Research Journal of Agricultural Science, 58 (2), 2026; ISSN: 2668-926X;

http://doi.org/10.59463/RJAS.2026.2.50

COMPARATIVE EFFICACY OF ALS- AND HPPD-INHIBITING HERBICIDES ON WEED FLORA IN MAIZE

Ramona, ȘTEF[1] *(ORCID: 0000-0001-6443-5896), Dan, MANEA[1] (ORCID: 0009-0007-4570-9127), Anișoara, DUMA-COPCEA[1] (ORCID: 0000-0002-7152-7307), Casiana, MIHUȚ[1] (ORCID: 0000-0001-6263-6475) Otilia, COTUNA[1] (ORCID: 0000-0001-6545-1353), Denisa, AIOANEI[1], Alin CĂRĂBEȚ[1]* (ORCID: 0009-0002-7321-4336)

[1] University of Life Sciences" King Mihai I" from Timisoara, Calea Aradului, no. 119, Timisoara, Romania

*Corresponding author: *ramonastef@usvt.ro; *alincarabet@usvt.ro*

Abstract. *Maize is highly susceptible to weed interference, with losses ranging from 30 to 100 percent. Weeds are one of the most significant biotic stress factors affecting corn crops. In the context of climate change, shifts in the structure of the weed community, and the emergence of herbicide tolerance and resistance, evaluating herbicide efficacy under local agroecological conditions is essential for updating control strategies. The aim of this study was to evaluate the efficacy of post-emergence herbicides with different modes of action (ALS and HPPD) in controlling the dominant weed community in maize crops. The experiment was conducted (in 2025) using a randomized block design in the town of Giarmata Vii, Timiș County. Four post-emergence herbicides were tested in the experiment, and their efficacy was assessed 14 and 28 days after application. The herbicides used in the experiment were: Principal Forte (ALS), Laudis (HPPD), Elumis (ALS + HPPD), and Capreno (ALS + HPPD). The efficacy of the herbicides in controlling weed flora was determined using the Abbott formula. The dominant species in the experimental treatments were: Xanthium strumarium, Ambrosia artemisiifolia, and Sorghum halepense, which exerted competitive pressure on the corn crop. The results showed that weed density was significantly reduced by the dual-action ALS and HPPD herbicides, Elumis (90%) and Capreno (95%). The perennial dicotyledons Convolvulus arvensis (35–65%) and Asclepias syriaca (18–30%) exhibited high tolerance to all tested herbicides; the herbicides' efficacy was limited to the aboveground parts without destroying the underground vegetative organs.*

Keywords*: weed control; herbicide efficacy; weed flora; post-emergence; Sorghum halepense*

INTRODUCTION

Maize (*Zea mays L.*) is one of the most important agricultural crops worldwide, due to its role in human and animal nutrition, as well as a raw material for numerous industrial applications and for bioethanol production (SHIFERAW et al., 2011; ERENSTEIN et al., 2022). Globally, the crop covers approximately 197 million ha, and in Europe it is cultivated on approximately 8.9 million ha. Romania ranks among the European Union's leading producers, cultivating over 2.6 million ha annually (FAOSTAT, 2019). Its high adaptability to varied soil and climate conditions and its high yield potential have facilitated the expansion of the crop into numerous agricultural regions, but production levels depend largely on the efficiency of cultivation techniques, with weed control being one of the key factors in achieving yield potential (ERENSTEIN et al., 2022).

Weed growth is one of the main factors limiting corn production, as weeds compete with the crop for light, water, nutrients, and space from the earliest stages of growth. Due to its relatively slow growth rate and wide row spacing, corn is particularly sensitive to weed competition during the first 4–6 weeks after emergence (BBCH stages 12–18), a critical period during which effective weed control is essential to prevent yield losses (HALL et al., 1992; KNEZEVIC et al., 2002; SOLTANI et al., 2016). Depending on the weed infestation level, the

http://doi.org/10.59463/RJAS.2026.2.50

dominant weed species, and the duration of competition, yield losses can exceed 80% in the absence of effective control measures (SOLTANI et al., 2016).

