueno" (78,33 %). Se concluye que las mezclas con diferentes mecanismos de acción superan a los herbicidas individuales, destacándose las combinaciones que incluyen Flumioxazina y Clomazone por su eficacia superior al 98 %.

Palabras clave: *Manihot esculenta*, herbicidas preemergentes, control de malezas, eficacia agronómica, mezclas de herbicidas.

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INTRODUCTION

Cassava (*Manihot esculenta* Crantz) is native to the tropical region of South America, specifically south-central Brazil and eastern Bolivia (Clement, Cristo-Araújo, D'Eeckenbrugge, Alves-Pereira, & Picanço-Rodrigues, 2010). From its center of origin, it spread throughout tropical America and later to Africa and Asia, becoming a fundamental crop for global food security (Amelework and Bairu, 2022). This species belongs to the Euphorbiaceae family and is characterized by a high capacity to adapt to diverse edaphoclimatic conditions, ranging from acidic, low-fertility soils to periods of moderate drought (Tironi et al., 2019).

In Paraguay, cassava is a preferred, staple, and ubiquitous food in rural communities, carrying economic, culinary, and dietary meanings that link it to food sovereignty and security (Finnis, Benítez, Candia Romero, and Aparicio Meza, 2013). In Paraguay, cassava is part of the economic base of smallholder farmers and constitutes a relevant raw material for the starch industry, within an agrarian context increasingly oriented toward export (Weisskoff, 1992). Cassava yields remain below their productive potential, and this gap stems from multiple management constraints, including low adoption of improved technologies and inadequate weed control (Zebalho et al., 2025).

Cassava is particularly sensitive to weed competition during its early stages, and several studies place the critical period of interference at approximately 60 to 90 days after planting (Costa, Ritter, Peres, Silva, and Vasconcelos, 2013).

The weed complex in cassava cultivation is dominated by broadleaf (dicotyledonous) species, with lower representation of monocotyledons (Miléo et al., 2016; Ola, O. T., Ekhator, Opabode, Akinyemiju, and Ogedengbe, 2021).

Among the most relevant perennial species are *Commelina erecta* (Santa Lucía), *Digitaria insularis* (Kapí'i pororo), and *Ipomoea* spp. (Ysypo'i), species with high regenerative capacity and sustained competition with the crop. The most frequent annual species included *Bidens pilosa*, *Amaranthus* sp., *Euphorbia heterophylla*, and *Cenchrus echinatus*, characterized by their rapid growth cycle and high seed production (Duarte, Silva and Deuber, 2007; Lópes, Soares, Chidichima and Dias-Arieira, 2020). This diversity of functional groups demands integrated management strategies that combine pre-emergent herbicides with different mechanisms of action to ensure effective control across the entire weed spectrum (Takano, Ovejero, Belchior, Maymone, and Dayan, 2021).

Weed management in cassava cultivation has traditionally depended on manual labor. Practices such as hand weeding with a hoe, machete, or sickle constitute the predominant method in various producing regions, as documented in Nigeria, where it is carried out two to three times per cycle (Ekeleme et al., 2020), in the Amazon (Fontes, Oliveira, and Morais, 2021), and in Central Africa (Muke, Nabahungu, Kinché, Vanlauwe, and Boeckx, 2024). However, this control approach presents significant limitations, most notably its high labor and time demands, making it an arduous task with high operational costs (Quee et al., 2016; Ekeleme et al., 2020; Muke et al., 2024). Against this backdrop, chemical weed control emerges as an operationally more efficient option, characterized by being faster, less labor-dependent, and offering more effective control, which translates into greater operational output and, in many cases, lower total costs (Ekeleme et al., 2021; Fontes et al., 2021).

Pre-emergent herbicides constitute an effective tool for early weed control in cassava, as they reduce interference during the crop's first weeks, a stage in which the species exhibits slow initial development and high susceptibility to competition. Depending on the herbicide and field conditions, residual control can be maintained for approximately 4 to 8 weeks, so it is often necessary to complement it with other practices to keep the crop weed-free throughout the critical period (Santiago, Cavalcante, Braz, and Procópio, 2018; Ekeleme et al., 2020; Da Silva et al., 2025).