In recent decades, the structure of the weed flora has changed significantly as a result of the intensification of agriculture, the simplification of crop rotation, climate change, and the repeated use of herbicides with the same mode of action. These changes have contributed to the spread of species with high ecological plasticity, the emergence of herbicide-resistant biotypes, and changes in the composition of weed communities (BENVENUTI and BALDONI, 2026). Currently, over 530 unique cases of resistance have been reported worldwide, involving 272 weed species and 21 modes of action, with acetolactate synthase (ALS) inhibitors representing the group with the highest number of resistance cases (BECKIE and HEAP, 2024). At the same time, cases of resistance to HPPD inhibitors have also been reported in recent years, highlighting the need to rotate and combine modes of action to limit selection pressure on weed populations (JHALA et al., 2023; TORRA et al., 2024).

In maize cultivation, these changes are reflected in the increased prevalence of problem species such as *Sorghum halepense*, *Ambrosia artemisiifolia*, *Xanthium strumarium*, *Convolvulus arvensis*, and *Asclepias syriaca*, which require effective control programs and the use of herbicides with different modes of action (CHIRIȚĂ et al., 2004; ȘTEF R., 2017; CHIFAN et al., 2019; ȘTEF et al., 2022; CĂRĂBEȚ et al., 2025). Acetolactate synthase (ALS) inhibitor herbicides represent one of the most widely used groups of selective herbicides in corn cultivation. They inhibit the biosynthesis of branched-chain amino acids, causing sensitive weeds to cease growth and providing effective control at low doses. However, repeated use of this chemical class has led to the emergence of the largest number of resistant biotypes reported to date, necessitating the use of strategies based on alternating modes of action (BECKIE and HEAP, 2024).

4-Hydroxyphenylpyruvate dioxygenase (HPPD) inhibitor herbicides act by blocking carotenoid biosynthesis, causing bleaching and necrosis in susceptible weeds. Due to their broad spectrum of control and high efficacy against numerous species of annual weeds, they have become an important component of modern corn cultivation technologies. Currently, ALS–HPPD herbicide combinations are regarded as one of the most effective approaches for broadening the control spectrum, improving treatment efficacy, and reducing the risk of herbicide resistance (JHALA et al., 2023).

In this context, a comparative evaluation of the efficacy of herbicides based on ALS and HPPD inhibitors, as well as combinations of these two modes of action, is of particular practical interest for optimizing weed control strategies and developing sustainable resistance management systems.

Given the changes in the composition of the weed flora and the need to diversify the modes of action used in weed control, the objective of this study was to conduct a comparative evaluation of the efficacy of certain post-emergence ALS- and HPPD-inhibiting herbicides, applied individually or in combination, on the main weed species in corn crops, with the aim of identifying the most effective solutions for controlling weed flora under the soil and climate conditions of western Romania.

MATERIAL AND METHODS

Experimental Site and Experimental Conditions

The experiment was conducted in 2025 in Giarmata Vii, Timiș County, Romania (45°47′N, 21°18′E), in a corn field. The area is characterized by a moderate temperate-continental climate with sub-Mediterranean influences, with an average annual temperature of

http://doi.org/10.59463/RJAS.2026.2.50

approximately 11–12°C and a multiannual average precipitation of 600–650 mm. The Pioneer PR37N01 maize hybrid (FAO 380) was used in the experiment; this semi-early-maturing hybrid is characterized by high yield potential, very good adaptability to various soil and climate conditions, drought tolerance, and stay-green traits.

Experimental Design

The experiment was organized using the randomized block design (CIULCĂ, 2006), with three replicates, each experimental plot having a harvestable area of 30 m².

The experimental factor was the applied herbicide; five experimental treatments were evaluated, including one untreated control and four herbicide-treated treatments.

Table 1.

Experimental Conditions

Variant	Commercial product	Active Ingredients	Mechanism of Action	Dosage
V1	Untreated control	-	-	-
V2	Principal Forte	Nicosulfuron + Rimsulfuron – Dicamba	ALS auxinic	480 g ha^{-1} + adjuvant
V3	Laudis OD 66	Tembotrione	HPPD	2,0 L ha^{-1}
V4	Elumis	Mesotrione + Nicosulfuron	HPPD + ALS	2,0 L ha^{-1}
V5	Capreno 547 SC	Tembotrione + Thiencarbazone-methyl	HPPD + ALS	0,22 L ha^{-1}

Herbicide Application and Efficacy Assessment

The herbicides were applied postemergence, when the maize plants were in phenological stage BBCH 14–16

The evaluated herbicides represented two main modes of action: acetolactate synthase (ALS) inhibitors, 4-hydroxyphenylpyruvate dioxygenase (HPPD) inhibitors, and combinations of the two modes of action.

The efficacy of the treatments was evaluated 14 and 28 days after application (DAA) by comparing the weed density in the treated plots with that recorded in the control plot.

Efficacy was calculated using the formula proposed by ABBOTT (1925):

$$E = \frac{C - T}{C} \times 100$$

where: E – herbicide efficacy (%); C – weed density in the control treatment; T – weed density in the treated treatment.

Efficacy was determined separately for each weed species and for each assessment time point.

Assessment of the weed flora

Prior to herbicide application, the weed flora was assessed using the quantitative-numerical method (CHIRILĂ, 2001 citat de ȘTEF R., 2017), which involves identifying and counting weeds by species within sample plots, with results expressed as the number of plants per m².

RESULTS AND DISCUSSIONS

Before applying herbicides, the degree of weed infestation and the species present in the corn crop were determined (Figure 1). The identified weed flora consisted of annual monocotyledonous and dicotyledonous species, as well as perennial species.

The dominant species was *Xanthium strumarium*, with an average density of 50 plants m^{-2}, accounting for 48% of all identified weeds. This was followed by *Ambrosia artemisiifolia*, with 33 plants m^{-2} and a share of 31%; together, these two species accounted for nearly 80% of

http://doi.org/10.59463/RJAS.2026.2.50

the total weed infestation. The high density of these species highlights the competitive pressure exerted on the crop, particularly during the early stages of growth, when corn has a reduced ability to compete.

Among the monocotyledonous species, *Sorghum halepense* had a density of approximately 10 plants m^{-2}, accounting for 10% of the weed flora. Although its proportion was lower than that of the dominant species, this perennial weed is known for its high regenerative capacity and the intense competition it exerts on row crops.

The perennial species *Convolvulus arvensis* and *Asclepias syriaca* were present at lower densities, approximately 8 and 4 plants per m^{-2} respectively, corresponding to proportions of 8% and 4%. Although their frequency was lower compared to the dominant annual species, the presence of underground vegetative organs gives these weeds a high regenerative capacity and increased tolerance to herbicides, making them difficult to control.

The lowest infestation was recorded for *Rubus caesius*, with approximately 1 plant m^{-2} and a proportion of 1%.