These herbicides act through different mechanisms of action: flumioxazin and sulfentrazone belong to the PPO-inhibitor group, generally more active against broadleaf weeds, while pyroxasulfone and S-metolachlor are very-long-chain fatty acid (VLCFA) synthesis inhibitors, applied mainly pre-emergence for the control of annual grasses and some broadleaf species. Clomazone acts as a carotenoid biosynthesis inhibitor and provides a complementary control spectrum depending on the target species. Combining herbicides with different mechanisms of action can broaden the control spectrum and contribute to resistance management, although the benefit depends on each component being effective and being integrated with other management practices (Parra Rapado et al., 2024; Jhala et al., 2024).

In Paraguay, in cassava, the availability of selective, registered herbicides remains limited, particularly for certain application modes, which restricts the development of consistent chemical management programs (Machado Filho et al., 2018; Fontes et al., 2021; Ekeleme et al., 2021). In this context, evaluating new molecules and combinations under local conditions is necessary, because efficacy and selectivity depend on the weed community, the cassava variety, the environment, and the establishment system (Santiago et al., 2018; Fontes et al., 2021; and Pinto Ruiz, Medina, Tarragó, and Burgos, 2024).

This study contributes to filling this information gap through the comparative evaluation of different active ingredients and their combinations applied pre-emergence for weed control in cassava under field conditions in cassava-producing areas of Paraguay.

MATERIALS AND METHODS

The study was conducted during the 2024–2025 growing season in the locality of Vacay 33, Bella Vista, Itapúa department (26°50'14"S; 55°40'43"W).

Soil preparation consisted of conventional tillage with a heavy disc harrow 30 days before planting, followed by leveling prior to the planting date. Planting was carried out on August 20, 2024, using cassava stakes with 5 to 6 buds, belonging to accession MPy 577, available from the germplasm bank of the Paraguayan Institute of Agrarian Technology, with a spacing of 1.0 m between rows and 0.7 m between plants, equivalent to 14,000 plants·ha^{-1}.

A randomized complete block design (RCBD) was implemented with eight treatments and three replications. The experimental unit consisted of plots measuring 2 m × 2 m (4 m²), separated by 0.5 m alleys to prevent herbicide drift. Within each experimental unit, three evaluation subplots measuring 1 m × 0.5 m (0.5 m² each) were demarcated, totaling 1.5 m² of usable area per replication, located in the middle of the plot.

The herbicide treatments evaluated are presented in Table 1. The absolute control plot received no herbicide application, serving to determine weed population density and for use in comparisons during the visual evaluation.

Applications were carried out in pre-emergence of the crop and weeds (upon completion of stem-cutting planting), using a CO_2-pressurized sprayer equipped with AXI 11002 nozzles, spaced 0.5 m apart and calibrated to a working pressure of 3.0 kgf·cm^{-2}, with an application volume equivalent to 200 L·ha^{-1}.

Weed control efficacy was evaluated at 21 days after application (DAA), using the visual methodology standardized by the Latin American Weed Association (ALAM, 1974), applying the percentage scale described in Table 2, where 0% represents absence of control and 100% represents total control of the damaging plants.

Percentage control data were subjected to arcsine square root transformation (arcsen √p) to meet the assumptions of normality and homoscedasticity. Analysis of variance (ANOVA) was performed using Fisher's F test ($p \leq 0.05$), and in cases of significance, Tukey's multiple mean comparison test ($p \leq 0.05$) was applied using InfoStat software, version 2020p (Di Rienzo et al., 2020). Graphical analyses were performed using Microsoft Office Excel 2023.

RESULTS AND DISCUSSION

In the experimental plot, various plant species were recorded, with a predominance of dicotyledons (60%) over monocotyledons (40%) (Table 3), although the abundance and coverage of grasses (especially *Digitaria* and *Cenchrus*) tend to be greater, making them more significant from the standpoint of competition with the crop.

The floristic composition observed in the sampling is consistent with weed communities typical of disturbed summer cropping systems, where species of Poaceae, Asteraceae, Amaranthaceae, and Euphorbiaceae tend to predominate. In this context, the high frequency of *Bidens pilosa*, *Digitaria* spp., *Amaranthus* spp., *Euphorbia heterophylla*, and *Richardia brasiliensis* coincides with previous weed surveys in regional agroecosystems, which supports the representativeness of the sampling and its value for describing the weed flora associated with summer crops (Castro, Lima, Tomquelski, Andrade and Martins, 2021).