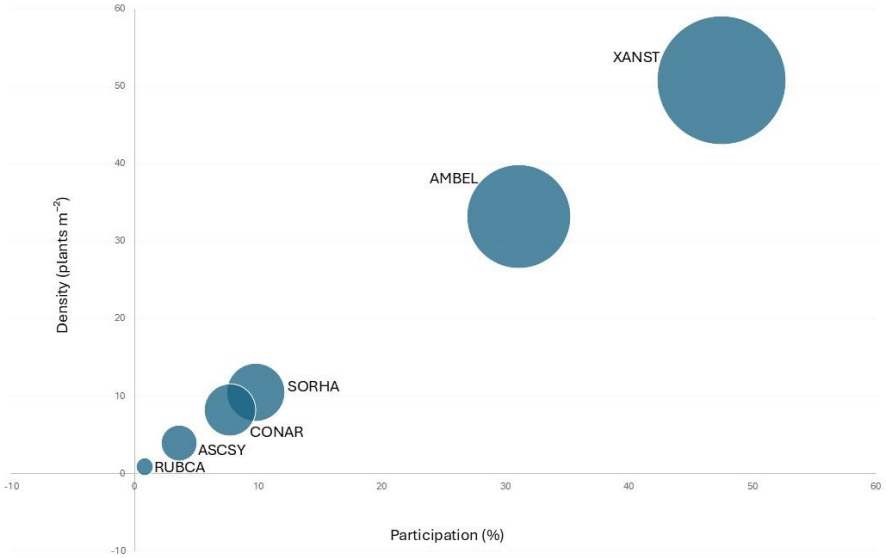

Figure 1. Composition of the weed community in the experimental maize crop, expressed as the density and relative abundance of dominant species prior to the application of herbicide treatments

The composition of the weed flora observed in this study is characteristic of modern corn-growing systems in Central and Eastern Europe, where annual species with staggered emergence, such as *Xanthium strumarium* and *Ambrosia artemisiifolia*, tend to dominate weed communities due to their high seed-production potential and adaptability to current cultivation technologies. In recent years, there has been an increase in the frequency of these species in corn crops, particularly in areas where crop rotation is limited and weed control relies predominantly on post-emergence herbicides (MIHÁLY et al., 2025).

The simultaneous presence of the perennial species *Convolvulus arvensis* and *Asclepias syriaca* adds an additional layer of complexity to weed management. Although their density was lower than that of annual species, their well-developed root systems and high

http://doi.org/10.59463/RJAS.2026.2.50

capacity for vegetative regeneration allow them to survive foliar treatments and reinfest the crop in subsequent years. Under these conditions, effective control of these weeds requires an integrated approach based on alternating the modes of action of herbicides and supplementing chemical control with agrotechnical and mechanical measures—a recommendation also supported by recent studies on perennial weed management (JHALA et al., 2023).

The first assessment of herbicide efficacy was conducted 14 days after application (14 DAA) to evaluate the early response of the main weed species to treatments based on ALS inhibitors, HPPD inhibitors, and combinations thereof (Figure 2). The results revealed clear differences among the herbicides, with their efficacy influenced by both the mode of action and the biological characteristics of the weed species.

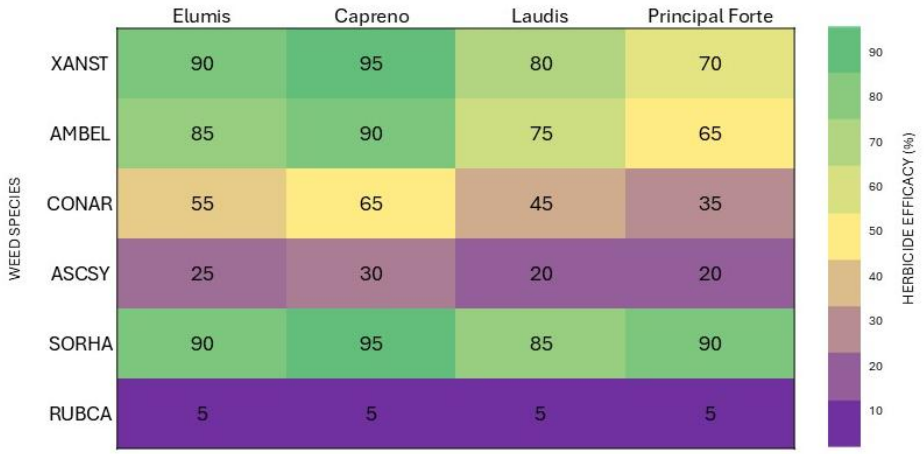

Figure 2. Efficacy (%) of herbicides against major weed species (14 DAA)