The prominent presence of *Bidens pilosa* is expected, as it is a cosmopolitan and invasive weed, widely naturalized in tropical and subtropical regions, capable of colonizing agricultural fields, roadsides, and other disturbed environments (Arthur, Naidoo, and Coopoosamy, 2012; Rojas-Sandoval et al., 2020; Kato-Noguchi and Kurniadie, 2024). Its ecological success is associated with high seed production, rapid dispersal, prolonged viability, and broad environmental plasticity, traits that favor its persistence in

Table 1. Description of the herbicide treatments evaluated in pre-emergence in cassava cultivation. Paraguay, 2025.

Treatments	Active Ingredients and Combinations
1	Clomazone 50% (2.5 L ha^{-1}) + Sulfentrazone 50% (0.5 L ha^{-1})
2	Flumioxazin 48% (150 g ha^{-1}+ Piroxasulfone 85% (200 g ha^{-1})
3	Metalachlor 96% (2 L ha^{-1}) + Flumioxazin 48% (150 g ha^{-1}
4	Flumioxazin 48% (150 g ha^{-1}) + Clamozone 50% (2.5 L ha^{-1})
5	Flumioxazin 48% (150 g ha^{-1})
6	Metalachlor (2 L ha^{-1})
7	Piroxasulfone 85% (200 g ha^{-1})
8	Control (untreated)

Table 2. Visual weed control evaluation scale (ALAM, 1974).

	Visual Weed Control Evaluation Scale					
Score	1	2	3	4	5	6
Efficacy (%)	0-40	41-60	61-70	71-80	81-90	91-100
Rating	Poor	Fair	Sufficient	Good	Very good	Optimal

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production systems under recurrent disturbance (Santos and Curry, 2011).

Analysis of herbicide treatment efficacy revealed statistically significant differences ($p < 0.0001$) by Fisher's test, allowing them to be grouped into three clearly defined categories (Table 4).

The clomazone + sulfentrazone, flumioxazin + pyroxasulfone, and S-metolachlor + flumioxazin treatments ranked among the best-performing, with no statistical differences among them and with control levels exceeding 98% on the main species present. This behavior is consistent with the literature on pre-emergent herbicides, which shows that mixtures tend to broaden the control spectrum and increase the reliability of early-season management relative to isolated active ingredients (Silva et al., 2023; Munaro et al., 2025).

The agronomic advantage of these combinations lies in their integration of complementary modes of action, which improves simultaneous control of grasses and broadleaf weeds and reduces the risk of early control failures (Salomão et al., 2021; Silva et al., 2023).

In soybean, combinations such as sulfentrazone + clomazone, flumioxazin + pyroxasulfone, and S-metolachlor + flumioxazin effectively controlled *Euphorbia heterophylla*, *Digitaria insularis*, *Commelina benghalensis*, and *Bidens pilosa* without significant phytotoxicity (Munaro et al., 2025).

Treatments with flumioxazin + clomazone, as well as the individual herbicides flumioxazin and pyroxasulfone, showed high control levels of 88.67% and 89.33%, respectively, although lower than the best-performing combinations. This result indicates that herbicide mixing alone does not guarantee greater efficacy; rather, its success

Table 3. Prevalence of the main weeds found in the experimental plot (control). Paraguay, 2025.

Class	Order	Family	Genus	Species	Common Name
Dicotyledon	Malpighiales	Euphorbiaceae	Euphorbia	heterophylla	Lecherita
Dicotyledon	Solanales	Convolvulaceae	Ipomoea	spp.	Ysypo´i
Monocotyledon	Poales	Poaceae	Digitaria	sanguinalis	Cebadilla
Dicotyledon	Asterales	Asteraceae	Bidens	pilosa	Kapi´una
Monocotyledon	Poales	Poaceae	Digitaria	insularis	Kapi´i Pororo
Monocotyledon	Commelinales	Commelinaceae	Commelina	erecta	Santa Lucia
Dicotyledon	Caryophyllales	Amaranthaceae	Amaranthus	sp.	Amaranto
Monocotyledon	Poales	Poaceae	Trichloris	crinita	Pasto crespo
Monocotyledon	Poales	Poaceae	Cenchrus	echinatus	Kapi´ati
Dicotyledon	Caryophyllales	Portulacaceae	Portulaca	sp.	Verdolaga
Dicotyledon	Malpighiales	Euphorbiaceae	Euphorbia	serpens	Tupasy Kamby
Dicotyledon	Brassicales	Brassicaceae	Raphanus	sativus	Nabo
Dicotyledon	Asterales	Asteraceae	Acanthospermum	australe	Tape kue
Dicotyledon	Gentianales	Rubiaceae	Richardia	brasiliensis	Ypé rupa
Dicotyledon	Malvales	Malvaceae	Sida	spp.	Typycha Hü

Table 4. Results of analysis of variance and Tukey's test for percentage of weed control. Paraguay, 2025.

Herbicide Active Ingredients	**Mean Weed Control (%)**			
	Transformed	**Real**	**TT***	**Rating**
Clomazone 50% + Sulfentrazone 50%	85,36	99,53	A	Optimal
Flumioxazin 48% + Piroxasulfone 85%	84,85	99,10	A	Optimal
Metalachlor 96% + Flumioxazin 48%	83,74	98,43	A	Optimal
Flumioxazin 48% + Clamozone 50%	72,66	91,00	B	Optimal
Flumioxazin 48%	70,47	89,33	BC	Very good
Piroxasulfone 85%	70,99	88,67	C	Very good
Metalachlor	62,30	78,33	D	Good
Control (untreated)[1]	0	0		
CV(error) = 0,527	**p-valor** (<0,0001)			

*TT: Tukey's test. Means followed by the same letter do not differ significantly from each other according to Tukey's test at 5% probability of error. [1]For the analysis of variance, the absolute control was not included.

depends on the complementarity between mechanisms of action, the control spectrum of each active ingredient, and its persistence in the soil (Silva et al., 2023; Carvalho, Ferrari Schedenffeldt, Pereira, & Monquero, 2025).

In particular, flumioxazin has shown high efficacy against broadleaf weeds and low residual biomass in various systems, while pyroxasulfone stands out for its contribution to grass control and its good performance when integrated into broad-spectrum mixtures (Kousta, Katsis, Tsekoura, A., and Chachalis, 2024; Silva et al., 2021; Albrecht et al., 2025).

On the other hand, metolachlor showed the lowest efficacy among the treatments evaluated, reflecting the limitations of relying on a single mode of action and on a herbicide whose performance can be affected by soil conditions and microbial degradation (Hejazirad et al., 2024).

In contrast, the S-metolachlor + flumioxazin association reinforces that well-designed mixtures can broaden the control spectrum and provide more reliable pre-emergent management than single treatments, especially when combining effective, residual active ingredients (Salomão et al., 2021; Silva et al., 2023 and 2023 Munaro et al., 2025).

The percentage of control exerted by the herbicide mixture Clomazone 50% + Sulfentrazone 50% on the 15 weed species found demonstrated excellent efficacy (99.53%) on most species, including Cebadilla (*Digitaria sanguinalis*), Kapi'una (*Bidens pilosa*), Kapi'i pororo (*Digitaria insularis*), Santa Lucía (*Commelina erecta*), Amaranto (*Amaranthus* sp.), Pasto crespo (*Trichloris crinita*), Kapi'ati (*Cenchrus echinatus*), Verdolaga (*Portulaca* sp.), Tupasy Kamby (*Euphorbia serpens* Kunth), Nabo (*Raphanus sativus*), Tape kue (*Acanthospermum australe*), Ypé rupa (*Richardia brasiliensis*), and Typycha Hū (*Sida* spp.) (Figure 1A). However, Lecherita (*Euphorbia heterophylla*) and Ysypo'i (*Ipomoea* spp.) showed lower control, indicating that these biotypes may exhibit natural tolerance or escapes from the mode of action of this specific mixture.

This result is consistent with recent studies in soybean and other crops, where associations with sulfentrazone and clomazone improved simultaneous control of grasses and broadleaf weeds, in addition to broadening the reliability of early-season management (De Castro et al., 2024;