At 14 DAA, the highest control rates were achieved in the treatments with Capreno and Elumis, which provided very good control of *Xanthium strumarium*, *Ambrosia artemisiifolia*, and *Sorghum halepense*. Laudis and Principal Forte showed lower efficacy against the overall weed flora, with the differences being more evident in the case of certain dicotyledonous species. Perennial weeds exhibited considerably higher tolerance to the applied treatments. *Convolvulus arvensis* was controlled only partially, while *Asclepias syriaca* showed low levels of control. Furthermore, *Rubus caesius* was very slightly affected by all treatments.

Mean efficacy values indicated for all six evaluated species revealed differences among the herbicides. Capreno recorded the highest average efficacy, at 63.33%, followed by Elumis at 58.33%, Laudis at 51.67%, and Principal Forte at 47.50%. The overall averages were strongly influenced by the reduced efficacy against perennial species, particularly *Asclepias syriaca* and *Rubus caesius*. In contrast, against the dominant annual species and *Sorghum halepense*, Capreno and Elumis achieved control rates ranging from 85 to 95%. The superior performance of the herbicides Capreno and Elumis can be explained by the complementary action of ALS and HPPD inhibitors, which broadens the control spectrum and allows for the simultaneous control of monocotyledonous and dicotyledonous weeds. This effect reduces the likelihood of survival for species with varying levels of sensitivity and ensures more uniform control of the weed community, a finding also reported in other studies conducted in corn crops (JHALA et al., 2023). In contrast, the reduced efficacy against perennial weeds highlights the

http://doi.org/10.59463/RJAS.2026.2.50

fact that post-emergence treatments act predominantly on the above-ground vegetative parts, without significantly affecting the underground regenerative organs. For this reason, effective control of species such as *Convolvulus arvensis* and *Asclepias syriaca* requires integrating chemical control with agrotechnical measures and rotating the modes of action of herbicides.

The evaluation conducted 28 days after herbicide application (28 DAA) confirmed the persistence of the biological effect of the treatments and highlighted the continued differences between herbicides based on a single mode of action and those combining ALS and HPPD inhibitors (Figure 3). Compared to the first evaluation, changes in efficacy were minor: Capreno showed a slight increase, Elumis and Laudis recorded moderate decreases, and Principal Forte maintained its average efficacy at the same level. These results indicate relatively good stability of the treatments' biological effect over the analyzed period.

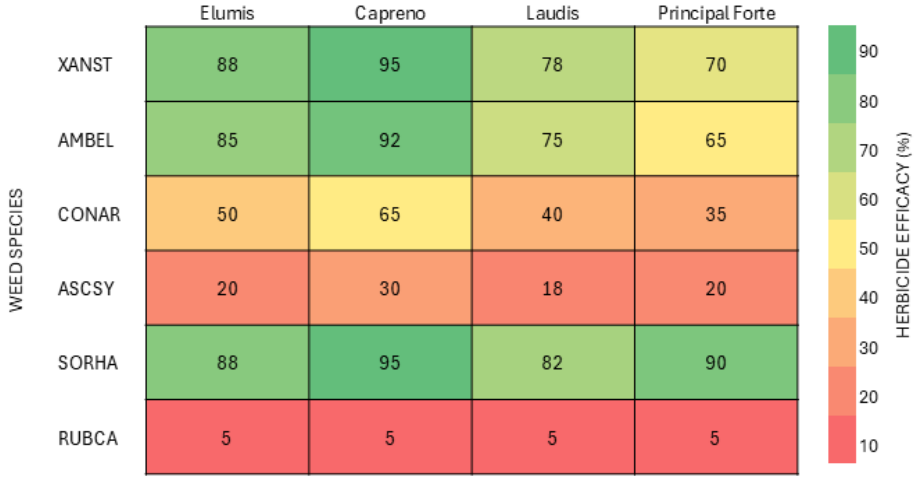

Figure 3. Comparative efficacy of herbicides (%) against major weed species (28 DAA)

Capreno and Elumis continued to provide the highest level of control over the main annual weed species, maintaining superior control over the dominant weeds in corn crops. In contrast, Laudis and Principal Forte showed a more pronounced decline in efficacy, particularly against dicotyledonous species. Similar to the first evaluation, perennial weeds remained inadequately controlled, with *Convolvulus arvensis* showing a moderate level of control, and *Asclepias syriaca* remaining the most tolerant species in the experiment. *Rubus caesius* showed no significant changes in its response to the treatments.

Twenty-eight days after application, Capreno maintained the highest average efficacy (63.67%), followed by Elumis (56.00%), Laudis (49.67%), and Principal Forte (47.50%) (Table 2).

Comparison between the two assessment dates indicated that treatment efficacy remained relatively constant between 14 and 28 DAA. Capreno showed a slight increase in average efficacy, from 63.33% to 63.67%, while Elumis and Laudis recorded slight decreases of 2.33 and 2.00 percentage points, respectively. For the herbicide Principal Forte, the average efficacy remained at the same level, 47.50%.

http://doi.org/10.59463/RJAS.2026.2.50

Table 2.

Mean herbicide efficacy at 14 and 28 days after application

Herbicide	14 DAA (%)	28 DAA (%)	Reduction (%)
Capreno	63.33	63.67	+0.34
Elumis	58.33	56.00	-2.33
Laudis	51.67	49.67	-2.00
Principal Forte	47.50	47.50	0.00

To highlight the differential response of the main biological groups of weeds to the evaluated herbicides, the efficacy of the treatments was analyzed separately for annual dicotyledons, perennial dicotyledons and perennial monocotyledons (Figure 4).

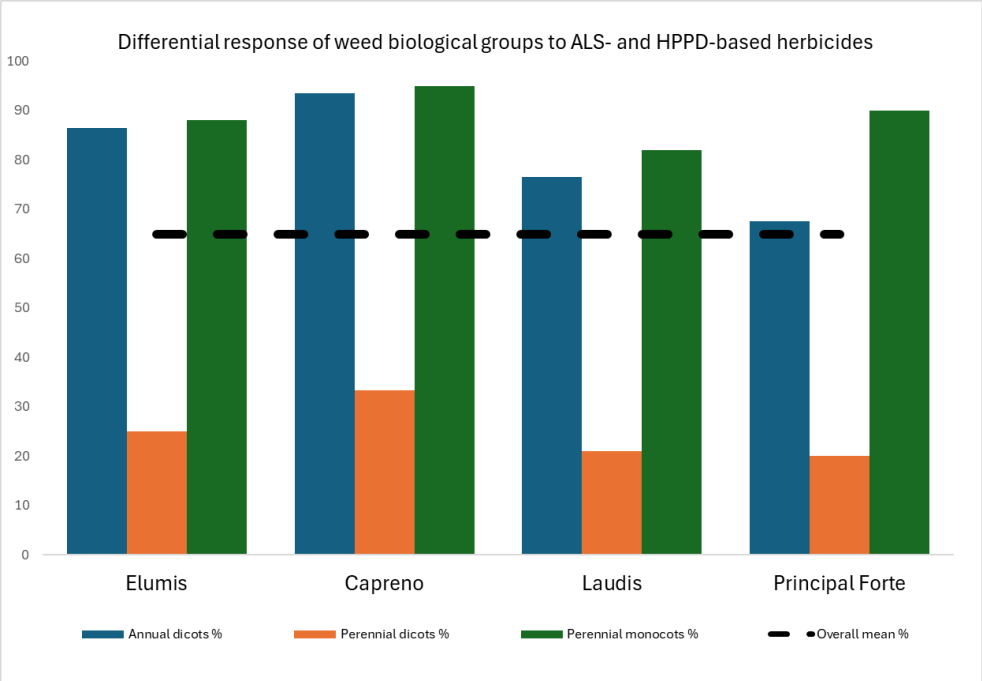

Figure 4. Differential response of annual and perennial weed groups to ALS- and HPPD-based herbicides