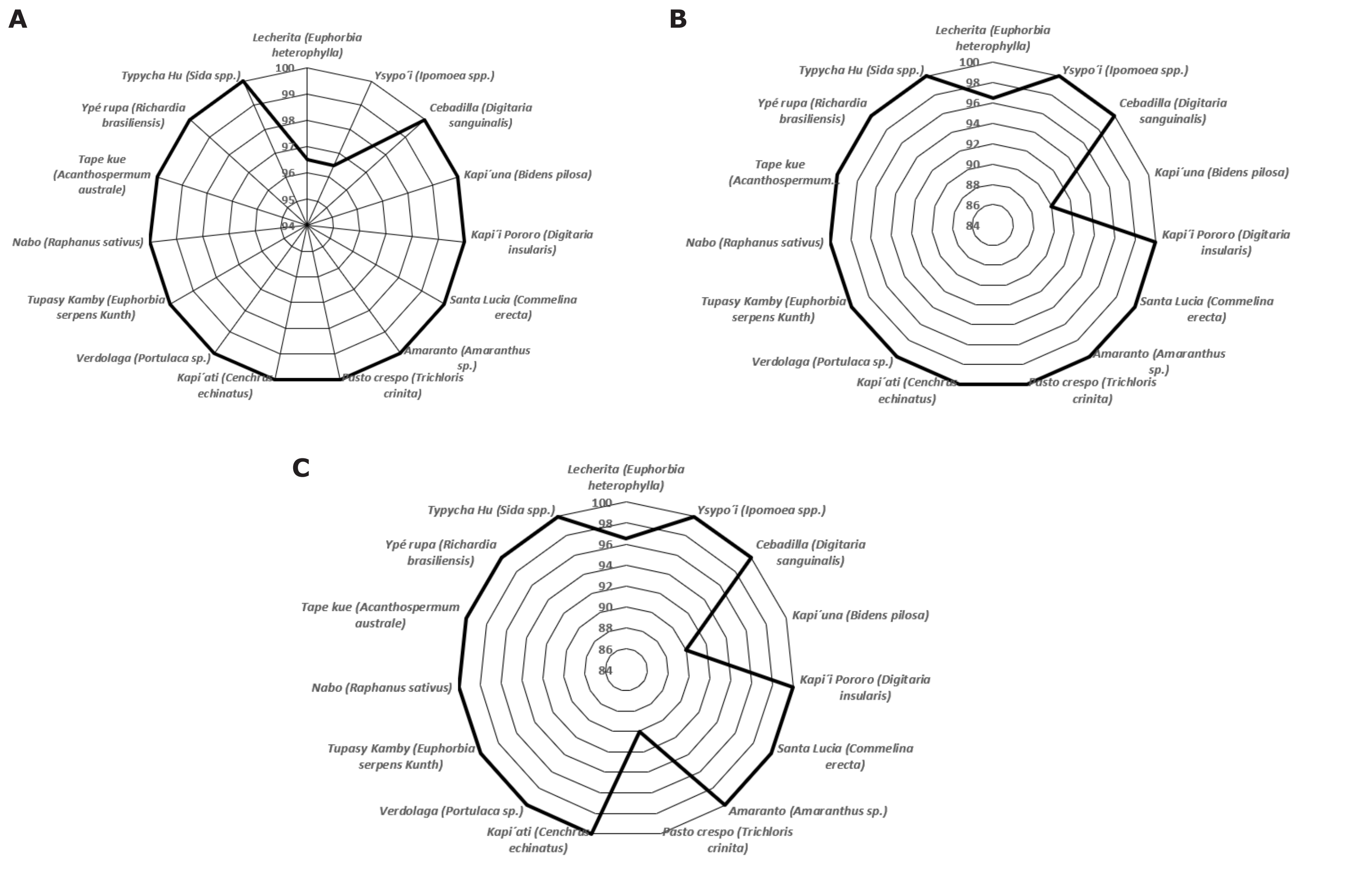

Figure 1. A. Percentage of control exerted by the herbicide mixture Clomazone 50% + Sulfentrazone 50% on the 15 weed species found. Paraguay. 2025. **B**. Percentage of control exerted by the herbicide mixture Flumioxazin 48% + Pyroxasulfone 85% on the 15 weed species found. Paraguay. 2025. **C**. Percentage of control exerted by the herbicide mixture Metolachlor 96% + Flumioxazin 48% on the 15 weed species found. Paraguay. 2025.

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Munaro et al., 2025; Albrecht et al., 2025).

The high efficacy observed on *Digitaria insularis*, *Bidens pilosa*, *Cenchrus echinatus*, *Commelina*, and *Amaranthus* is also consistent with prior reports describing good control of these species with residual programs based on sulfentrazone or mixtures including clomazone (Ovejero et al., 2013; Gazola et al., 2021).