The highest efficacies were recorded on annual dicotyledons and perennial monocotyledons, especially in the variants treated with Capreno and Elumis, where the values exceeded 85%. In contrast, the efficacy on perennial dicotyledons was considerably lower for all herbicides tested, ranging between 20.0 and 33.3%. These results highlight the higher tolerance of perennial species compared to annual weeds and confirm the advantage of ALS + HPPD combinations in controlling the main dominant species in the corn crop.

The superior performance of Capreno and Elumis treatments was primarily due to their high efficacy against the dominant species *Xanthium strumarium*, *Ambrosia artemisiifolia*, and *Sorghum halepense*. The combination of ALS and HPPD inhibitors provided a broader spectrum of control and more consistent efficacy against susceptible species, consistent with the observations reported by JHALA et al. (2023). However, the overall

averages were reduced by the poor response of perennial weeds, particularly *Asclepias syriaca* and *Rubus caesius*. The reduced efficacy observed against perennial species, particularly *Convolvulus arvensis*, *Asclepias syriaca*, and *Rubus caesius*, highlights their ability to regenerate from underground vegetative organs and their higher tolerance to the evaluated post-emergence treatments. These observations are consistent with the biological characteristics of these species, as described in the scientific literature, which limit the effectiveness of herbicides applied exclusively to aboveground vegetation.

CONCLUSIONS

The weed flora in the experimental maize field was dominated by *Xanthium strumarium* and *Ambrosia artemisiifolia*, which together accounted for approximately 79% of the total weed infestation. *Sorghum halepense* was the main monocotyledonous species, while *Convolvulus arvensis*, *Asclepias syriaca*, and *Rubus caesius* were present in lower densities but exhibited high tolerance to the treatments.

Among the herbicides evaluated, Capreno recorded the highest average efficacy at both 14 DAA (63.33%) and 28 DAA (63.67%). Elumis ranked second, with average efficacy values of of 58.33% at 14 DAA and 56.00% at 28 DAA. Laudis and Principal Forte showed lower average efficacy rates, ranging from 47.50% to 51.67%.

Capreno and Elumis provided the best control of the dominant species *Xanthium strumarium*, *Ambrosia artemisiifolia*, and *Sorghum halepense*, with individual efficacies of 85–95%. These results confirm the advantage of combinations of active ingredients with ALS and HPPD mechanisms for broadening the spectrum of control.

The efficacy of the treatments remained relatively constant between the two evaluation time points. Capreno showed a slight increase of 0.34 percentage points, Elumis and Laudis recorded decreases of 2.33 and 2.00 percentage points, respectively, and Principal Forte maintained its average efficacy.

None of the treatments provided satisfactory control of all perennial weeds. *Asclepias syriaca* and *Rubus caesius* showed the highest tolerance, and *Convolvulus arvensis* was only partially controlled. For these species, an integrated management approach is necessary, based on alternating modes of action, crop rotation, and the use of complementary agrotechnical measures.

BIBLIOGRAPHY

BECKIE H.J., HEAP I., 2024, Herbicide resistance is complex: a global review of cross-resistance in weeds within herbicide groups, Weed Science, 72(5), 465–486.

BENVENUTI S., BALDONI G., 2026, Weed Flora Evolution in the Era of Climate Change: New Agronomic Issues as a Threat to Sustainable Agriculture, Agronomy, 16(7), 764.