The use of Flumioxazin 48% + Pyroxasulfone demonstrates a high level of control across the range of weeds listed. According to the data, the product achieved 100% control in the vast majority of the species evaluated; the only exceptions to this control were observed in two species: "Lecherita" (*Euphorbia heterophylla*) and "Kapi'una" (*Bidens pilosa*), which recorded high but slightly lower control, at 96% and 90%, respectively (Figure 1B).

The flumioxazin + pyroxasulfone mixture showed high, broad-spectrum residual control, consistent with soybean trials where this combination was the only one among the top performers across all evaluations, effective against *Digitaria insularis*, *Ipomoea* spp., *Urochloa plantaginea*, and *Amaranthus hybridus* (Albrecht et al., 2025). This performance is biologically consistent: flumioxazin (a PPO inhibitor) acts with rapid, soil-residual action, while pyroxasulfone (a VLCFA inhibitor) has shown very good pre-emergent performance and, compared with other herbicides in the same group, the best numerical control and yields similar to the weed-free control (Green and Owen, 2011; Soltani, Soltani, Brown, and Sikkema, 2019).

The herbicide formulation based on metolachlor + flumioxazin demonstrated high, consistent control across a broad spectrum of weeds, with lower efficiency on species such as the wiregrass *Trichloris crinita* and *Bidens pilosa* (90%), and 96% on lecherita *Euphorbia heterophylla* (Figure 1C).

Therefore, control close to 90% on *Bidens pilosa* is agronomically valuable, given its high seed production, staggered emergence, and difficulty of control, and because flumioxazin was the most efficient herbicide for its management, outperforming S-metolachlor (Brighenti, 2019). The S-metolachlor + flumioxazin formulation also showed high, consistent control across a broad spectrum, although with relatively lower efficacy on some species.

The combined formulation of flumioxazin and clomazone shows a more variable and moderate control profile compared to the previous mixtures, with reduced efficacy observed on key species, particularly Cebadilla (*Digitaria*