CĂRĂBEȚ A., GROZEA I., COTUNA O., MANEA D., VÎRTEIU A.M., STROIA C., SCEDEI D., LALESCU D., ȘTEF R., 2025, Analysis of the efficacy of MCPA herbicide in the control of *Convolvulus arvensis* and *Chenopodium album in flax crops*, Scientific Papers. Series A. Agronomy, 68(2), 769–780.

CHIFAN R., ȘTEF R., GROZEA I., 2019, The cyclohexanediones effect on the *Sorghum halepense* control in the sunflower agroecosystem, Research Journal of Agricultural Science, 51(4), 262–267.

CHIRIȚĂ R., LAUER K.F., SARPE N., 2004, Control of Johnson grass in maize with new broad-spectrum herbicides in Western Romania, Zeitschrift für Pflanzenkrankheiten und Pflanzenschutz – Journal of Plant Diseases and Protection, Special Issue 19, 725–731.

CIULCĂ S., 2006, Experimental Methodologies in Agriculture and Biology, Editura Agroprint, Timișoara, Romania, 138–144.

ERENSTEIN O., JALETA M., MOTTALEB K.A., SONDER K., DONOVAN J., BRAUN H.-J., 2022, Global maize production, consumption and trade: trends and R&D implications, Food Security, 14, 1295–1319.

FAOSTAT, 2019, Crops and Livestock Products Database, Food and Agriculture Organization of the United Nations.

HALL M.R., SWANTON C.J., ANDERSON G.W., 1992, The critical period of weed control in grain corn (*Zea mays*), Weed Science, 40, 441–447.

HEAP I., 2025, The International Herbicide-Resistant Weed Database. https://www.weedscience.org

JHALA A.J., KUMAR V., YADAV R., JHA P., JUGULAM M., WILLIAMS M.M. II, HAUSMAN N.E., DAYAN F.E., BURTON P.M., DALE R.P., NORSWORTHY J.K., 2023, 4-Hydroxyphenylpyruvate dioxygenase (HPPD)-inhibiting herbicides: past, present, and future, Weed Technology, 37(1), 1–14. https://doi.org/10.1017/wet.2022.79

KNEZEVIC S.Z., EVANS S.P., BLANKENSHIP E.E., VAN ACKER R.C., LINDQUIST J.L., 2002, Critical period for weed control: the concept and data analysis, Weed Science, 50, 773–786.

MIHÁLY Z., TÓTH I.E., GYÖRGY J., NAGY S., DORNER Z., 2025, Regional patterns in weed composition of maize fields in eastern Hungary: The Balance of Environmental and Agricultural Factors, Agronomy, 15(8), 1814.

SHIFERAW B., PRASANNA B.M., HELLIN J., BÄNZIGER M., 2011, Crops that feed the world 6: Past successes and future challenges to the role played by maize in global food security, Food Security, 3, 307–327.

ȘTEF R., 2017, Chemical control of the invasive species *Ambrosia artemisiifolia* L. in sunflower agroecosystem, SGEM International Multidisciplinary Scientific GeoConference Proceedings, 17(63), 161–168.

ȘTEF R., MANEA D., GROZEA I., CHIFAN R., GHEORGHIESCU B., ARSENE G.-G., CĂRĂBEȚ A., 2022, *Asclepias syriaca:* A new segetal species in Romania, Scientific Papers. Series A. Agronomy, 65(1), 703–712.

TORRA J., MORA G., MONTULL J.M., ROYO-ESNAL A., NOTTER J.S., SALAS M., 2024, A 4-Year field study monitoring the evolution of trp574leu-resistant plants in an *Echinochloa crus-galli* population under different crop rotation and herbicide programs in maize, Pest Management Science, 80(11), 5843–5851. https://doi.org/10.1002/ps.8315

TURSUN N., DATTA A., SAKINMAZ M.S., KANTARCI Z., KNEZEVIC S.Z., CHAUHAN B.S., 2016, The critical period for weed control in three corn (*Zea mays* L.) Types, Crop Protection, 90, 59–65.