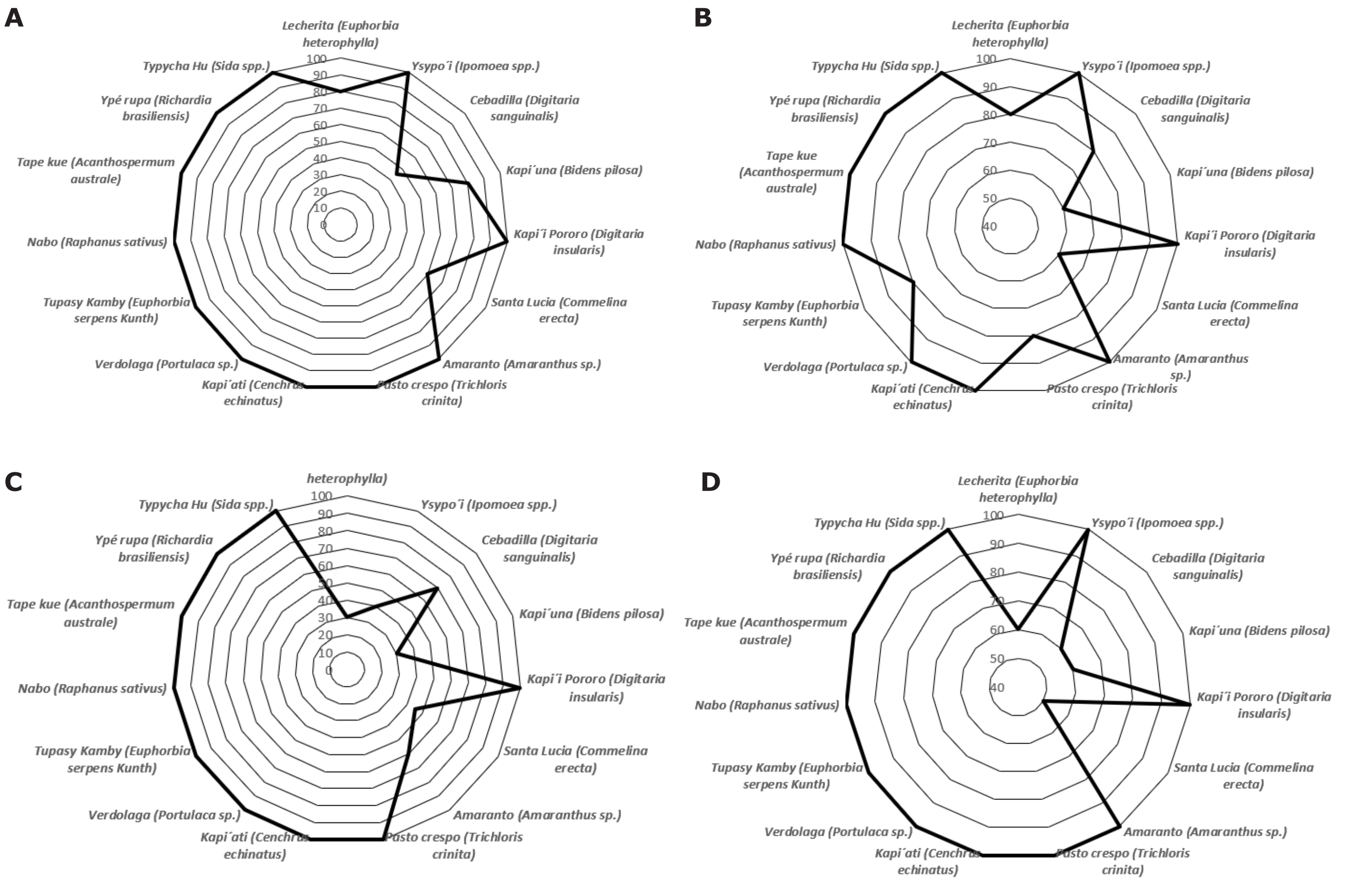

Figure 2. A. Percentage of control exerted by the herbicide mixture Flumioxazin 48% + Clomazone 50% on the 15 weed species found. Paraguay. 2025. **B**. Percentage of control exerted by the herbicide Flumioxazin 48% on the 15 weed species found. Paraguay. 2025. **C**. Percentage of control exerted by the herbicide Metolachlor 96% on the 15 weed species found. Paraguay. 2025. **D**. Percentage of control exerted by the herbicide Pyroxasulfone 85% on the 15 weed species found. Paraguay. 2025.

sanguinalis) with only 40% efficacy, and Santa Lucía (*Commelina erecta*) with 60% (Figure 2A).

Species such as Lecherita (*Euphorbia heterophylla*) and *Bidens pilosa* showed 80% control (Figure 2A).

The individual application of flumioxazin at 48% presents a significantly more limited and variable control spectrum compared to its formulations in mixture (Figure 2B). This pattern of selective control fully agrees with De Carvallo et al. (2025) and Munaro et al. (2025), who identify it as a viable option for complex species.

The application of S-metolachlor showed limitations against several species, particularly dicotyledons, which is consistent with studies where this herbicide performed better on grasses than on broadleaf weeds (Da Silva et al., 2024; Albrecht et al., 2025). Combinations with S-metolachlor were useful for controlling monocotyledons, but *Euphorbia heterophylla* remained a relevant exception in integrated management (Da Silva et al., 2024).

The application of pyroxasulfone at 85% as a pre-emergent herbicide shows a control spectrum above satisfactory on most species, except on Santa Lucía, Lecherita, Cebadilla, and Kapi'una, which are weeds of great importance due to their competitive strength (Figure 2D).

Pyroxasulfone showed high residual efficacy, but its performance depends on the target flora and soil conditions, so the notion that it performs better within complementary mixtures is better supported than a general claim about dicotyledons or monocotyledons (Yamaji, Honda, Hanai, and Inoue, 2016). Pyroxasulfone alone was strong on grasses but poor on several broadleaf weeds, while in mixture it achieved 96.5–99.8% control of diverse flora (Albrecht et al., 2025). This reinforces the importance of using mixtures for a better weed control spectrum.

CONCLUSION

Pre-emergent herbicide mixtures constitute the most effective and consistent strategy for managing the weed complex present in cassava cultivation. Among the combinations evaluated, the most recommended are Clomazone + Sulfentrazone, Flumioxazin + Pyroxasulfone, and Metolachlor + Flumioxazin, due to their broad spectrum of action against the main problematic species identified, encompassing both dicotyledons and monocotyledons, and their superiority over individual applications.

These mixtures stand out as an efficient and recommendable technology for sustainable weed control in cassava cultivation, within the framework of integrated management that helps delay the emergence of resistant biotypes.

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